

P&IDs and Symbols

Overview

The acronym “P&ID” is widely understood within the process industries as the name for the principal document used to define a process – the equipment, piping and all monitoring and control components. *The Automation, Systems and Instrumentation Dictionary*, 4th edition’s definition for a Piping and Instrumentation Drawing (P&ID) tells what they do. P&IDs “show the interconnection of process equipment and the instrumentation used to control the process”.¹

Sets of symbols are used to depict mechanical equipment, piping, piping components, valves, equipment drivers and instrumentation and controls. These symbols are assembled on the drawing in a manner that clearly defines the process. The instrumentation and control (I&C) symbols used in P&IDs are generally based on ISA-5.1-1984-(R1992), Instrumentation Symbols and Identification.²

This book will aid in solving the long existing and continuing problem of confusing information on P&IDs. The fact that there is confusion can be understood because there really is no universal standard that specifies what information should be included on a P&ID or even, for that matter, the meaning of the letters P&ID. You may know exactly what “P” means, or what “D” means or what a P&ID contains, but the person in the facility down the road probably doesn’t agree. For instance, the “P” in P&ID may stand for Piping or Process. The “I” refers to Instrument or Instrumentation. The “D” is for Drawing or Diagram. P&IDs may even be called “Flow Diagrams”, which are not to be confused with Process Flow Diagrams discussed in the previous chapter. P&IDs are sometimes called “Flow Sheets”, a term often preceded by the department that initiated or developed them, like “Engineering”, or “Controls”, or other descriptors. In this book, for simplicity, we will refer to the document by the acronym, P&ID.

There is no universal, national or international, multi-discipline standard that covers the development and content of P&IDs. However, much of the information and use of a P&ID is covered by ISA-5.1, which is an excellent, flexible document that defines, primarily, instrument symbolism.

This book uses ISA-5.1 as the definitive reference. We are aware the document is under review and revision at this writing, in early 2004. Some changes will probably be included when the revision is issued, but we are sure the intent and focus of the standard will be maintained.

Another professional organization, Process Industry Practices (PIP), has developed and published many recommended practices. Among these is one on P&IDs. There is additional information about PIP in Chapter 10.

The P&IDs in your facility have probably been produced and revised over many years by many different developers. Many different individuals have documented revisions to the content – and even the symbolism – of your P&IDs to reflect process improvements and additions, as well as changing control technology. Unless you have been incredibly and unbelievably fortunate maintaining your site standards, some of your P&IDs will use symbolism and format that differ from the original and even from each other. As you well know, inconsistent symbolism and format of your P&IDs can be annoying, confusing, and more importantly, it makes information they contain subject to misunderstandings.

Although the P&ID is the overall document used to define the process, the first document developed in the evolution of a process design is often the PFD, the Process Flow Diagram, discussed in Chapter 1. Once a PFD is released for detail design, the project scope has been established and P&ID development may commence.

P&IDs develop in steps. The key members of the design team – perhaps plant design, piping, process, and project specialists, all lay out a conceptual pass at showing vessels, equipment and major piping. The instrumentation and controls are typically added next, since they often require significant additional space on the P&ID. Or, in the words of one project manager, “you guys sure do have lots of bubbles”. Then, the contributions of the specialists in electrical, mechanical equipment, vessels and other disciplines are added. These specialists fill in the information blocks containing equipment numbers, titles and definitive text reserved for critical information regarding the equipment: size, rating, throughput, and utility usage (horsepower). The developmental process is an iterative one. Information is added in steps until the document is complete with all necessary details.

P&IDs are controlled documents formally issued at various stages. Control means changes to the drawings are identified and clearly documented in some manner and there is verification checking or some other quality assurance procedure in effect. The care needed to control the content of P&IDs can be understood in light of the fact that P&IDs carry the definitive information from which many design entities draw their work. From the P&ID comes the Instrument List and the specification, acquisition and installation of all instrumentation and controls. From the P&ID comes the motor list with horsepower. From the P&ID come the piping line list, sizes, service and purpose. The drawings even document critical information regarding tanks, vessels and other equipment – all of which are used to lay out equipment and start the specification and purchasing efforts. In some states, P&IDs carry professional engineers' stamps.

P&IDs are distributed to members of the project team and interested client personnel after quality control checking and under rigorous revision control. This formal issue process will occur several times in the course of a project. The drawings are so important that key milestones are often built into the project schedule based on the different issues of P&IDs. Some typical formal P&ID drawing issues may include:

- A – Issue for scope definition
- B – Issue for Client Approval
- C – Issue for bid, bidding of major equipment
- D – Issue for detailed design
- 0 – Issue for construction (or 1, or 2, or 3, etc.)

Before we start looking at a P&ID we shall define a few terms, with particular focus on instrumentation and controls.

Figure 2-1 contains a few simple definitions. An instrument is a device for measuring, indicating, or controlling a process. This includes both simple and complex devices. Pressure gauges or dial thermometers are typical simple ones. Complex devices may include process analyzers – perhaps a gas chromatograph, which defines types and quantities of gases in a process stream.

The term “Process Control” can be understood from any dictionary definition of the two words. In its simplest form, a process is a series of steps and control is to regulate. So process control is the regulation of a series of steps.

All types of process control include three functions: sensing, comparing and correcting.

Sensing

First, we have to know where we are by sensing the relevant characteristic of our environment – otherwise known as the process. One definition of process sensing is to ascertain or measure a process variable and to convert that value into some understandable form (see Figure 2-2).

Figure 2-1: Instrument & Process Control Defined

- **Instrument**

- A device for measuring, indicating, or controlling

- **Process control**

- All first-level control – process or discrete – consists of three parts:
 - Sensing
 - Comparing
 - Correcting

Figure 2-2: Sensing & Comparing Defined**• Sensing**

To ascertain or measure a process variable and convert that value into some understandable form

• Comparing

To compare the value of the process variable (PV) with the desired value set point (SP) and to develop a signal to bring the two together. The signal depends on:

- How far apart the PV & SP are
- How long they have been apart
- How fast they are moving toward or away from each other

The flow of fluid in a pipe or air in a duct, the level of liquid in a tank, the pressure of gas in a vessel, the temperature of the fluid inside a distillation tower are all process variables. Normally, in process control, these variables are measured continuously. A transmitter measures the process in some way and transmits the information to a central location where the comparison takes place. The central location is usually a control room where plant operators monitor the

process, or, for purists, the rack room where the process control computer is located that performs the comparison.

Comparing

Figure 2-2 contains a formal definition of the comparing function. The value of the process variable is compared with the desired value (the set point), and action is taken to develop a signal to bring the two together. The control is automatic and continuous. Comparison takes place in a pneumatic or electronic controller or via a shared display shared control system, such as a distributed control system (DCS), a programmable logic controller (PLC), a computer chip embedded in a field instrument, or even a desktop computer. These devices may look at three characteristics of the process:

P-Proportional or gain – how far away the process variable is from the set point

I-Integral or reset – how long the process variable has been away from the set point

D-Derivative or rate – how fast the process variable is changing

It is just coincidental that the three components of a process control algorithm yield the same acronym (PID) as the primary design drawing that details the process under control.

Correcting

The control device then develops a signal to bring the process variable and the set point together. This signal is transmitted to a field device that changes the value of the process variable. This device is most often a control valve or a variable speed pump drive. See Figure 2-3.

Figure 2-3: Correcting Defined

- **Correcting**

- To bring the process variable closer to the set point. This is accomplished by the final control element – most often this is a *control valve*

- **Control valves, usually, but not always:**

- Are pneumatically actuated, often by a 3-15 psi signal
- Can be moved directly by a pneumatic controller
- Are actuated by a transducer if the controller signal is electronic or digital

The Control Loop

In automatic control, the three devices – the transmitter that senses, the controller that compares, and the control valve that corrects – are interconnected to form a control loop. The interconnection may be pneumatic, electronic, digital, or a combination of all three. The pneumatic component is typically a 3-15 psig (pounds per square inch gauge) instrument air signal. If the interconnection is electronic, a 4-20 mA (milliamperes) signal is usually used, although other signal levels are also used. The signal level is a function of the control system selected. As yet, there is no agreement in industry on a digital transmission standard, and entire books are written on the relative merits of the various protocols.

Figure 2-4: Loop Defined

A combination of interconnected instruments that measures and/or controls a process variable

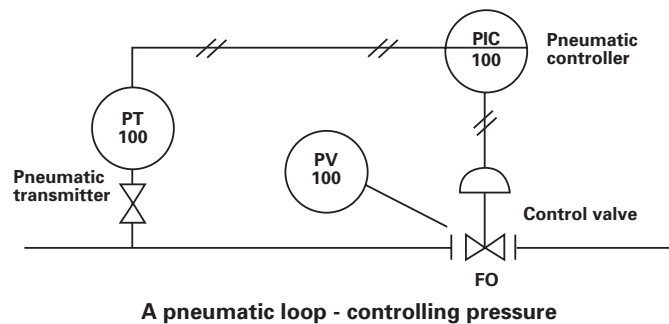


Figure 2-4 shows a pneumatic loop controlling the pressure in a pipeline. The loop number is 100, so all the devices in the loop will have the number 100. The double crosshatched lines indicate information is transmitted pneumatically from the transmitter PT-100 to the indicating controller PIC-100, and from PIC-100 to the control valve PV-100 with a signal varying from a low of 3 psig to a high of 15 psig. The control valve moves according to the value of the 3-15 psig signal. It has a FO identifier, meaning that if the primary power source to the valve is lost, in this case pneumatic pressure, the valve will Fail Open.

What's Missing?

Is the drawing of the simple pressure loop complete? There probably is no right answer to that – other than, “What do you think?”. We are not really ducking the question. But remember, the people responsible for the P&ID will have to live with the drawing for many years. The “stakeholders” in the project need to decide how much detail is provided on a P&ID. The intended uses of the P&ID as a design document, a construction document and to define the system for operations all will, in some way, influence the detail shown. A list of a few things that might be shown include:

Air sets – Sometimes a symbol is added to pneumatic devices that indicates where instrument air is connected and an air set is needed. The air set is made up of any combination of a pneumatic regulator, a filter and a pressure gauge.

Set points – Some firms add the set points for regulators and switches, although we believe these are better shown on a Loop Diagram.

Root valve – The instrument root valve between the process and the transmitter may have a size and specification called out.

Control valve size – Sometimes the size of the valve is inferred by the size of the piping or by the size of piping reducers; sometimes the size is provided as a superscript outside the instrument bubble.

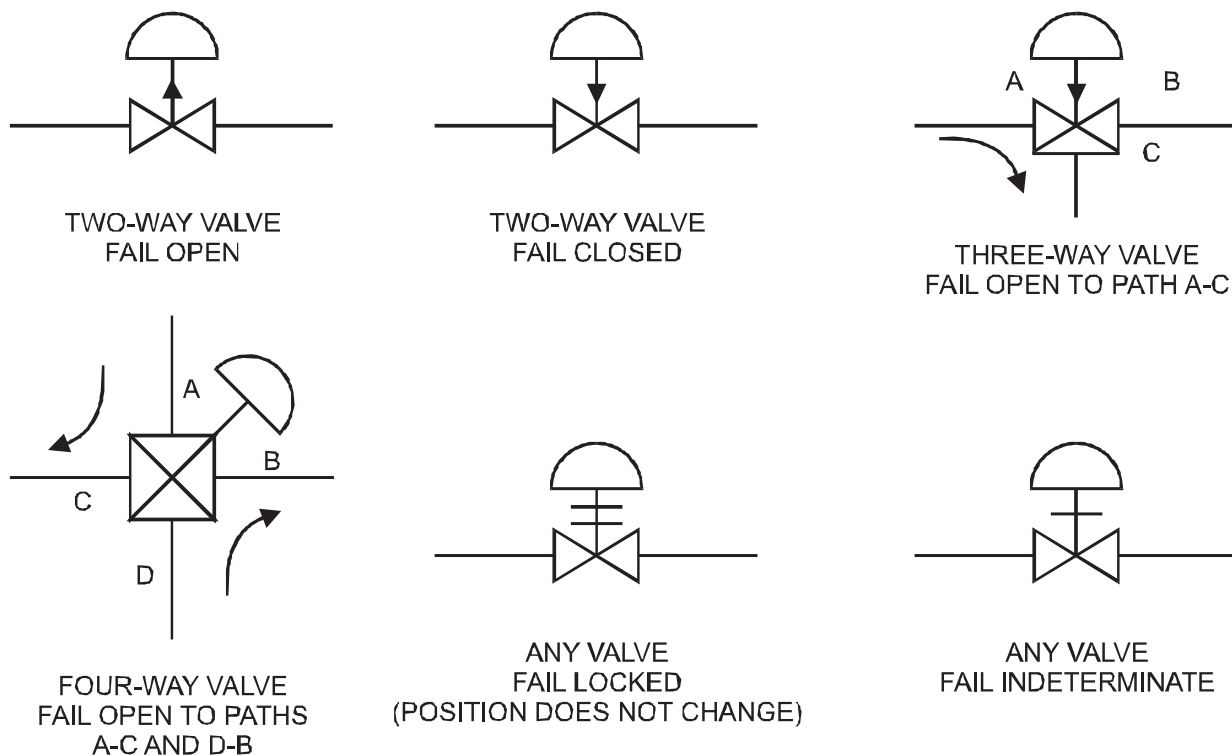
Valve positioner – In our opinion, the use of a valve positioner can be defined in the construction and purchasing specifications and Installation Details. We see no need to show positioners on the P&ID.

Controller location – The panel, bench board, control room or other location can be added as an identifier outside, but near to, the controller bubble. These will usually appear as an acronym or a few letters that are further identified on the P&ID legend sheet.

Control Valves

Control valves may fail in various positions – open, closed, locked, or indeterminate. The position of a failed valve can have a significant impact on associated equipment, and, therefore, it is of interest to operations personnel. Valve fail action is often discussed and agreed upon during the P&ID review meetings, so it is natural and efficient to document the agreed-upon action on the

Figure 2-5: Actuator Action and Power Failure



P&ID. For valve fail action, the term “Power” means the medium that moves the valve actuator and therefore the valve trim. The most common “Power” medium is instrument air. Power does not refer to the signal, unless the signal is the medium that moves the actuator.

The fail positions may be identified on the P&ID using letters below the valve symbol: FO for Fail Open; FC for Fail Closed; FL for Fail Last or Locked; and FI for Fail Indeterminate. Figure 2-5, Actuator Action and Power Failure, shows other methods of indicating the fail position of control valves. Looking at the figures, an arrow up signifies the valve fails open. An arrow down is fail close. A crossing line is fail indeterminate. Two crossing lines indicate fail locked or last position.

It is important to remember that fail position refers to the loss of the primary power at the valve, the motive force. Pulling the electronic signal off the valve transducer or electro-pneumatic positioner may induce a different reaction than the failure indication shown. A springless piston actuated valve will fail indeterminate upon loss of air. However, if there is a positioner, it will be driven in one direction or the other upon loss of the electronic signal.

Natural Gas Can Substitute for Air

Pneumatic systems are not always pressurized by instrument air. Offshore hydrocarbon production platforms have a ready supply of compressed gas available, albeit natural hydrocarbon gas. For smaller platforms without electric power, a gas filter dryer serves quite well in preparing the pneumatic medium to control the platforms. Obviously, smoking at work is frowned upon.

The control panels are a complex mass of pneumatic tubing, containing specialized components like first-out pneumatic indicators called “winkies”. Natural gas doesn’t have a noticeable smell. The familiar rotten egg smell of natural gas is actually due to a stenching agent – an odorant added later as a safety feature for consumers. It’s a very effective solution to a specific challenge.

Figure 2-6: An Electronic Loop

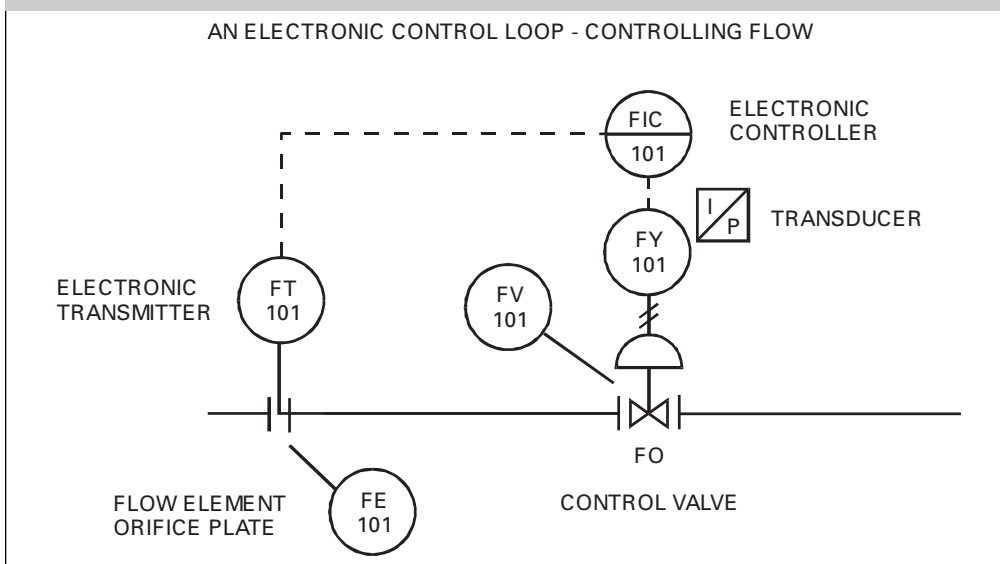


Figure 2-6 shows an electronic loop controlling flow in a pipeline. The loop number is 101. The dotted line indicates that information is transmitted electronically from the flow transmitter, FT-101, to the indicating controller, FIC-101, and from the controller to the current to pneumatic converter (I/P), FY 101. FT-101 senses the differential pressure proportional to the flow rate in the line caused by FE-101, a flow element or orifice plate. FT-101 transmits a 4-20 mA dc (direct current) signal corresponding to the varying differential pressure. FIC-101, an electronic flow indicating controller, transmits a 4-20 mA dc signal to the converter or transducer, FY-101, that converts the 4-20 mA dc signal into

To Show or Not to Show?

One of the challenges you will face is the depiction of third party systems on your P&IDs. If you have an island of equipment furnished by a third party, how much of that equipment should show on your drawing? If the third party system suppliers have their own P&IDs, do you copy them into your drawing set, or possibly just include their P&ID with your set? As usual, there really is no right answer; each facility is managed differently, each project has a different scope and each stakeholder in the P&IDs has different requirements.

It is not inexpensive to redraw a P&ID within your drawing set, nor is it a particularly good idea to have two drawings that show the same thing – yours, and the system supplier's. The drawings will probably only agree on the day they are checked and issued for use. As soon as someone makes a change, you start to "chase revisions".

One successful and cost effective approach has been to show the interface points between the vendor's system and your control system – just show the components seen on the operator station. Then, on your drawing, refer to the vendors P&ID and operating manual for further details.

a pneumatic signal. This signal changes the position of the valve actuator, which in turn changes the position of the inner works of the control valve, changing the flow through the control valve.

Simple instruments permit direct reading of a process variable in the field. These devices include pressure gauges, thermometers, level gauges and rotameters. Other loops are slightly more complex, transmitting a signal to the remote control system to indicate or record the value of a process variable in the control room, but without a controlled output. Both these classes of instruments are shown on a P&ID.

Members of the instrumentation and control design group add all the loop and local instruments to the P&ID, one at a time, until the complete instrumentation and control system is defined on the drawing. The proper location of local instruments should not be neglected, as they can be the first line of contact for those running and maintaining the facility. Your facility can only be improved when the operators and maintenance personnel assist with the endeavor.

ISA-5.1

ISA-5.1 is the standard most often used in process industries as the basis for depicting instrumentation and control systems on P&IDs and other documents. It is broad in scope and flexible in usage. The following is a quote from ISA-5.1, paragraph 4.4.1, entitled Symbols.

"The examples in this standard illustrate the symbols that are intended to depict instrumentation on diagrams and drawings. Methods of symbolization and identification are demonstrated. The examples show identification that is typical for the pictured instrument or functional interrelationships. The symbols indicate the various instruments or functions have been applied in typical ways in the illustrations. This usage does not imply, however, that the applications as designations of the instrument or functions are restricted in any way. No inference should be drawn that the choice of any of the schemes for illustration constitutes a recommendation for the illustrated methods of measurement or control. Where alternative symbols are shown without a statement of preference, the relative sequence of symbols does not imply a preference."³

The basic process control tagging standard for most industrial facilities is based on ISA-5.1. You will find, however, that additional information or interesting interpretations have been added to further define local requirements, to meet specific system requirements, or even to maintain site tradition. It is critically important that the standards used at your facility are completely defined and rigidly followed.

Without careful control of the symbols and usage, your documentation will rapidly devolve into a mess that is difficult to understand and use. More importantly, when the drawings are confusing to read or difficult to work with, people simply stop using them. Drawings and documentation must be continuously updated to agree with improvements and additions. When there is any problem with using the drawings, if they are confusing, ambiguous, difficult to read, or inaccessible, they will not be maintained. Drawings that are not maintained with vigilance quickly become useless, or worse, inaccurate.

Device Definition

As can be seen from Figures 2-4 and 2-6, a combination of identification letters, numbers, and symbols is used to define the devices in a loop. The identification letters are specified in ISA-5.1 and reproduced as Figure 2-7.

Figure 2-7 consists of twenty-six rows and five columns. The first column lists, alphabetically, twenty-six process variables, or as ISA-5.1 states, the “measured or initiating variable”.⁴ The first letter of any tag name, therefore, will indicate the process variable being measured. The most common process variables in a process plant include:

F – Flow

L – Level

P – Pressure

T – Temperature

There are several letters — C, D, G, M, N, O, which can be specified by the user. Of course, the user must clearly document the specified meanings on the site P&ID legend sheet, and those meanings should be maintained, without ambiguity or change, for the entire facility or, ideally, the entire company. Many sites will use ISA-5.1 as the starting point. The legend sheet table can then be modified to incorporate assigned letter designations, or even specifically define acceptable or standard letter combinations for the facility.

Using X for the first letter is a special case. From ISA-5.1, “The unclassified letter X is intended to cover unlisted meanings that will be used only once or used to a limited extent. If used, the letter may have any number of meanings.”⁵ The function of the letter is defined both on the legend sheet as well as implied with a few descriptive letters adjacent to the bubble. When properly applied, the letter X does not appear frequently — only once, or to a limited extent. Instead, the user-defined letters should be used for devices that appear regularly, even if infrequently. Thus, in many modern industrial facilities, X may not be needed, since most devices appear with some regularity. For those of you that have an entire facility filled with XT transmitters or XY transducers,

Figure 2-7: Identification Letters

	FIRST-LETTER (4)		SUCCEEDING-LETTERS (3)		
	MEASURED OR INITIATING VARIABLE	MODIFIER	READOUT OR PASSIVE FUNCTION	OUTPUT FUNCTION	MODIFIER
A	Analysis (5,19)		Alarm		
B	Burner, Combustion		User's Choice (1)	User's Choice (1)	User's Choice (1)
C	User's Choice (1)			Control (13)	
D	User's Choice (1)	Differential (4)			
E	Voltage		Sensor (Primary Element)		
F	Flow Rate	Ratio (Fraction) (4)			
G	User's Choice (1)		Glass, Viewing Device (9)		
H	Hand				High (7, 15, 16)
I	Current (Electrical)		Indicate (10)		
J	Power	Scan (7)			
K	Time, Time Schedule	Time Rate of Change (4, 21)		Control Station (22)	
L	Level		Light (11)		Low (7, 15, 16)
M	User's Choice (1)	Momentary (4)			Middle, Intermediate (7,15)
N	User's Choice (1)		User's Choice (1)	User's Choice (1)	User's Choice (1)
O	User's Choice (1)		Orifice, Restriction		
P	Pressure, Vacuum		Point (Test) Connection		
Q	Quantity	Integrate, Totalize (4)			
R	Radiation		Record (17)		
S	Speed, Frequency	Safety (8)		Switch (13)	
T	Temperature			Transmit (18)	
U	Multivariable (6)		Multifunction (12)	Multifunction (12)	Multifunction (12)
V	Vibration, Mechanical Analysis (19)			Valve, Damper, Louver (13)	
W	Weight, Force		Well		
X	Unclassified (2)	X Axis	Unclassified (2)	Unclassified (2)	Unclassified (2)
Y	Event, State or Presence (20)	Y Axis		Relay, Compute, Convert (13, 14, 18)	
Z	Position, Dimension	Z Axis		Driver, Actuator, Unclassified Final Control Element	

From ISA-5.1

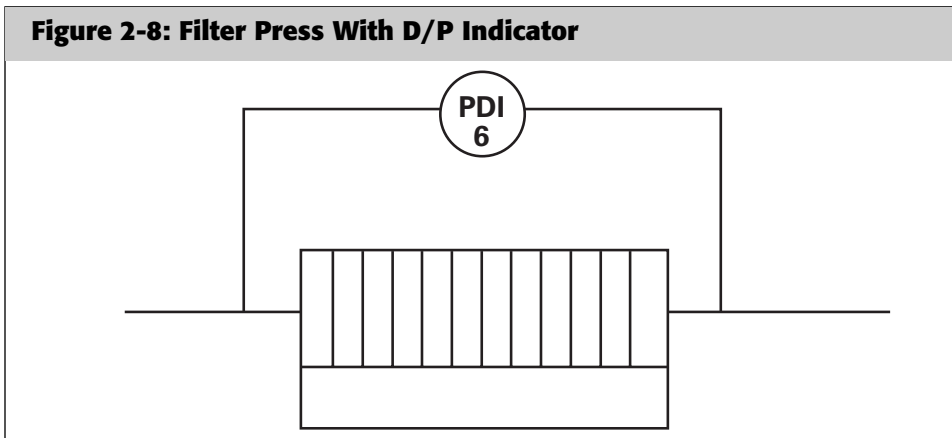
don't worry, this provision of ISA-5.1 is frequently ignored. You are not alone. Worry only if you are inconsistent!

The second column, marked "Modifier", adds additional information about the first letter, the process variable. For example, if an instrument is used to

measure the difference between two pressures, perhaps the upstream and downstream pressure of a filter press, a P for pressure is used as the first letter and a D for differential as a second letter modifier. See Figure 2-8 and 2-9. When instantaneous flow is being measured and a totalizer is added to provide total flow over time, the device identification is FQ. The first letter of the tag name is F for flow and the second letter is Q from the second column, signifying integrate or totalize.

The next three columns further define the device. The first of these delineates a readout or passive function. For example, Figure 2-8 shows that the filter press differential pressure is measured and indicated, as shown by a third letter I, for indicator. The absence of a dividing line in the middle of the circle (or “bubble”) shows the differential pressure is displayed locally.

Figure 2-8: Filter Press With D/P Indicator



Therefore, PDI shows locally the pressure drop across the filter. Figure 2-9 shows that the pressure differential value is transmitted to a central location. The second column of succeeding letters shows that we would use a T for transmitter, so the device would be a PDT.

Figure 2-9: Filter Press With D/P Transmitter

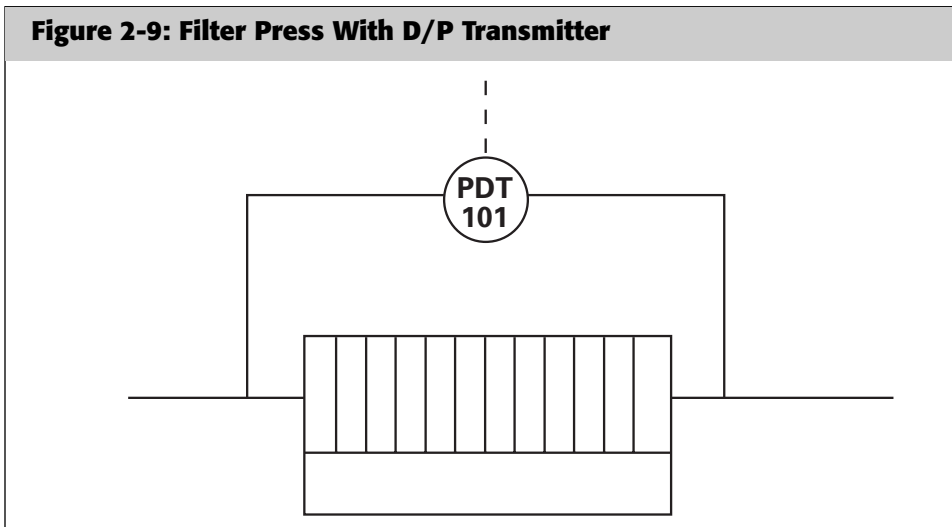


Figure 2-10: Typical Letter Combinations

First-Letters	Initiating or Measured Variable	Controllers			Readout Devices		Switches and Alarm Devices*			Transmitters			Solenoids, Relays, Computing Devices	Primary Element	Test Point	Well or Probe	Viewing Device, Glass	Safety Device	Final Element
		Recording	Indicating	Blind	Self-Actuated Control Valves	Recording	Indicating	High**	Low	Comb	Recording	Indicating							
A	Analysis	ARC	AIC	AC	AR	AI	ASH	ASL	ASHL	ART	AIT	AT	AY	AE	AP	AW	BG		AV
B	Burner/Combustion	BRC	BIC	BC	BR	BI	BSH	BSL	BSHL	BRT	BIT	BT	BY	BE		BW	BG		BZ
C	User's Choice																		
D	User's Choice																		
E	Voltage	ERC	EIC	EC	ER	EI	ESH	ESL	ESHL	ERT	EIT	ET	EY	EE			FG		EZ
F	Flow Rate	FRC	FIC	FC	FR	FI	FSH	FSL	FSHL	FRT	FIT	FT	FY	FE	FP				FV
FQ	Flow Quantity	FQRC	FQIC	FCV, FICV	FQR	FQI	FQSH	FQSL		FQIT	FQIT	FQT	FQY	FQE					FQV
FF	Flow Ratio	FFRC	FFIC	FFC	FFR	FFI	FFSH	FFSL						FE					FFV
G	User's Choice																		
H	Hand		HIC	HC					HS										HV
I	Current	IRC	IIC		IR	II	ISH	ISL	ISHL	IRT	IIT	IT	IY	IE					IZ
J	Power	JRC	JIC		JR	JJ	JSH	JSL	JSHL	JRT	JIT	JT	JY	JE					JV
K	Time	KRC	KIC	KC	KR	KI	KSH	KSL	KSHL	KRT	KIT	KT	KY	KE					KV
L	Level	LRC	LIC	LC	LR	LI	LSH	LSL	LSHL	LRT	LIT	LT	LY	LE		LW			LV
M	User's Choice																		
N	User's Choice																		
O	User's Choice																		
P	Pressure/Vacuum	PRC	PIC	PC	PR	PI	PSH	PSL	PSHL	PRT	PIT	PT	PY	PE	PP			PSV, PSE	PV
PD	Pressure, Differential	PDRC	PDIC	PDC	PDR	PDI	PDSH	PDSL		PDRT	PDIT	PDT	PDY	PE	PP				PDV
Q	Quantity	QRC	QIC	RC	QR	QI	QSH	QSL	QSHL	QRT	QIT	QT	QY	QE					QZ
R	Radiation	RRC	RIC	RC	RR	RI	RSH	RSL	RSHL	RRT	RIT	RT	RY	RE					RZ
S	Speed/Frequency	SRC	SIC	SC	SR	SI	SSH	SSL	SSHL	SRT	SIT	ST	SY	SE		RW			SV
T	Temperature	TRC	TIC	TC	TR	TI	TSH	TSL	TSHL	TRT	TIT	TT	TY	TE	TP	TW			TV
TD	Temperature, Differential	TDRC	TDIC	TDC	TDR	TDI	TDSH	TDSL		TDRT	TDIT	TDT	TDY	TE	TP	TW			TDV
U	Multivariable				UR	UI	VSH	VSL	VSHL	VRT	VIT	VT	UY	VE					UV
V	Vibration/Machinery Analysis				VR	VI	WSH	WSL	WSHL	WRT	WIT	WT	WY	WE					VZ
W	Weight/Force	WRC	WIC	WC	WR	WI	WDSH	WDSL		WDRT	WDIT	WDT	WDY	WE					WZ
WD	Weight/Force, Differential	WDRC	WDIC	WDC	WDR	WDI								WE					WDZ
X	Unclassified																		
Y	Event/State/Presence	ZRC	ZIC	ZC	ZR	ZI	ZSH	ZSL	ZSHL	ZRT	ZIT	ZT	ZY	ZE					YZ
Z	Position/Dimension	ZRC	ZIC	ZC	ZR	ZI	ZSH	ZSL	ZSHL	ZRT	ZIT	ZT	ZY	ZE					ZV
ZD	Gauging/Deviation	ZDRC	ZDIC	ZDC	ZDR	ZDI	ZDSH	ZDSL		ZDRT	ZDIT	ZDT	ZDY	ZDE					ZDV

Other Possible Combinations:

- FO (Restriction Orifice)
- FRK, HIK (Control Stations)
- FX (Accessories)
- TJR (Scanning Recorder)
- LLH (Pilot Light)
- PFR (Ratio)
- KQI (Running Time Indicator)
- QQI (Indicating Counter)
- WKIC (Rate-of-Weight-Loss Controller)
- HMS (Hand Momentary Switch)

Note: This table is not all-inclusive.

*A, alarm, the annunciating device, may be used in the same fashion as S, switch, the actuating device.

**The letters H and L may be omitted in the undefined case.

By starting with a process variable at the left of Figure 2-9 and adding the letters defined in the succeeding columns, the complete function of the control system device is defined.

Figure 2-10, Typical Letter Combinations, a reprint of a page in ISA-5.1⁶, shows many possible letter combinations and describes the device represented by the letters. Reading across Figure 2-10, starting with an F, the initiating or measured variable for flow rate, the succeeding letters describe the devices and functions as follows:

Letter Combination	Description
FRC	Flow Recorder Controller. A recorder for the value of instantaneous flow, integral with a flow controller.
FIC	Flow Indicating Controller. An instantaneous flow indicator combined with a flow controller.
FC	Blind Flow Controller. A flow controller without any indication or recording of instantaneous flow.
FCV	A self-actuated control valve controlling flow.
FICV	An FCV with an integral instantaneous flow indicator.
FR	Flow Recorder.
FI	Flow Indicator.
FSH	Flow Switch High. A switch which changes state on high flow.
FSL	Flow Switch Low. A switch which changes state on low flow.
FSHL	Flow Switch High-Low. A switch which changes state on high or low flow, and does not change in between the high and low flows.
FRT	Flow Recording Transmitter. For transmitting and recording in the same device.
FIT	Flow Indicating Transmitter. Transmitter with an integral indication of instantaneous flow.
FT	Blind Flow Transmitter. Transmitter with no indication of instantaneous flow.
FY	Solenoid, Relay, Computing Device. For example, current (I) to pneumatic (P) converters are correctly identified (in accordance with ISA-5.1) as FY in a flow loop, with a further definition of I/P shown outside the symbol, often in a square box.

Common misconception

According to ISA-5.1, it is not correct to use the succeeding letters CV for anything other than a self-actuated control valve. A control valve in a flow loop is identified as an FV. FCV is a self contained flow regulator.

Letter Combination	Description
FE	Primary Element. An orifice plate.
FP	Test Point. A point provided in the piping where a test measurement is made; the instrument is not normally connected to the point permanently. The point is normally valved or otherwise isolated.
FG	Flow Glass. G for glass or viewing device. A sight flow indicator. An uncalibrated view of the flow is provided.
FV	Flow Valve. Control valve in a flow loop.

Interesting interpretations – and an opinion:

An electro-pneumatic transducer, commonly called an I/P, probably has more combinations of “ISA standard” tags than any other control system component. We say “ISA standard” somewhat facetiously, since clearly all approaches cannot be correct, yet you can be sure that someone along the way assured someone else that their particular approach was in accordance with ISA-5.1. Creative tagging of I/Ps include, even within a single facility, no tag at all, I/P, IP, FY, XY, NY and so forth. “No tag” can easily occur when the I/P arrives on site pre-mounted to a control valve by the valve vendor, and the control valve is the only tag within your system.

The correct tagging of an I/P is to use the first letter of the loop in which the I/P appears, “the process variable”, followed with a “Y” as the output function “convert”. Thus a flow loop I/P would be an FY. To be crystal clear, the I/P would be written in a function block or a box adjacent to the bubble. The reason for the creative tagging of I/P may be that, with the widespread use of electronic instrument databases, some may see an advantage in developing a unique identifier for an I/P, so a database sort can list all the I/Ps on a project under one identifier independent of the loop it serves.

There will be a lot of I/Ps on a project. The ability to list all occurrences of a component is handy when specifying and purchasing a component. Also, from a practical standpoint, this author was once asked, “since they are called I/Ps, why not tag them as “I/Ps”? It is hard to argue with that logic! The I/P tag works since there is not another common device that would call for the use of I/P; there isn’t a data clash.

Detailed explanations to justify the I/P tag typically start with: “I is the process variable for current and P is pneumatic pressure, so it works.” Well, that may be true. It certainly works, but it isn’t technically true from an ISA-5.1 view, so some practitioners may be appalled. The “process variable” letter is intended for the entire loop, not for that one device in the loop, so it should technically be F, P, T, L, etc., the variable that the loop is measuring or controlling. “P” is not actually listed as an output function. P is “pressure” only as a process variable, the first letter in the tag string.

Instrument Numbering

In addition to the letters, the instrumentation and control design group assigns a sequence number to each function. All the devices within that function carry the same sequential number – in other words, the loop number. A single loop number is used to identify the devices that accomplish a single specific action – usually an input and an output for PID control, an input for indication of a process variable, or a manual output. This number, combined with the letter designation, positively and uniquely identifies each device within that set.

These numbers may follow the suggestions in ISA-5.1. However, there are many other numbering systems used in industry. ISA-5.1 suggests that loop numbering may be parallel or serial. By parallel, ISA-5.1 means starting a new number sequence for each first letter. Therefore, there may be an FRC-101, a PIC-101, and a TI-101. By serial, ISA-5.1 means using a single numerical sequence for all devices. Therefore, there may be an FRC-101, a LR-102, a PIC-103, and a TI-104.

A block of numbers is sometimes used to designate certain types of devices. For example, all safety valves might use the 900 series: PSV-900, PSV-901, PSV-902, etc.

Instrument numbers may also be structured to identify the loop location or service. For example, see Figure 2-11, Instrument Numbering. The first digit of the number may indicate the plant number; hence, FT-102 is an instrument in plant 1. Another method of identifying the instrument location is with a prefix, for example: 2 (area), or 03 (unit), or 004 (plant 4) which identifies the service area of the loop: 2-FT-102 is loop 102 in area 2, or 03-FT-102 is loop 102 in unit 03, or 004-FT-102 is loop 102 in plant 4. These numbers can also be combined to show area-unit-plant in one number: 234-FT-102 is a flow transmitter in loop 102, which serves area 2, unit 3 and plant 4. To be completely confusing, remember that the loop number defines the items in the loop, so the loop may serve the area listed above, but a particular device may be physically located in another area.

A variation of this system is to tie the P&ID numbers to a particular area, and then to sequentially number the instruments on that P&ID sheet. For example, P&ID 25 carries up to 100 loops, or instrument loop numbers 2500 to 2599. The elegance of this system is that you can find the correct P&ID for an instrument based upon the tag number alone, since the tag number includes the P&ID number. Frequently the area number is nested in the P&ID number anyway, so you will also know the area served by the loop just by looking at the loop number.

The numbering system chosen for your P&IDs and loops should be tested and verified to ensure they work as expected with the various electronic applications used within your facility. Loop number 1 and loop number 001 will have markedly different treatment by some databases and by the maintenance planning and inventory control software.

Figure 2-11: Instrument Numbering


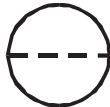
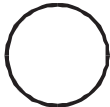


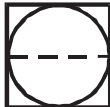

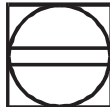





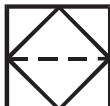


- **Use Basic Number if project is small and there are no area, unit, or plant numbers:**
 - Basic Number FT-2 or FT-02 or FT-002
- **If project has a few areas, units, or plants (9 or less), use the first digit of the plant number as the tag number:**
 - FT-102 (1 = area, unit, or plant number)
- **If project is divided into area, units, or plants:**
 - 1-FT002
 - 01-FT002
 - 001-FT002

Many different numbering systems are used. Some incorporate a major equipment number into the instrument identification. Still another variation deviates from the “unique number” requirement by use of the “loop” number as a coding system to group similar commodity type devices. The number that appears in the loop number place on the instrument circle is a component identifier that is tied to a master device specification. This approach can be useful for calling out devices that don’t interface to the control system, such as local indicators like pressure gauges – in other words, commodity type devices.

For example, in your facility, PI-100 is listed in the component’s specification as a 4 1/2" diameter pressure gauge with a range of 0-150 psig and a stainless steel Bourdon tube. As long as all your PI-100s are the same, this system works. There will be many component numbers when this system is used on temperature gauges, since there are so many variations of stem length, dial size and ranges. When you have a different material of construction or other change, a different number has to be used. Of course, a more complete pressure gauge specification can be used when actually purchasing the gauge. This approach is not common, but with care, it can be useful.

The letters and numbers that identify loop components have to appear on a drawing somewhere, so the next step is to put the chosen function identifier and loop number, the tag number, on the P&ID. ISA-5.1 provides the information needed to further define the location of an instrument and controls device through the use of specific symbols. The symbols are shown in Figure 2-12.

Figure 2-12: General Instrument or Function Symbols

	LOCATIONS			
	ON CENTRAL CONTROL PANEL	BEHIND CONTROL PANEL	IN THE FIELD	ON LOCAL CONTROL PANEL
DISCRETE INSTRUMENT				
SHARED CONTROL/DISPLAY (e.g., DCS)				
COMPUTER FUNCTION				
PROGRAMMABLE LOGIC CONTROLLER				

The circles, squares, hexagons and diamonds all have meaning. A circle means the device is field mounted (located in the process area of the plant). If a line is added through the center of the circle, the device is located in the primary location normally accessible to the operator (the central control room). If a second line is added, parallel to the first, the device is located in an auxiliary location, normally accessible to the operator (a local panel or on the starter cassette in the motor control center). A dotted line through the center of the circle shows the device is normally inaccessible to the operator (behind the panel). If an external square is added to the circle, the symbols represent devices or functions that are part of a shared display shared control system (a distributed control system, a DCS). If we substitute a hexagon for the circle or the squared circle, the symbols represent a computer function. A diamond within a square is used to define functions within a programmable logic controller, a PLC.

Line symbols are used to define the ways information is transferred between the field devices and the central control location.

Line Symbols

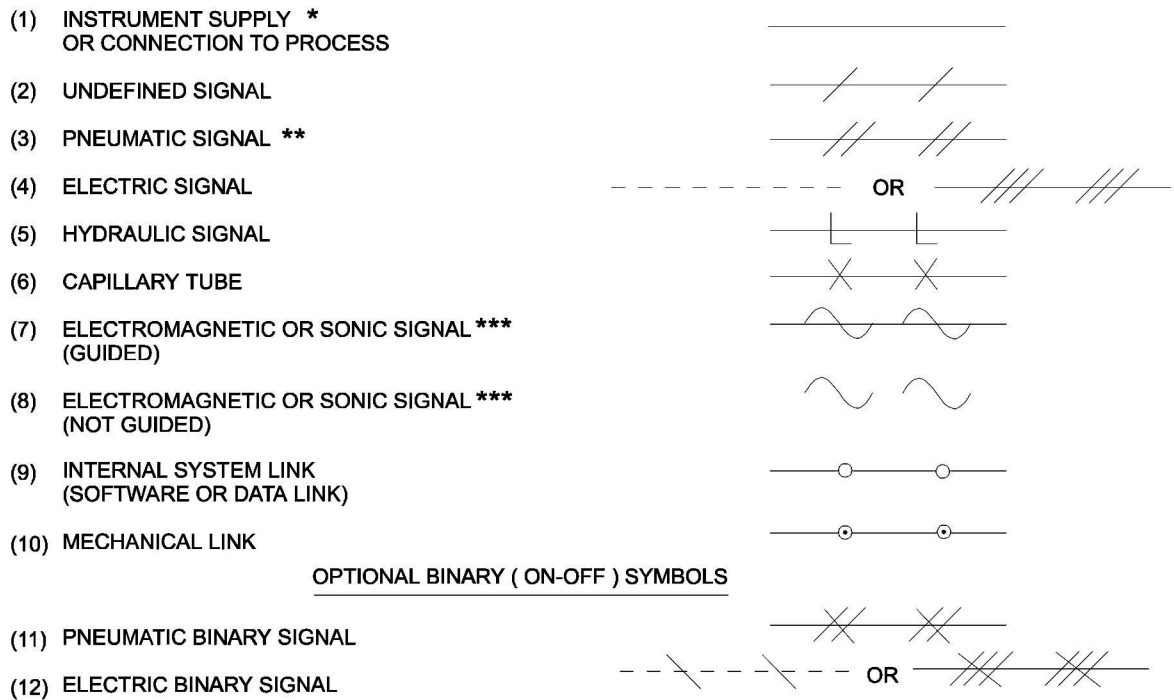
Figure 2-13, Instrument Line Symbols, is copied from ISA-5.1.⁷ The symbols describe how signals are transmitted between devices. First, the lines used are to be lighter than the associated process piping. The process sensing line, the pipe or tubing that connects a pressure transmitter directly to the process, is the lightest acceptable “pipe” line. A line with a double parallel crosshatch defines pneumatic transmission – usually, but not always, instrument air (some gas pipelines use natural gas, some plants use nitrogen).

For binary or on-off pneumatic signals, an optional symbol calls for the addition of a single opposing strike on the crosshatch of the pneumatic signal line. This is not commonly used, if for no other reason than the additional information regarding the nature of the signal is probably not critically important to the P&ID. Two symbols are shown for electronic transmission – the dotted line and the triple crosshatch. In the United States, the dotted line is predominant. Further definition of the electronic signal as binary or discrete is available by adding an opposing strike thru across the electric line. However, this electric binary symbol is not commonly used. Unguided electromagnetic transmission – including heat, radio waves, nuclear radiation and light – is shown by a series of sine waves. If the sine waves are superimposed on a line, the waves are guided. Internal system links such as software or data link are shown as a dash and a circle. This symbol is commonly used for a digital signal.

The advent of digital communication to field devices introduces the option to use either a dashed electric signal line or a data link line type to connect field transmitters and valve controllers. One approach may be to keep the dashed line symbol for field device wiring and the line-circle-line symbol to define

Figure 2-13: Instrument Line Symbols

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



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 | } Options | HS - Hydraulic Supply |
| IA - Instrument Air | | NS - Nitrogen Supply |
| PA - Plant Air | | SS - Steam Supply |
| ES - Electric Supply | | WS - Water Supply |
| GS - Gas 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.

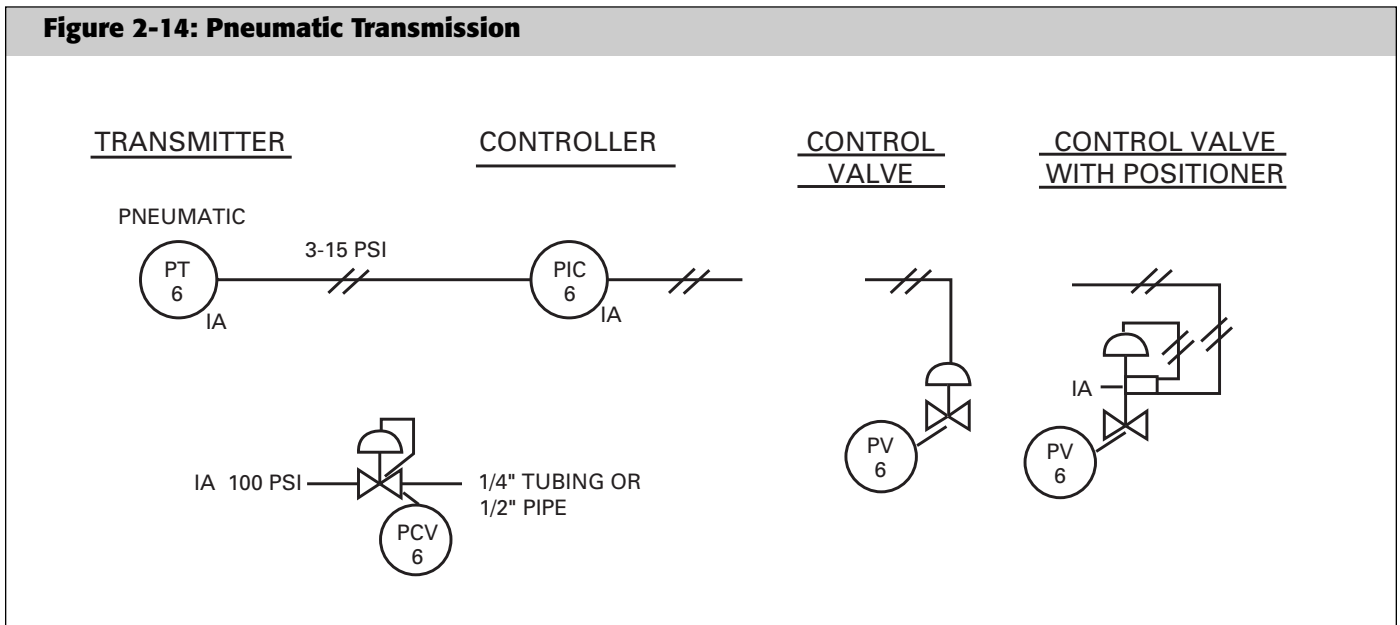
** The pneumatic signal symbol applies to a signal using any gas as the signal medium. If a gas other than air is used, the gas may be identified by a note on the signal symbol or otherwise.

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

function relationships within the control computer or for main data links between control computers. A line with a single crosshatch is an undefined signal, perhaps to be used in the early development stage of a P&ID.

Pneumatic Transmission

Figure 2-14: Pneumatic Transmission



A complete pneumatic transmission system is shown in Figure 2-14. For the purposes of this example, pneumatic signal pressures are 3-15 psig. In practice, signal pressures can also be 6-30 psig, albeit less commonly. PT-6, a field mounted pressure transmitter, develops and transmits a 3-15 psig signal proportional to pressure of the process. The signal is transmitted to a field-mounted indicating controller, PIC-6. The controller develops and transmits the 3-15 psig corrective signal to the control valve PV-6.

If the valve operator (actuator or top works) can move the control valve through its entire range with the 3-15 psig signal, regardless of the process pressure, the pneumatic line is connected directly to the valve operator. If the 3-15 psig signal is not sufficient to operate the valve for all of its design conditions and range, a positioner is added to the valve operator. The function of the positioner is to compare the incoming signal with the actual valve position and develop the output air pressure necessary to position the valve in accordance with the incoming signal. The output pressure from the positioner to the valve is at a higher pressure, normally 30 psig up to and including full instrument air line pressure of 100 psig or higher.

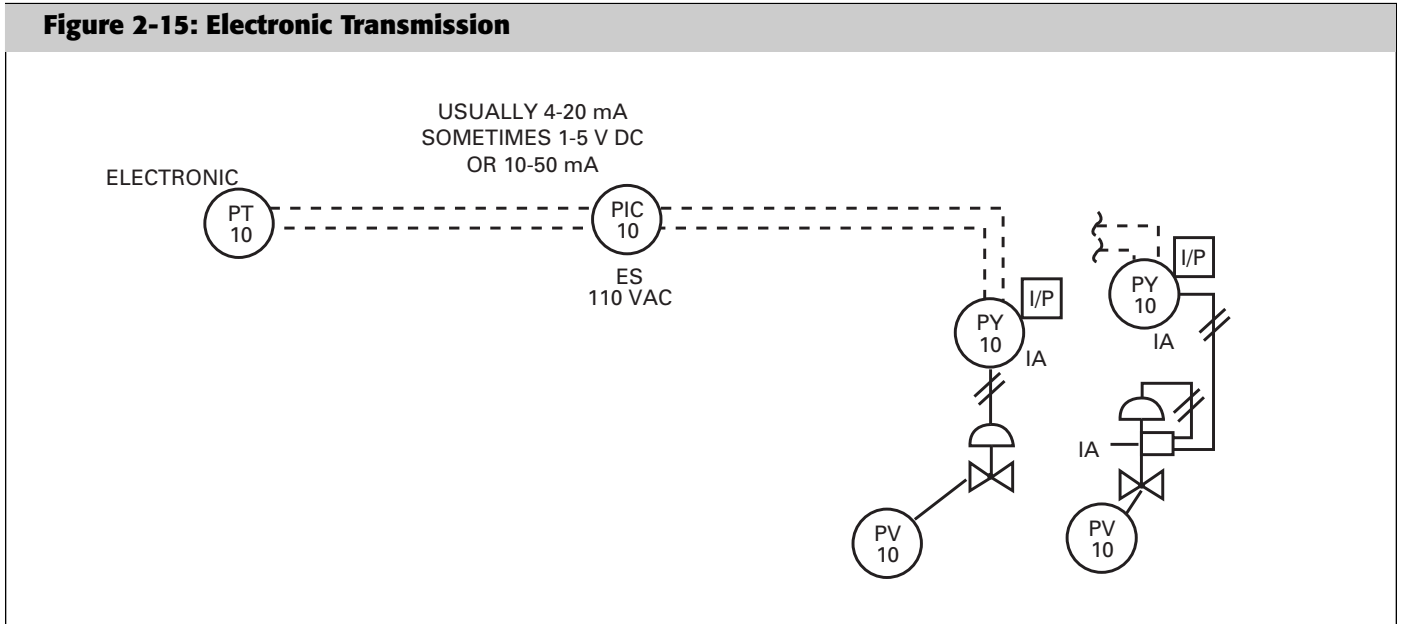
Figure 2-14 shows that we need a source of instrument air (IA) at the transmitter, another at the controller, and another at the valve positioner. The IA is usually distributed in the field by a complete instrument air piping system, often at a nominal line pressure of 100 psig. Pressure regulators, shown in the figure as PCV-6, are located at the individual users to reduce the instrument air pressure to that required by the field device. Pressure regulators that serve pneumatic devices do not always, or – depending upon your industry – do not

commonly carry loop identifiers. They may appear on the drawings as an untagged symbol, like a darkened triangle or some variation of an A with a line through it to the pneumatic device served.

Electronic Transmission

Figure 2-15 shows a typical electronic transmission system.

Figure 2-15: Electronic Transmission



Many electronic transmission systems for instrumentation and controls are called “a two wire system”. This means the field transmitter has only two wires connected to it. The signal transmitted usually has a 4 mA to 20 mA, nominally 24 volt dc range, although some installations may use a 10-50 mA dc or a 1-5 volt dc signal.

Most control valves are pneumatically operated, so even in the modern electronic control system, the electronic signal will be converted to pneumatic to actually change the position of the valve. The device that does this is a converter or transducer, typically an I/P or an electro-pneumatic positioner. An I/P is shown on Figure 2-15 as a PY, a traditional tagging convention. P is for pressure and Y is for solenoid, relay or computing device.

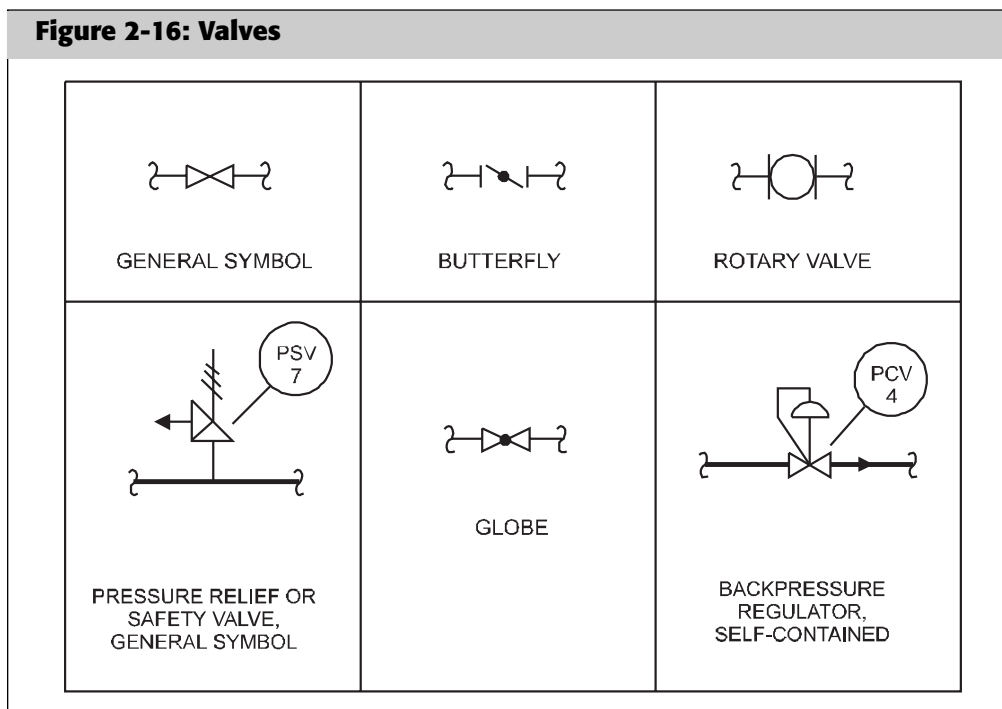
To clarify further, a function block, a small (1/4") square surrounding the letters I/P, is added to the right of the converter instrument circle. A pneumatic or electro-pneumatic positioner is frequently not tagged separately from the valve, probably because it is usually installed and shipped as part of the control valve. However, for your use, there is a symbol and a tag for positioners (ZC) included in ISA-5.1.⁸ Symbolically, a simple box on the stem of a control valve can be used to indicate the presence of a positioner. An electro-pneumatic posi-

tioner is indicated when the electronic signal terminates on the box instead of a pneumatic signal.

There are many other symbols included in ISA-5.1 for specific instruments. We will not try to show them all. The following figure shows a few types of valves.

Valves

The general valve symbol, the “bow tie”, may be used to indicate the body of a control valve or a hand-operated valve. Some projects use this symbol as a generic control valve symbol rather than trying to define the control valve type by using the butterfly, globe or rotary symbols, shown in Figure 2-16.



It is important at this stage to balance the importance of the information with the expense of maintaining that information. In deciding to reflect the actual control valve type through the use of the specific valve symbol, you should ask if that information is important to the function of the drawing, since it serves your team and those that will make use of the drawing in the future.

For a P&ID, is it germane to understanding the process? Is it necessary to know that a control valve is a butterfly style when reviewing the P&ID? Do the preponderance of P&ID users care what kind of control valve is used, or is it enough to know there is a control valve there? The expense of the information is the cost to maintain the correct symbol. We are using the control valve symbol as one example of questions that should be asked when deciding what goes on a P&ID and what does not.

P&IDs are developed (rather than maintained), for the most part during a design project. The actual type of control valve may not be known until the valve is purchased, which is long after the P&IDs have been issued for detail design. You may be pretty sure a valve will be a butterfly valve, but you really won't know until the valve is purchased. If you are showing the actual valve type on the P&ID, someone will have to review each valve symbol after control valves are purchased to ensure the correct valve type symbol was chosen. There is a cost for that review, correction, and, even more so, to re-issue the drawings. On a large project, the cost of copying and distributing the drawings can be astronomical. Once the P&ID is issued and the project is complete, the details regarding that particular device are available elsewhere – on Loop Diagrams, Data Sheets, the Instrument Index, etc.

Additional valve symbols are shown in Figure 2-16. The symbol for safety or relief valves consists of an angle valve combined with a spring. Pressure regulators are control valves with actuators, but without an external control signal – designated in the example as a PCV, a self activated valve that regulates pressure. The pressure sensing line is shown upstream, if the PCV controls back pressure, and downstream if it controls downstream pressure.

One of the most common methods of measuring flow and transmitting that measurement is with an orifice plate and a differential pressure (d/p) cell.

Figure 2-17: Typical Transmitters – Flow

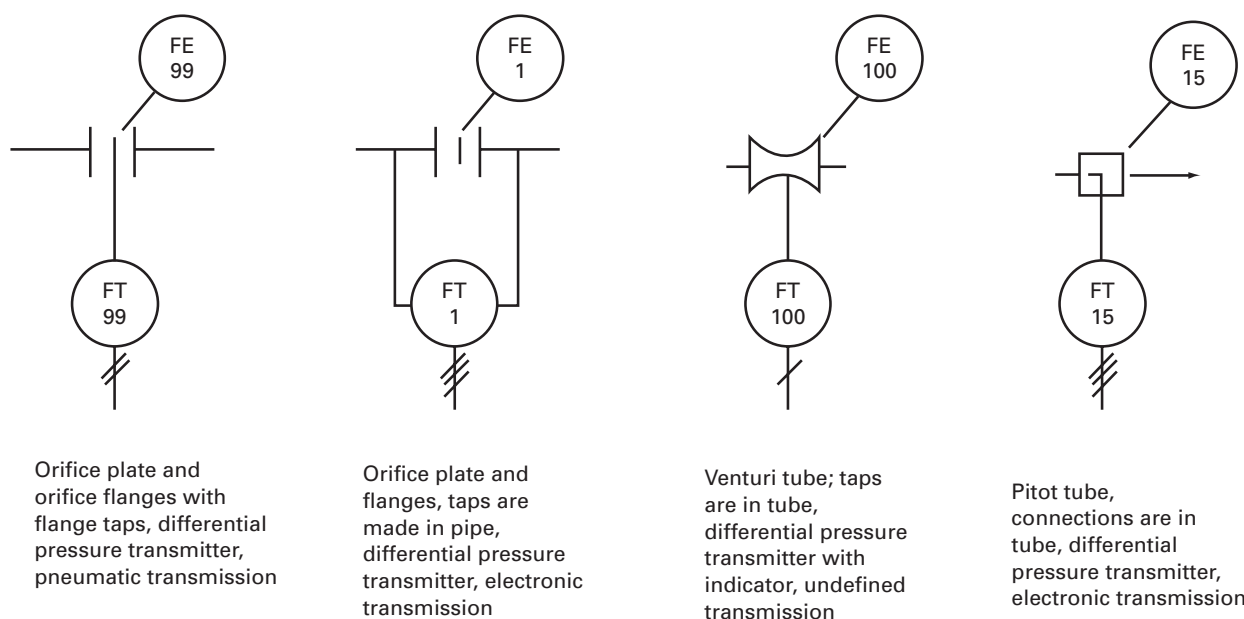
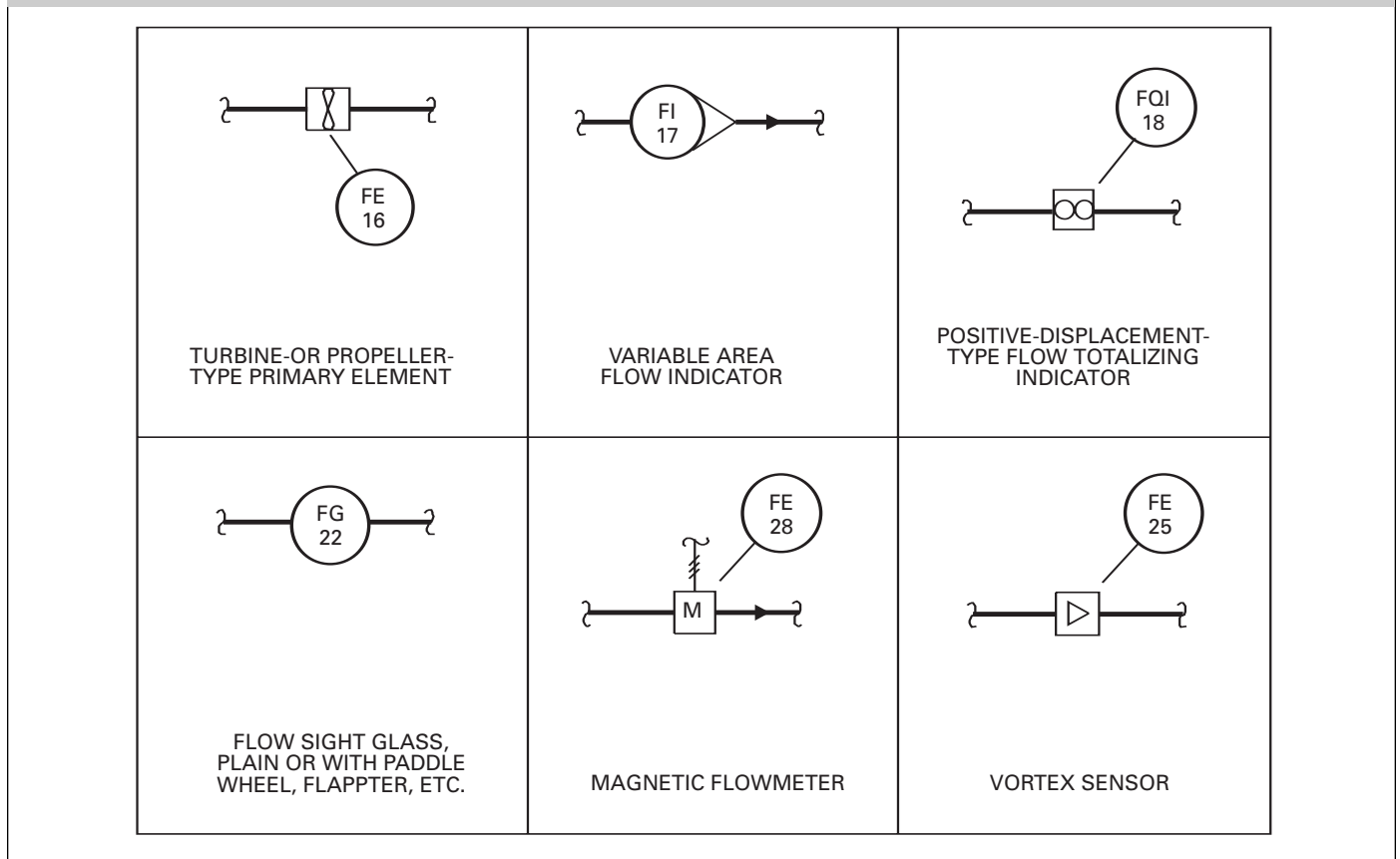


Figure 2-17 shows several variations of primary flow elements that produce a pressure differential relative to flow: an orifice plate and flanges with flange taps, an orifice plate and flanges and pipe taps, a venturi tube, and a pitot tube.

Figure 2-18: Flow Devices



From ISA-5.1

Other methods of flow measurement are shown in Figure 2-18. A turbine meter measures the varying speed of a turbine blade in a flow stream. A variable area meter, also known as a rotameter, measures flow through the relative position of a “float” or plummet against a graduated tube. A positive displacement device is used to measure liquid flow volumetrically, such as the water meter in a residence. A sight flow glass is a glass window set into a process line to indicate, but not measure, flow. A magnetic flow meter measures the very small voltage developed when a conductive liquid passes through a magnetic field. The vortex meter measures the change in a process stream as a vortex develops and recedes.

We have presented an overview of the symbols in ISA-5.1. As a review, please do the following exercises.

Match the descriptions from Figure 2-19 with instrument symbols taken from Figure 2-20. When you have finished, check your answers with the answer sheet in Appendix A.

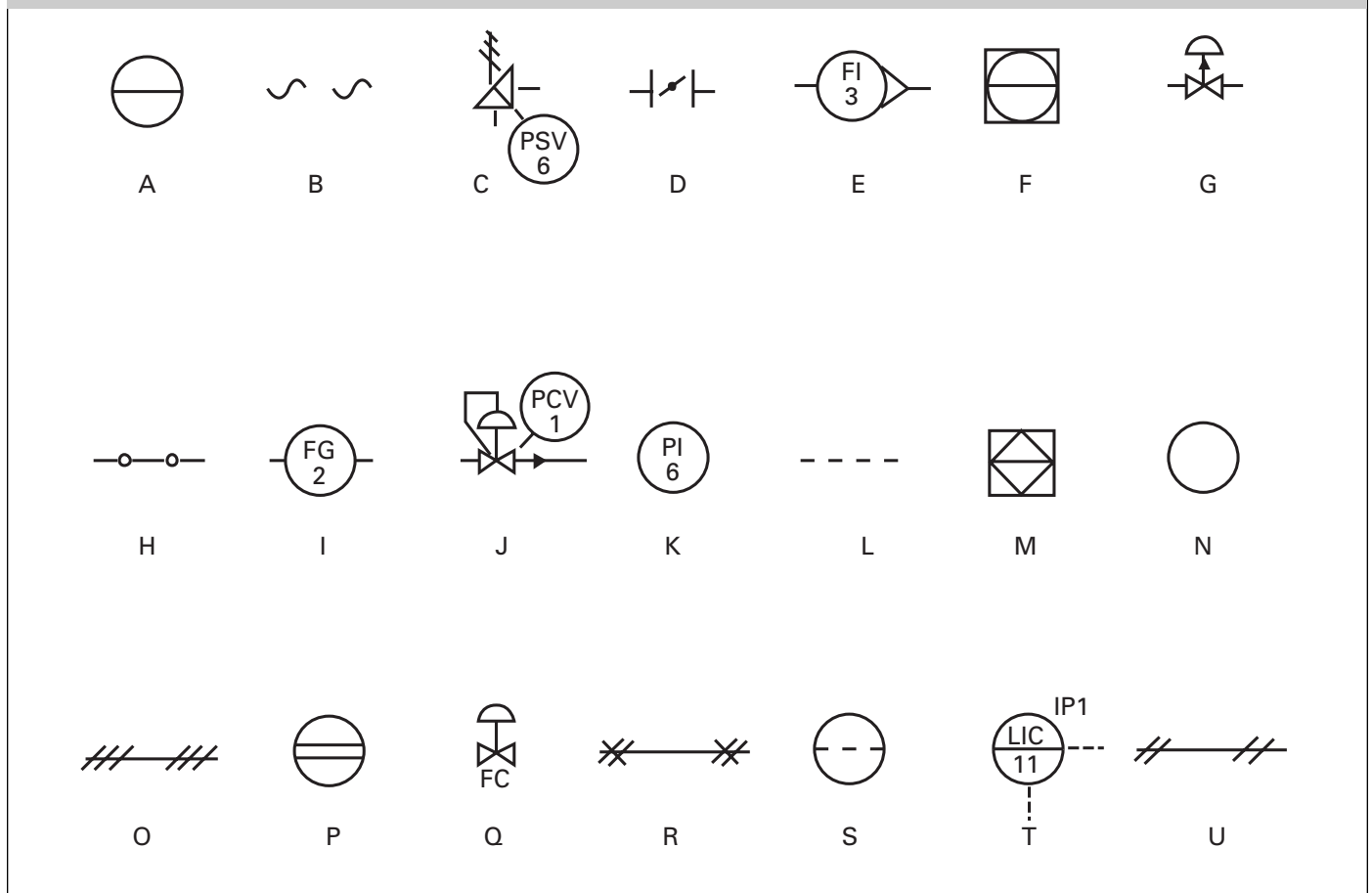
Figure 2-19: Descriptions

Instructions: Match the drawing/symbols on the next page with the instrument function title/description below.

1. () Pneumatic Line Symbol
2. () Discrete Instrument - Primary Location Normally Accessible to Operator
3. () Safety Valve
4. () Discrete Instrument - Auxiliary Location Normally Accessible to Operator
5. () Board Mounted Electronic Level Controller
6. () Butterfly Valve
7. () Back Pressure Regulator - Self Contained
8. () Internal System Link - Software or Data Link
9. () Discrete Instrument, Normally Inaccessible (Behind the Panel)
10. () Shared Display or Control - Primary Location Normally Accessible to Operator
11. () Electromagnetic or Sonic Signal, Not Guided
12. () Electric or Electronic Signal
13. () Variable Area Meter (Rotameter)
14. () Control Valve - Pneumatic Actuator, Fail Open
15. () Electric or Electronic Signal
16. () Discrete Instrument - Field Mounted
17. () Control Valve, Fail Closed
18. () Pneumatic Binary Signal
19. () Pressure Indicator
20. () Programmable Logic Controller - Primary Location Normally Accessible to Operator
21. () Flow Gauge

PFD Defines Process Conditions

As the project design progresses, information from the PFD is used to define process conditions for equipment and piping. The equipment or vessel group sizes vessels using information first established on the PFD. The piping group, or perhaps the process group, calculates the pipe sizes. The mechanical equipment group selects equipment. Equipment requirements may influence the process throughput, which has an iterative impact on the process design. Equipment changes introduce process changes that change line sizes. Equilibrium is reached eventually, as the project team establishes more details and pertinent information becomes available. All this information is recorded and updated on the P&ID. The P&ID is the coordinating document among design groups. Each design group must continually add information to the P&ID and check the information added by other groups. As piping and equipment details become available, the instrumentation and controls design group establishes the process-sensing points, calculates the control valve sizes and begins to add control loop definition.

Figure 2-20: Symbols

Frequently information added to a P&ID is a coded reference to more complete data that is maintained separately on Specification Forms (data sheets) and databases. The number shown on a pipe is an alphanumeric coded number. The number provides access to additional information on a line list and in the piping specification. This additional information might include materials of construction, pressure ratings, connection methods and service.

Detailed Design

At some point, the project's decision-makers conclude the P&IDs are sufficiently developed to start the detailed design. The design process goes into high gear. Some projects mark this point as a schedule milestone. The P&IDs, and perhaps other drawings and documents, are formally issued for detailed design. They are so marked on the revision blocks of drawings issued for detailed design, or some similar variation. This point corresponds to a significant ramp up in staffing and the start of design document generation.

The instrumentation and controls design group then increases its activity to place symbols and tag numbers on the P&IDs to depict each instrumentation and control system device or function. Instrument tag numbers indicate the

process variable and the device's function. The tag number provides access to more complete information on the Specification Forms and other instrumentation and control systems documents.

There are no universal standards that address the format to be used in developing P&IDs. The format used by most design groups has been developed over many years. However, here are a few guidelines that serve as a simplistic *de facto* standard:

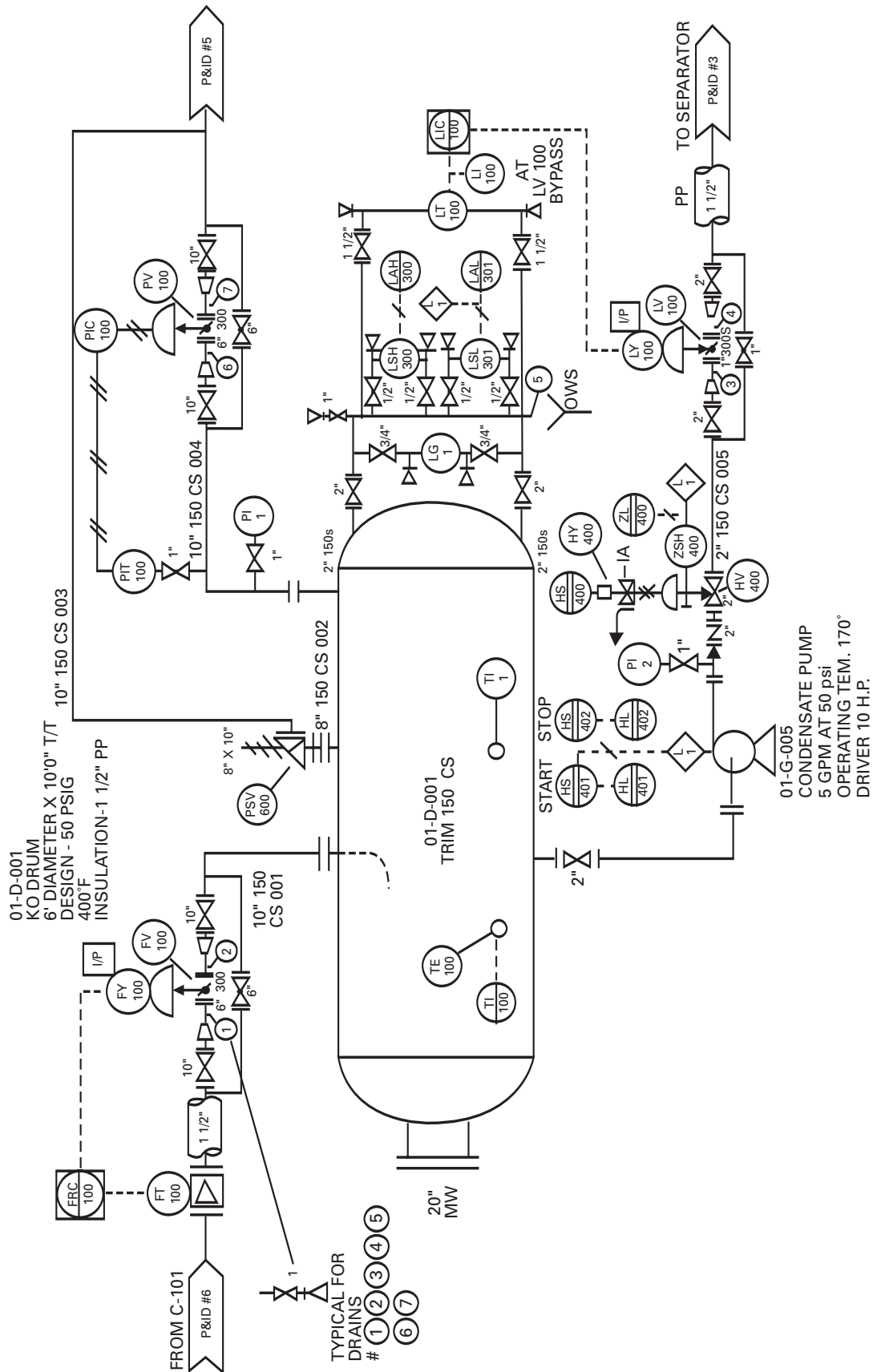
- The process flows from the left of the P&ID to the right.
- P&IDs are developed as “D” size sheets (22" x 34") or larger, but should be legible when reduced to “B” size (11" x 17") for ease of use in the office and in the field.
- P&IDs should show sufficient information to define the process without crowding. One to three pieces of equipment with auxiliaries is normally sufficient for one P&ID.
- To reduce clutter, a typical detail can be used for repeated components (see the “typical drain” on Figure 2-21).
- When piping gets complex, auxiliary P&IDs are used.
- Add notes for understanding and clarity.
- Show relative sizes of equipment, but do not include specific elevations or dimensions.
- Every set of P&IDs should include a legend sheet, or sheets, to define the symbols and abbreviations used.
- The free space on a P&ID should facilitate addition of future process changes; it is best not to start with congested P&IDs.

There is always a trade-off on the subject of how much information and how much detail should be included on P&IDs. Most of the specialist groups tend to want more information on the P&IDs, and project groups want to show less information and keep P&IDs uncluttered. Therefore, it is also good to ask yourself, “Is this information really of value to the end users of the P&ID? Or, is this information kept better elsewhere?”

For this book, our project team uses the Process Flow Diagram from Chapter 1, Figure 1-1, to develop a P&ID, Figure 2-21. The P&ID includes the KO Drum, 01-D-001, and its associated equipment, piping and instrumentation and control components.

Figure 2-21 includes examples of several control loops. This example P&ID also includes several different methods of documenting the control components. It shows how information might be displayed on a P&ID, but it is not meant to be a realistic design for a KO Drum and associated equipment.

Figure 2-21: P&ID



Equipment Identification

The drawings developed during design will be identified, at a minimum, by a drawing number and a revision number or letter. This information, and more, will be included on a title block. Title blocks have not been shown on the P&ID for simplicity and to conserve space. We will address drawing numbers, revision numbers, and letters and title blocks in Chapter 9.

A unique number is used to identify equipment on P&IDs. For example, equipment number 01-D-001 appears in at least two places – on the PFD and on the P&ID. The D-001 used on the PFD has now been expanded to include a prefix, 01, to signify the drum is located in plant 01. In this example, the rating for the trim piping, ANSI 150 carbon steel, is shown directly on the vessel symbol, 150CS. Additional information is frequently shown on the top and the bottom of the P&ID drawing. In particular, equipment rating, size and nominal or design throughput is provided on the P&ID. However, there is no standard way of showing this information. Some designs show equipment information within or adjacent to the symbol itself. Others will show the detailed information along the bottom of the drawing, relying on proximity to tie the symbol and the data. Or, possibly the equipment number is used to link the data and the symbol.

The vessel group has designed vessel 01-D-001 and the P&ID symbol now reflects that design. It is a horizontal vessel, six feet in diameter and ten feet from tangent to tangent. The tangent lines define the cylindrical part of a vessel. The heads complete the vessel. Also shown are a 20" diameter access port, which used to be called a manway (MW), and the internal piping to direct the incoming wet gas.

As shown in the vessel data text on the drawing, the vessel is designed to withstand a maximum internal pressure of 50 psig at 400°F. There is a lot of information included in the two simple letters PP within the vessel information text. The "1 ½" PP" means the vessel will be insulated with one and one-half inches of insulation for personnel protection. This insulation is placed on equipment and piping to protect personnel from injury through contact with a hot surface. The entire vessel is not insulated because we want the gas to cool. The portion of 01-D-001 to be insulated is defined in a plant or project specification – perhaps that which can be reached from the ground or platform, or might be touched when climbing a permanently installed ladder.

Our P&ID shows pump 01-G-005 information adjacent to the pump symbol. Other designs may show more or less information elsewhere. We have elected not to show a symbol for the pump driver, although some designs may include this information. We have shown pump driver start and stop information. When every motor in the facility is started and stopped the same way, the

motor data can be provided by a single typical symbol, with details furnished for exceptions only.

Piping and instrumentation and control system connections are now sized and shown on the P&ID. These connections require coordination among several groups.

For example, the instrumentation and controls group has added to the P&ID the symbols for a thermocouple (TE-100) and its well (the small circle). The vessel group and the instrumentation and controls group agree, after consulting the project and plant specifications, that the vessel connection, size and type will be a one-inch 3,000 psig threaded coupling. The agreed locations will be included on the vessel design drawing and on the Location Plan. See Chapter 8 for more information on Location Plans.

The vessel design drawing is typically a stylized plan and elevation schematic showing the layout of the vessel with a connection schedule listing the purpose, size, rating, connection information and location of all the connections furnished by the vessel fabricator. Remember that the vessels go out for bid, purchase and fabrication relatively early in the project, so the control systems design team must focus on defining the vessel requirements early to support that schedule.

The piping group has determined the size and rating for the main process piping, based on the information on the PFD, and the project and/or plant specifications. They add this information and line numbers to the P&ID and then flesh out the balance of the secondary piping information as the design progresses. The vessel group uses this information to specify the vessel connection size and type. Our P&ID uses a simple line numbering system to identify all lines. There is no industry standard for line numbers, although PIP may be addressing the issue. Our system includes the line size in inches, the pressure rating of the line in pounds per square inch, the material of the line by an abbreviation, and a sequence number. For example, the incoming line to 01-D-001 is 10" 150 CS 001. This is a 10-inch carbon steel line rated at ANSI Class 150 and identified by sequence number 001.

Since there is no industry standard for line numbers, other designs might show more or less information on a P&ID. Some designs show only a sequential number on the P&ID. All additional information is shown on a separate line list or a separate database. Some line lists show information defining the start and end of the line, "From and To" information. The pipe schedule and nominal pressure rating is normally provided. Design flow rates can be shown in the line list, but this information might be better provided, maintained, and coordinated using the P&ID. On our P&ID we have shown the nominal pressure rating.

Other designs include more complex line numbers on the P&ID. Many include a symbol or an abbreviation for the service, which calls out the material flowing in the line. A sampling of these abbreviations includes:

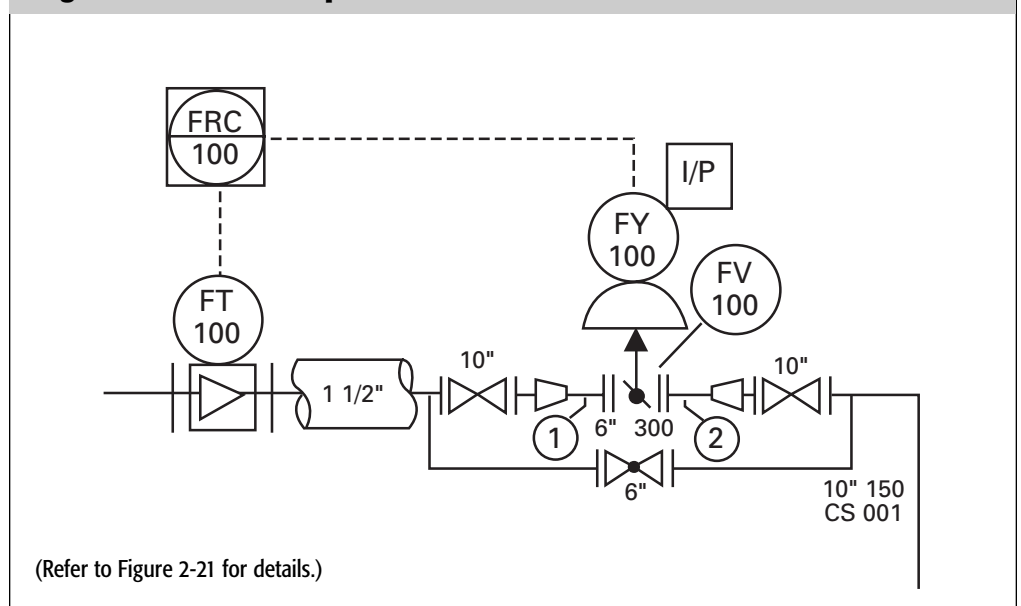
A - air	FO - fuel oil	S-25 - 25 psig steam
C - condensate	IA - instrument air	S-100 - 100 psig steam
CW - cooling water	N - nitrogen	PA - plant air
FG - fuel gas	S - steam	PW - potable water

The line list or data base might include additional information about the flowing material – for example, flow in gallons per minute, pounds per hour, cubic feet per minute, pressure, temperature, viscosity, density, and specific gravity. Standard units should be used throughout the P&ID set. For instance, liquids may always be given in gallons per minute, steam in pounds per hour, air in standard cubic feet per minute, and gases in whatever units are typical for your industry. The paper industry may give units in bone dry tons of wood fiber per day. The units are probably metric if the parent company is European or Canadian. To minimize the space needed for line identification, units are frequently not listed on the line callouts; they are only shown on the legend.

Concurrent with the foregoing P&ID development, the instrumentation and controls group will decide on the overall control scheme. This usually occurs after consultation with the owners' representative and the project process group. Both of these groups have valuable information on the best means of control for a process.

On our example project, the instrumentation and controls group has added three control loops to the P&ID. There is a flow loop (FRC-100) on line number 10" 150 CS 001.

Figure 2-22: Flow Loop FRC-100

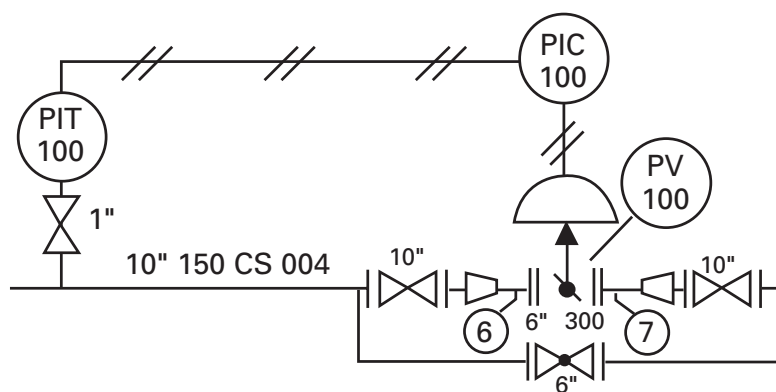


In Figure 2-22, the electronic flow transmitter (FT-100) is a vortex shedding type. It measures flow by the change in the downstream vortex of the flowing fluid. The vortex is introduced into the fluid by a bar across the flowing stream. The controller (FIC-100) is part of a shared display shared control system – a DCS in our facility. The DCS is located in the central control room or, as stated in ISA-5.1, a “primary location normally accessible to operator”.⁹

The signals in the loop are transmitted electronically as shown by the dotted lines. The electronic signal is converted to a pneumatic one at FY-100, the I/P (current-to-pneumatic) converter installed on the control valve, FV-100. FV-100 is a butterfly control valve with a diaphragm operator which includes a spring to open the valve. If the air supply to the valve is lost, the valve will fail to the open position, as shown by the upward arrow on the valve operator. FV-100 is installed with block and bypass valves, as defined, hopefully, in the owner’s design requirements’ specification. The block and bypass valves permit the control valve to be isolated and process flow continued by manually operating the bypass valve. The instrumentation and controls group has calculated the size of the control valve using the flow, pressure drop and temperature agreed upon with the piping and process groups. The control valve size is 6" and its flanges are rated at ANSI 300 in accordance with the project specifications. The piping group has, therefore, shown reducers in the line to and from FV-100 while using full-line-size (10") shut-off valves.

The instrumentation and controls group will size and document all the relevant control valve information on Specification Forms or data sheets. They send this information to the purchasing group which purchases the valves. The selected valve vendor will supply dimensional information for each valve to the instrumentation and controls group. This information is forwarded to the piping group so they may complete the piping design.

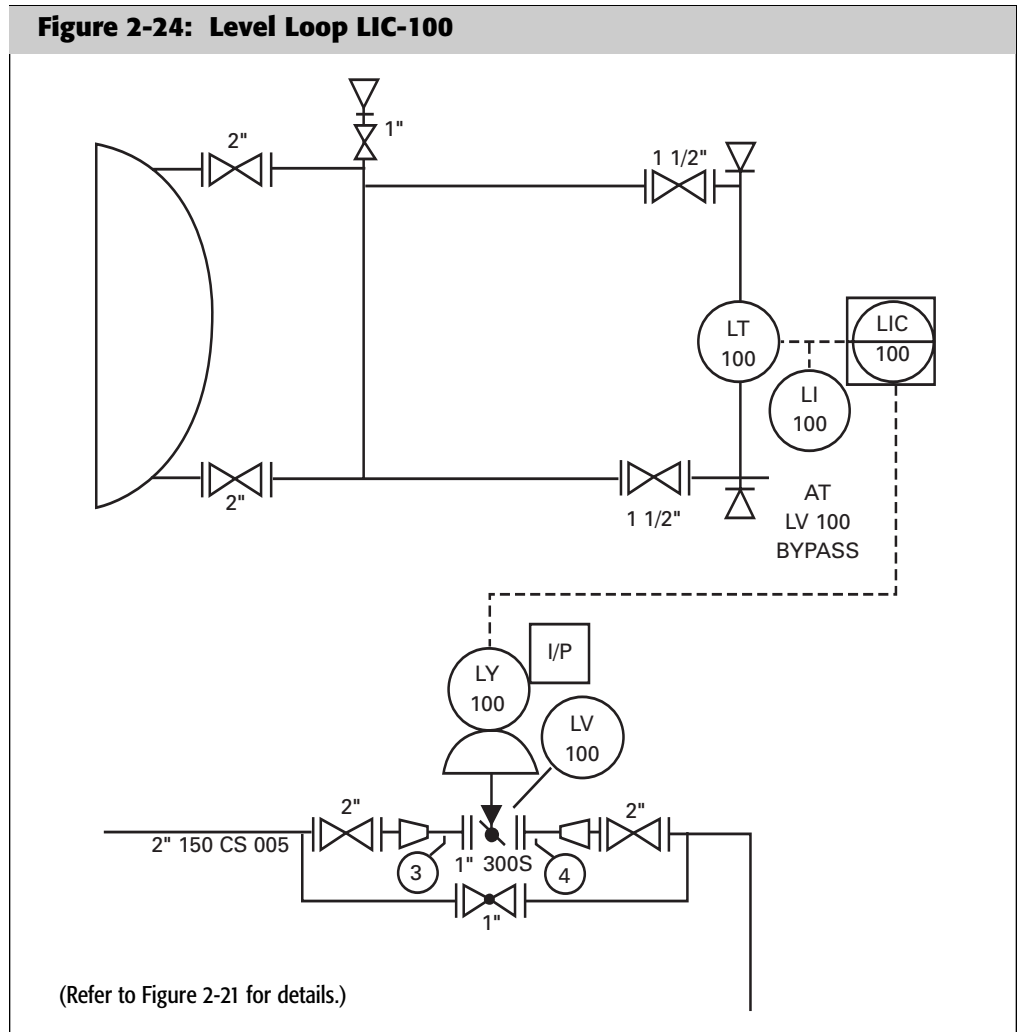
Figure 2-23: Pressure Loop PIC-100



(Refer to Figure 2-21 for details.)

There is a pneumatic loop, PIC-100, on line 10" 150 CS 004. This loop controls the pressure in the KO drum. PIT-100 senses the pressure in the line and transmits a pneumatic signal to PIC-100, a field mounted pneumatic controller. PIC-100 develops the correcting signal and transmits it to PV-100, a 6" butterfly valve. PV-100 fails to the open position upon loss of its air supply.

Figure 2-24, Level Loop LIC-100, is an electronic level loop consisting of LT-100, LIC-100, LI-100, LY-100 and LV-100.



LT is shown as a displacement type transmitter, LIC-100. The indicating controller is part of DCS system. LI-100, a local electronic level indicator is shown by a note to be located at the bypass of control valve LV-100. This might be necessary if control valve LV-100 is out of service for maintenance but the electronics of the DCS are still in service. A process operator could monitor the drum level by manually positioning the bypass valve while watching the drum level on LI-100. LY-100 is the I/P converter. LV-100 is a butterfly control valve that fails closed upon loss of its air signal, since the power to the valve actuator is only the instrument signal.

The piping group added 1" plugged drain valves upstream and downstream of all control valves to drain any residual liquid in the line when valve maintenance is necessary. In use, the drains are connected to a portable recovery system. After the liquid is drained, the control valve may be removed without atmospheric contamination.

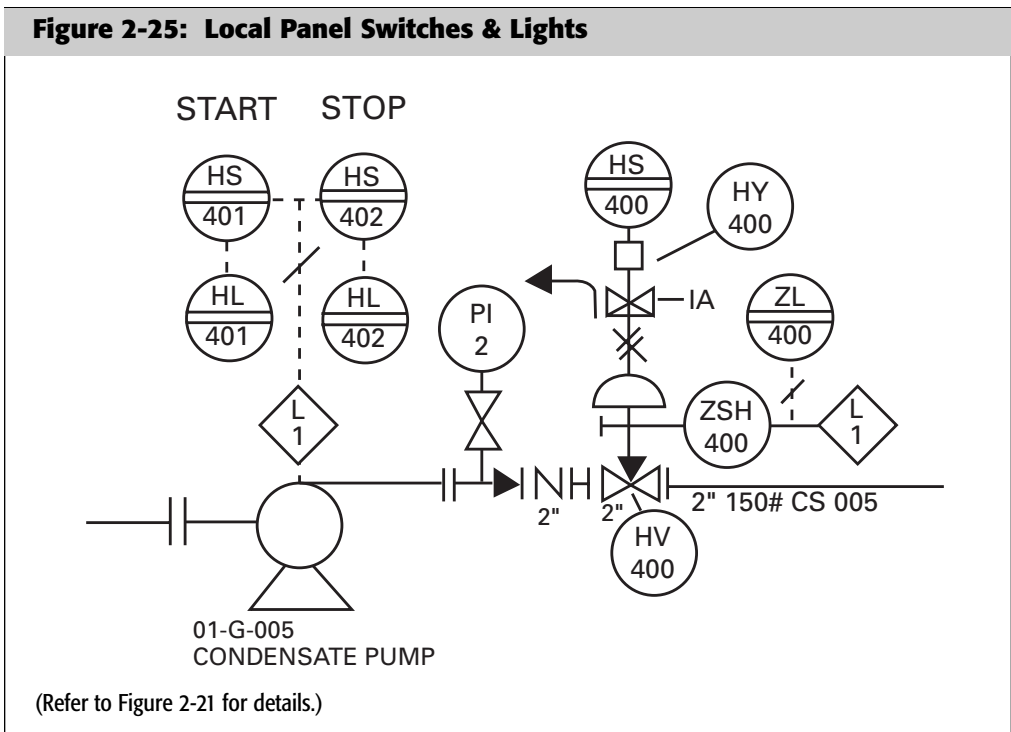
The level devices are all connected to a strongback, also called a pipe stand, or bridle connected to KO Drum 01-D-001. A strongback is a continuous pipe, typically 2" nominal, connected to a vessel through top and bottom block valves. The level instruments are mounted to the strongback and include the level gauge (LG-1), high level switch (LSH-300), low level switch (LSL-301), and level transmitter (LT-100).

Level devices are sometimes, but not always, connected to vessels in this manner for several reasons. First, attaching level instruments to an isolatable strongback, or instrument bridle, facilitates testing the instruments without disturbing production, or without opening the entire vessel. If suitable for the process fluid, the strongback can be isolated, the vent valve opened and a compatible process fluid can be introduced through the drain to prove the function of the level devices. Secondly, vessels usually have long delivery times and, therefore, they are purchased early in the project. The level instruments are normally purchased much later. Accurate dimensional information for installing the level devices may not be available when it's necessary to install the connections directly on the vessel. Therefore, in this example, two 2" connections are placed on the vessel for the strongback. The instrument connections to the strongback are scheduled much later in the project.

Thirdly, vessel connections are more expensive than piping connections. We are not advocating connecting all level devices to strongbacks rather than directly to the vessel, but we are showing this type of installation as a possibility.

In Figure 2-25, the buttons and lights (HS/HL 401&402) start, stop, and indicate the state of pump 01-G-005. The tag marks are located in a circle with two parallel lines. This tells us these buttons and lights are located on a local panel or, as stated in ISA-5.1, "auxiliary location normally accessible to operator".¹⁰ This local panel might also be the motor control center. An identifier can be added to indicate which panel contains the components. Usually a three-letter acronym is sufficient to call out the panels. These acronyms must be identified on the legend sheet.

HS-400, also on the local panel, energizes solenoid valve HY-400. This opens HV-400, a pneumatically operated on-off valve. The tee symbol (T) on the actuator shows there is a manual operator on the on-off valve. A manual operator permits the operator to override the pneumatic signal and close the valve.



As shown by the diamonds with the internal L1 legend, there is some on-off, or logic, or interlock control relating to 01-D-001. The P&ID shows the on-off control involves hand switches (HS 401/402), position switch high (ZSH-401), and level switch low (LSL-301). It is necessary to refer to Logic Diagram L-1 in Chapter 6 to define the on-off control.

The safety valve (PSV-600) has been sized, and a specification form prepared by a member of the project team. Safety valves are sometimes the responsibility of the instrumentation and controls group, sometimes of the process group, or sometimes of the mechanical group. The responsible group will insure (or assure) that safety valves are shown correctly on the P&ID.

There are two pressure gauges shown on the P&ID: PI-1 and PI-2 — one to indicate the pressure in the vessel and the other to indicate the discharge pressure of pump 01-G-005.

To minimize contamination, the strongback drains into an OWS, an oily water sewer. This is a separate underground piping system that is connected to an oil recovery system. A symbol for an oily water sewer is shown as the “Y” with the OWS label.

A typical sketch is shown for the seven drain valves, upstream and downstream of control valves FV-100, LV-100 and PV-100, plus one to drain the strongback.

In this chapter, we have looked at P&IDs in depth, describing what information might be shown on a P&ID and what form that information might take.

We looked at instrumentation symbols and what they mean. We based the instrument symbols on ISA-5.1.

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1. *The Automation, Systems and Instrumentation Dictionary*, 4th edition (Research Triangle Park, NC: ISA – The Instrumentation, Systems, and Automation Society, 2000) p.273.
 2. ISA-5.1-1984, *Instrumentation Symbols and Identification* (Research Triangle Park, NC: ISA – The Instrumentation, Systems, and Automation Society, 1984).
 3. *ibid.* p.16
 4. *ibid.* p.21
 5. *ibid.* p.19
 6. *ibid.* p.22
 7. *ibid.* p.28
 8. *ibid.* p.32
 9. *ibid.* p.29
 10. *ibid.* p.29