

READING P & IDs MADE EASY

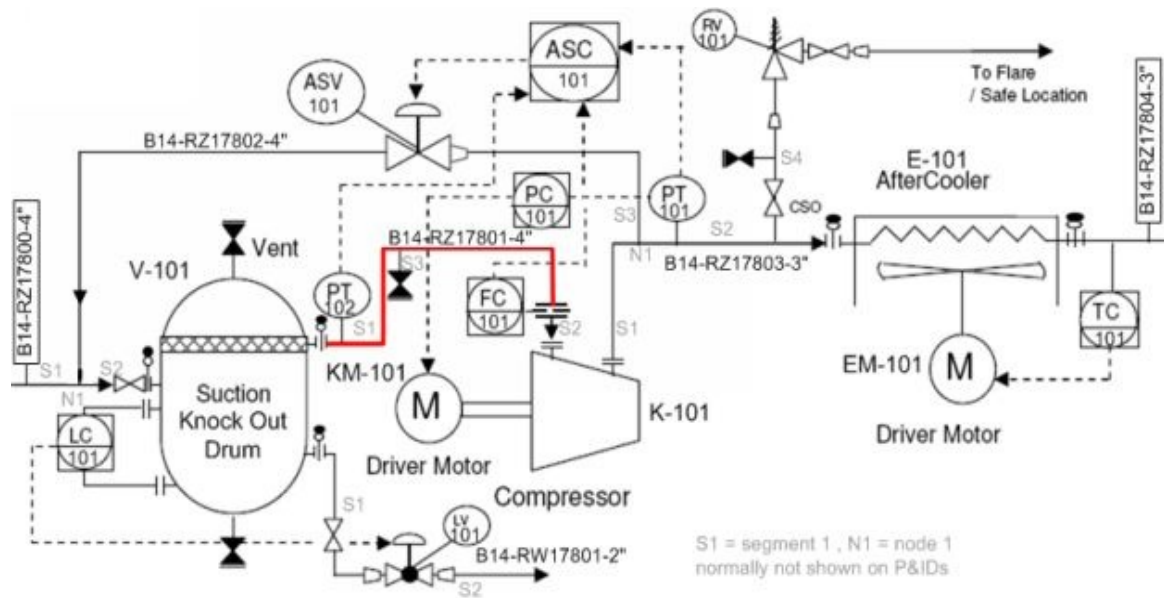
All you will ever need to easily read P & IDs
in one clear and concise book, make your life
in the process industries incredibly easy...
Perform Plant Operations, Safety, Maintenance
and Plant Engineering tasks more efficiently...
Earn yourself Job Security and Lasting Respect from
Bosses and Workmates throughout your career...

Reading Piping and Instrumentation Drawings



Brad S. Smith

READING P & IDs MADE EASY *All you will ever need to easily read P & IDs in one clear and concise book, make your life in the process industries incredibly easy, perform Plant Operations, Plant Safety, Plant Maintenance and Plant Engineering tasks more efficiently and earn yourself job security and lasting respect from bosses and peers at work...*



By Brad S. Smith

BIBLIOGRAPHY

Hello, I'm Brad S. Smith and my background is in Instrumentation and Controls and also Power Engineering (Plant Operations). I have formal college educational training in Instrumentation and Controls and Power Engineering (Plant Operations).

I have lots of experience working in an Engineering group for a large Oil and Gas company, have worked in various Instrumentation and Controls roles for big companies like Air Liquide – *Air Separation Into Liquid Nitrogen For The Oil and Gas Industries*, SaskPower – *Electricity Generation*, and some major players on the international Oil and Gas platform. Apart from the technical side of things, I also have operational experience as a Plant Operator in the oil and gas industry.

So what does that mean for you, because I am writing this for you?

It means you will get from this book relevant information that has been tried and tested. Its information that you can readily use in your work to optimize your production with minimum waste of time as this will shorten your learning curve by a significant factor. You will gain skills that will enable you to easily and efficiently read P & IDs regardless of level of complexity, resulting in less stress in your work. Imagine having the ability to read P & IDs, a skill that empowers you to be able to virtually see what's in the field from your office. No one can dispute the fact that P & IDs are foundational to the operational, maintenance and modification of the process that they graphically represent. This skill is foundational for anyone in the Process Industries, Chemical Industry and Power Generation sectors!

Let's face it, you need the P & IDs to make a plan that will work in the process industries, no matter you are an Engineer, Maintenance Technician, Plant Operator, Safety Personnel or simply Management. If you can easily read a P & ID, then you are a step ahead at work. Anyone with a good plan in life will succeed. This book will help you to succeed in your work or school life whether you are a Field Tech, an Engineer, a Student, Safety Personnel or a Plant Operator. Your confidence at work will soar after reading this book.

P & IDs can seem mysterious, but I say they don't have to remain that way. I am determined to teach anyone interested the what, why, when, where, and how of everything Piping & Instrumentation Diagrams in this comprehensive resource available for you right now...Remember, those who succeed do so because they take action. So Page Up and ORDER NOW!

**Remember, If You Just Put In the Work, You Will Be Justly
REWARDED...**

Brad S. Smith

Table of Contents **Contents** [Chapter 1: Introduction to Reading a P & ID Made Easy](#)

[Chapter Goals:](#)

[Who Is This Course For?](#)

[Benefits You Get When You Finish This Course:](#)

[Course Delivery Methodology:](#)

[Chapter 2: Importance of Reading P & IDs in Industry and Engineering & Technical Schools & Where You Fit Into The Puzzle](#)

[Chapter Goals:](#)

[What is a P & ID and What Is It All About?](#)

[When to Use P & IDs and Who Uses Them?](#)

[Why does P & IDs Look Complicated and Intimidating?](#)

[Why is a P & ID Important?](#)

[Chapter Review:](#)

[Chapter 3: P & ID Structure and Typical Information it Gives You](#)

[Chapter Goals:](#)

[The Two Forms of Information on a P & ID:](#)

[The P & ID Parts:](#)

[List of Symbols Found On a Main Drawing](#)

[The Relative Size of The Symbols](#)

[The Relative Position of the Symbols](#)

[Connecting Lines](#)

[Direction of Process Flow](#)

[Line Schedule Number](#)

[Area 5 - Issue Descriptions](#)

[Issue Notes](#)

[Area 6 – Notes](#)

[Zone Numbers](#)

[Chapter Review:](#)

The review questions are available at [ReviewQuestions](#).

Chapter 4: The P & ID Legend Sheet/Master Sheet/Lead Sheet – The Key for Reading P & IDs

Chapter Goals:

What a Legend Sheet/Mastersheet/Lead Sheet is and how IMPORTANT it is to reading a P & ID:

Mastering Line Designations:

Mastering Instruments Designations:

What is that Instrument Symbol?

Where is the device located?

Why is that device here?

Common Instrument Abbreviations

Line Symbols

Mastering Graphic Symbols:

Chapter Review

Chapter 5: The Symbols and Meanings for Common Items Found on a P & ID

Chapter Goals:

Vessels:

Size and Shape of Vessels:

Vessels Associated Equipment worth mentioning:

Heat Exchangers:

Tracing Material Flow through a Heat Exchanger:

Pumps:

Centrifugal Pump:

Rotary, Gear, or Positive Displacement Pump:

Vacuum Pump:

Tracing Flow Through Pumps:

Compressors:

Tracing Flow through Compressors and Blowers:

Instruments:

Piping:

Other Symbols of Equipment Found on a P & ID:

Steam Traps:

Chapter Review:

Chapter 6: Valves in Control Loops and Primary Flow Elements as Parts of a P & ID

Chapter Goals:

Valves and their role in the Plant:

Valve Identification Numbers:

How are Valves Controlled?

Identify Automatic Valve Fail Position from a P & ID symbol:

Transducer Functions:

Why are Valves, Instruments and Control Loops important?

What about Pipe fittings?

Chapter Review:

Chapter 7: Line Designations on a P & ID

Chapter Goals:

Understanding Piping information on a P & ID:

Line Label Example:

Helpful Hints on Line Designations:

Heat Trace and Insulation on a P & ID Explained:

Instrument Lines on a P & ID made easy:

Chapter Review:

Chapter 8: Insights into How Process Operations are controlled

Chapter Goals:

Understanding the importance of Control Loops on a P & ID:

What is a Process Control Loop?

Describe, from a P & ID of the process, how a Process Variable is measured and controlled

Identifying and Explaining Functions of Instruments in a Control Loop:

Mastering Interlocks for reading a P & ID:

[Management of Changes on a P & ID made easy:](#)

[Chapter Review:](#)

[Chapter 9: How to Trace a Process Flow on a P & ID](#)

[Chapter Goals:](#)

[Why you need to know how to Trace Process Flows on a P & ID:](#)

[How to find the beginning of a Process Line from Another P & ID:](#)

[How to follow a process line to Another P & ID:](#)

[How to Trace a Process Stream explained:](#)

[Chapter Review:](#)

[Chapter 10: Demonstration Exercise – Reading a P & ID](#)

[Chapter Goals:](#)

[Chapter 11: Review Questions, Practise Questions, and Practical P & ID Reading Exercises Resource Locator](#)

Chapter 1: Introduction to Reading a P & ID Made Easy

Chapter Goals:

Who Is This Course For?

ISA and Control Engineering offer resources to help Engineers, Technicians (Tradesmen such as Instrumentation, Electrical, Millwrights, Scaffolders, and Pipefitters...), Plant Operators, Students, and others who want to review or learn how to read Piping and Instrumentation Drawings (P & IDs). In short, if you work in the process and power plant industries, or you are in college learning any courses that will take you into these industries, this book/course is for you.

From my experience working in Process and Power Plants, I saw a lot of folks struggling in their duties simply because they did not know how to read P & IDs. There is nothing that knocks down your self-esteem at work other than having to always depend on your fellow workers to perform certain tasks just because you lack the knowledge and confidence to do it for yourself.

I remember easily beating competition during an interview at my first job as an Instrumentation and Controls Professional by displaying a sharp knowledge of Reading P & IDs. From then on I've never underestimated the power of the ability to read P & IDs in industry or school courses. This knowledge can mean the difference between getting an opportunity and missing it for good.

P & IDs are used by Field Technicians and Mechanics, Security, Safety, Health and Environmental personnel (SSHE), Engineers, and Plant Operators to better understand the process and how the various instruments are interconnected. They can also be useful in training workers and contractors. Knowing this, you can see already why you should take seriously this training as it will give you a valuable skill set that you will always use in your career.

Friends, based on the questions that I get, and some of the posts I see on the various plant automation websites and email discussion lists and web forums, reading a Piping and Instrumentation Diagram is becoming a very important skill that can set you apart from competition in the process and power plant industries. Even in Engineering or Tech Schools, this skillset will take you very far. This means job security and self-reliance...besides ability to work in a safe and efficient manner.

Just picture yourself at home in your house. You are more comfortable in your house because you know it inside out. What I intend to give you in this course is a comparable level of comfort with P & IDs at your job, College, or anywhere you encounter them. I can achieve this by teaching you how to easily read P &

IDs regardless of how intimidating they may look – all in this book.

The trick is to break down a typical P & ID into small parts and study each part one step at a time. That is the approach I will use in this book for you. At the end of the course, you will be able to put together what you have learned in order to read a real and complete set of P & IDs.

Prerequisites: For this training, you should have previous work experience, or knowledge of facilities and processes in a plant area. Alternatively, you should be in college for Engineering or Technical Training. I've to mention though that this book would not be good if it did not cater for anyone interested in knowing about P & IDs regardless of experience or prior technical training. Therefore, the baseline for the prerequisites is simply your interest to learn about the subject matter...as long as you are interested and motivated to learn, you will do just fine. The only difference is you will have to put more effort if you don't already have some background to this subject. I am here to help you. That's my goal for writing this book.

Benefits You Get When You Finish This Course:

When you successfully complete this course, you will be able to use the skills you have acquired in order to read real P & IDs regardless of level of complication. With this training, you will be able to tackle any kind of a P & ID without needing assistance from anyone else other than yourself and the P & ID package. Asking for help is never a bad thing, but you need a good level of self-reliance for your own good.

Reading P & IDs Made Easy will enable you to: Identify
symbols and function labels commonly found on P & IDs

Describe how system components are related, and move from one
P & ID to the next Trace process stream flow and control loop
functions between several P & IDs Simplify your job planning
functions in your work in the process and power plants Help you
pass your Process & Power Plant Industries related courses in Engineering
or Technical school Enable you to carry out any complex tasks in
the process and power plant industries that require knowledge of reading P
& IDs, *e.g.* planning equipment lockouts

Course Delivery Methodology:

This book is designed as a self-study workbook. You will go through chapters of information one step at a time, and answer review questions for that chapter or section using a resource found here:

howtoreadpipingandinstrumentationdiagrams.com. This ensures that you are not bombarded with too much information at the same time. You have a choice to check your answers immediately as you go, or you may choose to finish a chapter and then check your answers.

The trick is in doing what you feel comfortable with. More like what conforms to your style of learning. If you miss a question though, you should go back and review the material. Use the questions to help pinpoint to you, concepts that you may need to go back and revise. **You should also make note of any questions that you find challenging and discuss with someone who is competent in the subject matter.** You may also contact me with your questions using the form found at howtoreadpipingandinstrumentationdiagrams.com.

In Chapter 10, Hands on Exercises for Review, you will find an exercise that will allow you to gauge how well you have learned the material covered in this course. Once you go through it a few times, the content will come together easily for you and you will find your life at work improved a lot. I urge you to complete this exercise in Chapter 10 before claiming that you have grasped the concepts in this course.

This is a very important practical exercise that you should do at the end of the course. We will call this a demonstration exercise. In that demonstration exercise, you will apply the knowledge and skills you have gained from the course to read a P & ID for an area of your plant that you work in. In your work area, you will use the P & IDs to:

- . Locate process equipment
- ii. Trace process stream flow to and from your plant's battery limits
- iii. Describe instrumentation and controls for the process
- v. Explain how the complete process in your work area works in terms of equipment, piping, and instrumentation and controls

You might want to take advantage of some additional resources that I've created

to support this book by going here to sign up onto a shortlist to access the help:
[Additional Reading P & IDs Resources](#)

Chapter 2: Importance of Reading P & IDs in Industry and Engineering & Technical Schools & Where You Fit Into The Puzzle

Chapter Goals:

At the end of this Chapter, you should be able to:

- 1. Define what a P & ID is
- 2. State what P & ID stands for
- 3. Describe and State why P & IDs are important to the design, construction, and operation of your facility
- 4. State some of the people who uses P & IDs and give examples of when you might use a P & ID
- 5. State why P & IDs look complicated and intimidating, and explain how to simplify the puzzle by breaking down a typical P & ID into small parts and study each part one step at a time before putting together what you have learned in order to easily read a real and complete P & ID

What is a P & ID and What Is It All About?

P & ID stands for **P**iping and **I**strumentation **D**igram. It is defined by the Institute of Instrumentation and Control as follows: *A diagram which shows the interconnection of process equipment and the instrumentation used to control the process.*

In the process industries, a P & ID is a diagram which shows the piping and vessels in the process flow, together with the instrumentation and control devices. That means a P & ID is a drawing or blueprint of the systems in a section of your plant. A P & ID will show you the components needed to run, monitor, and control specific processes. A P & ID is made during the design and construction of the Plant. The P & ID is a living or evergreen document. That is to say, it is a dynamic document and is continually edited and updated as the plant equipment or control strategies change. Any changes must be reflected on the latest issue of the P & ID.

A P & ID does not describe the chemical reactions involved or give you procedures for carrying out certain tasks in the Plant. It will instead give you information that you can use to design the same. In some Plants, a P & ID may be known as a Process and Instrumentation Diagram or a Process and Control Diagram (P & CD).

A P & ID layout includes: Equipment Piping that connects the equipment Lines and instruments used to monitor and control the process
P & IDs play an important role in the Process Engineering field to show interconnectivity, but they don't necessarily include specifications. Specifications are usually provided in separate documents. But still P & IDs are incredibly useful in several ways including but not limited to:

- 1. Evaluation of construction processes
- 2. They serve as a basis for Programming Process Controls
- 3. Designing a conceptual layout of a chemical or manufacturing plant
- 4. Developing Guidelines and Standards for facility operation
- 5. Forming recommendations for cost estimates, equipment design, and pipe design
- 6. Producing Documents that explain how the process works
- 7. Provide a common language for discussing Plant Operations

- i. Creation and Implementation for Safety and Control Philosophies

Function and Purpose of P & IDs: P & IDs are foundational to the operation, maintenance and modification of the process that it graphically represents. At the design stage, the P & IDs also provide the basis for the development of the system control schemes, like Hazard and Operability Study (HAZOP).

In the Process and Power Industries, a P & ID is a graphic representation of:

- . Key piping and instrument details
- ii. Control and shutdown schemes
- iii. Safety and regulatory requirements
- v. Basic start up and operational information

When to Use P & IDs and Who Uses Them?

P & IDs for a Plant area are important to any person who has a responsibility for maintaining a safe and efficient operation of a process system. Some of the people who may need to use P & IDs during the course of their duties are Operations personnel, Maintenance personnel, and Engineering staff. Even Management and Safety personnel use these drawings too.

The following are examples of times when an Engineer, Operator, Instrument Mechanic/Technician, Electrician, Millwright, Pipefitter, Scaffolder, Insulator or Maintenance Planners may need to check a P & ID:

Training both new and experienced workers and Contractors	Performing process hazard reviews
Planning a job to be done by maintenance staff	Lockout before repair or replacement of a piece of Process Equipment – This is one of the major uses for Plant Operators
Writing a high quality Job Safety Analysis (JSA) or Field Level Hazard Assessment (FLHA)	Troubleshooting if a problem develops in the Plant
Emergency Preparedness and dealing with emergency situations	Planning and/or making Engineering Modifications

From what we have seen so far, P & IDs can be seen as a schematic illustration of the functional relationship of piping, instrumentation and system equipment components used in the field of instrumentation and control or automation. P & IDs are typically created by Engineers who design a manufacturing process for a physical plant.

These facilities usually require complex chemical or mechanical steps that are mapped out with P & IDs to construct a Plant and also to maintain Plant Safety as a reference for Process Safety Information (PSI) in Process Safety Management (PSM). If something does go wrong in the Plant, reviewing the P & IDs is usually a good place to start.

P & IDs are invaluable documents to keep on hand, whether they are used to streamline an existing process, replace a piece of equipment, or guide the design and implementation of a new facility. With the record they provide, changes can be planned safely and effectively by the use of Management Of Change process (MOC).

Why does P & IDs Look Complicated and Intimidating?

More often than not, P & IDS look very complicated and intimidating because they show so much information that you are not familiar with. The trick is to break down a typical P & ID into small parts and study each part one step at a time. That is the approach I will use in this book for you. At the end of the course, you will be able to put together what you have learned in order to read real P & IDs. That will boost your self-esteem and self-reliance on your job by a very significant factor.

Why is a P & ID Important?

P & ID (Piping and Instrumentation Diagrams) drawings outline the plant's operation, identify or describe the role of process equipment, and show all the interconnecting pipe lines. The instrumentation part provides the main schematic of how the plant process are controlled to facilitate a smooth, economic, and safe operation.

The P & ID is an important document establishing the blueprint for every Process and Power Plant. Therefore every P & ID must be kept up to date at all times throughout the life cycle of the Plant. Plant modifications must be reflected in the P & ID drawings when adding new piping and/ or revamping specific parts of the plant. For example, if an additional valve is installed, the change must be noted on a new issue of the P & ID for the system. This is very important for a smooth, economic, and safe operation of the Plant.

I can't overemphasize that any changes made in a process system must be noted on the P & IDs. This is usually not the responsibility of Either Plant Operations or Maintenance personnel, but that of Engineering. However, good communication between all parties can ensure the P & ID drawings are always kept up to date and reflecting actual Plant Systems.

Keeping P & IDs current ensures safety of personnel and assists Operators, Tradesmen, and Engineers in understanding the Plant's operation. **Your safety and that of your fellow workers may depend on a P & ID, therefore it is very important to keep information recorded on the P & IDs for specific areas consistent with actual plant operations.**

Some processes come under government regulations, for instance air emissions from utility boilers. P & IDs that cover these processes may be needed to document Plant Operations. Please bear in mind that the government does not regulate how the P & IDs must be drawn. **Everyone at the Plant benefits from correct use of P & IDs, of which knowing how to read them forms a fundamental need for achieving that goal. If you cannot read P & IDs, you may be a danger to both yourself and other workers.**

In short, P & IDs are important for:

- i. As an Aid to Working Safely
- ii. Maintaining a Safe and Efficient Process Operation

- iii. As a tool for Understanding and Communicating about a Process
- v. Training both new and experienced workers

What Are The Limitations of P & IDs?

Because P & IDs are graphic representations of Processes, they will have some inherent limitations. P & IDs are neither necessarily drawn to scale nor geometrically accurate. Therefore, they can't be relied on as real models. There is also no generally accepted universal standard for drawing P & IDs.

Consequently, it's not surprising they may look different from company to company. Sometimes even within the same company, you may find differences - that is all based on the internal standards of the company, the type of system software being used, and the preference of the creator. That is why it is important to design and review the documentation that gets down to the real nuts-and-bolts of support documents.

What Are The P & IDs Support Documents?

We need additional documents to clarify the details and specifications because P & IDs are schematic overview graphics. I will go through some of them in the following list:

- . **Process Flow Drawings (PFDs)** – P & IDs originate from PFDs. A PFD is a picture of the separate steps of a process in sequential order. Elements that may be included on a PFD include: sequence of actions, materials or services entering or leaving the process (inputs and outputs), decisions that must be made, people who become involved, time involved at each step and/or process measurements.
- .. **Equipment and Instrumentation Specifications (EIS)** – Standards and details too extensive to fit into the P & ID are included in the EIS including Scope, Standards, Codes and Specifications, Definitions and Terminology, Materials of Construction, Design Basis, Mechanical/Fabrication, Guarantees, Testing and Inspection, Documentation and Shipping.
- . **Piping Material Specifications (PMS)** – Here is where you will find details concerning materials of construction, gaskets, bolts, and fittings.

- . **Functional Requirements Specification (FRS)** – How the Plant or System operates is detailed in the FRS. It includes the Functional Description, Communication, and Scope Definition of the process.

What's The Difference between a PFD and a P & ID?

Instrumentation detail varies with the degree of design complexity involved. Simplified or conceptual designs are called Process Flow Diagrams (PFDs). A PFD shows fewer details than a P & ID and is usually the first step in the design process. It is more of a bird's eye view, or a 30 00 ft. view. More fully developed Piping and Instrumentation Diagrams (P & IDs) are shown in a P & ID

What Should a P & ID include?

Whilst there are no specific standards for the way P & IDs should be drawn, there has been standard suggested by the Process Industry Practice (PIP), a consortium of Process Industry Owners and Engineering Construction Contractors who serve the industry. PIC001: **Piping and Instrumentation Diagram Documentation Criteria** details what a P & ID should contain:

- . Mechanical equipment with names and numbers
- . All valves and their identifications
- . Process piping, sizes and identification
- . Miscellaneous – vents, drains, special fittings, sampling lines, reducers, increasers and swaggers
- . Permanent start – up and flush lines
- . Flow directions
- . Interconnections reference
- . Control inputs and outputs, interlocks

1. Seismic category
2. Interfaces for class changes
1. Quality level
2. Annunciation inputs
3. Computer Control System input
4. Vendor and Contractor interfaces
5. Identification of components and subsystems delivered by others
5. Intended physical sequence of the equipment
7. Equipment rating capacity

What shouldn't a P & ID Include?

1. Instrument root valves
1. Control relays
1. Manual Switches
1. Primary instrument tubing and valves
1. Pressure, Temperature and Flow data
1. Elbow, Tees, and similar standard fitting
1. Extensive explanatory notes

Chapter Review:

The review questions are available at [ReviewQuestions](#).

Chapter 3: P & ID Structure and Typical Information it Gives You

Chapter Goals:

At the end of this Chapter, you should be able to identify and explain the written information in the following parts of a P & ID:

- i. The Title Block
- ii. The Main Diagram
- iii. Line Schedules
- iv. Equipment descriptions – provided in written form
- v. Notes – also provided in written form
- vi. Zone Numbers – provided in written form as well

The Two Forms of Information on a P & ID:

Generally, there are two types of information that are covered in P & IDs, and as a result, also covered in this course: **Written Information** – such as titles, label tables, and equipment specifications **Symbols and Drawings** – used as representations of information in graphical form P & IDs appear to be very complicated because there is a lot of information included on them. However, much of the information is generally represented on P & IDs in a Standardized way. That means certain information is usually represented the same way. This makes your life easy, and is true most of the time on P & IDs. I need to tell you right now that there may be slight differences though.

P & IDs may be hand drawn or produced using a computer and some special drawing software like AutoCAD. There are various vendors out there who sell software that can help with this task. That is beyond the scope of this training. A symbol for a certain type of valve, as an example, may look slightly different on diagrams at different sites; or one plant may have a unique way of numbering and labelling instrumentation. This is nothing to worry about, as the Legend (also called Master Sheet) will tell you what each symbol stands for at any plant. I am going to discuss more on The Legend in one of the upcoming sections.

This course will cover common practices that are used to produce P & IDs. As a golden rule in industry, if you have any questions about your area, ask your Supervisor before proceeding. That can make a difference between going home for good and keeping your job. You don't want to endanger your job security just because you failed to seek clarification from your boss concerning something that was not clear to you.

The P & ID Parts:

The P & ID is a keystone document at the plant, and as such, it should be organized in a logical progression. This helps to simplify how we read the information from a P & ID. While many, or most of the companies set their own standards for P & ID organization, it can still be thought of as chapters of a book or scenes from a movie that interconnect to tell your Engineering Process story.

It should provide a succinct and easy to understand illustration of all the equipment to be included in the Process Flow, alert information around a hazard, safeguards and potential faults so that errors can be minimized or eliminated. It will help support the development of Operating and Maintenance procedures. As a storyboard of the Process, it's a way to see that changes can be made safely and effectively using Management Of Change (MOC). In the next sections, we are going to be exploring the 6 parts of a P & ID that you may most likely encounter in reading P and IDs.

The layout and amount of information on P & IDs will vary from company to company. The example given below shows six parts of a P & ID namely:

- . Title Block
- . Main Diagram
- . Line Schedules
- . Equipment Descriptions
- . Issue Descriptions
- . Notes

Figure 3.1 below shows some of the parts of a P & ID in a logical setup that we will exploit in our understanding of the art of reading these drawings. In this course we are going to explore the parts numbered 1 to 6 in Figure 3.1. These parts will not always be the same on P & IDs from different companies. That is to say how P & IDs are drawn will differ in terms of placement of these parts. Nonetheless, you can always expect these parts to be there somewhere on a P & ID.

The amount of detail provided will depend on the company standards. Hence it will vary from site to site. Equipment descriptions, for example, may be placed

at the top of the P & IDs at some sites instead of near the bottom as shown in the example diagram below. That is normal and acceptable. Most P & IDs do not include a line schedule at all. Regardless, in this course we will build skills that will enable you to easily use information that is often given on P & IDs.

Figure 3.1 – Parts Of A P & ID You Are Most Likely To See

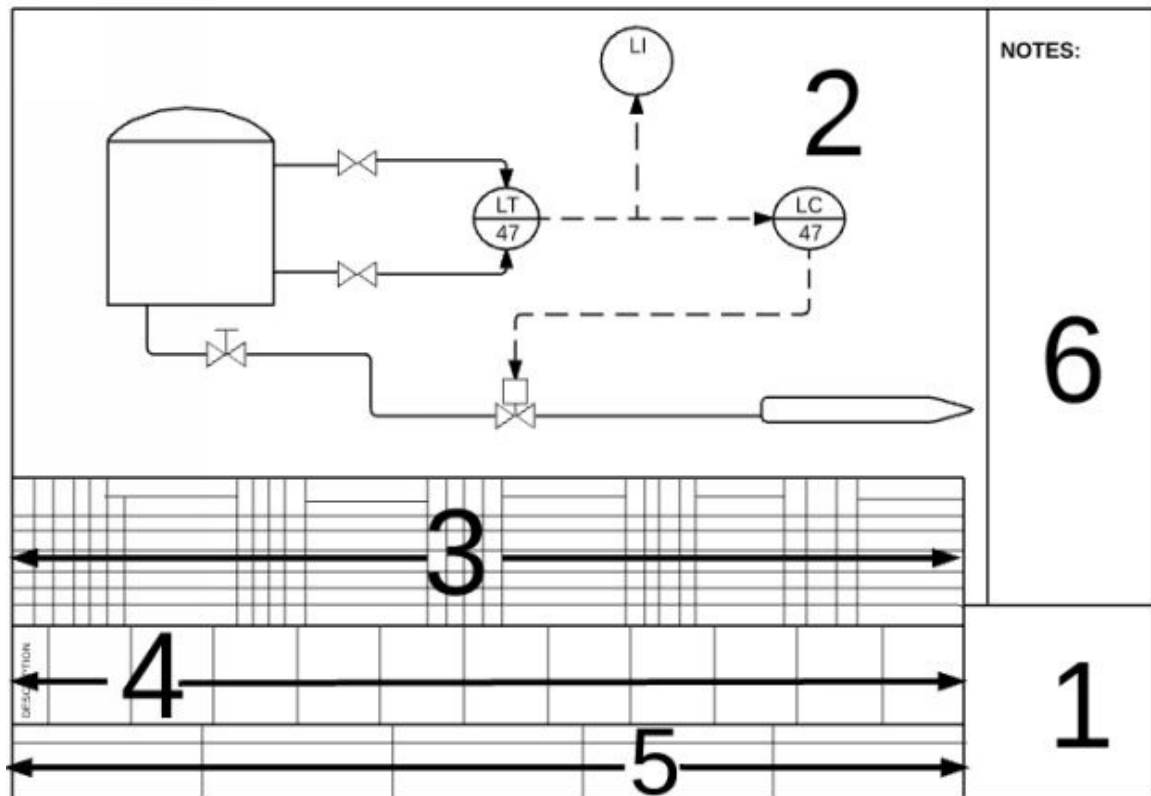


Figure 3.1 above shows some of the parts of a P & ID in a logical setup that we will exploit in our understanding of the art of reading these drawings. Again the parts are:

- . Title Block
- . Main Diagram
- . Line Schedules portion
- . Equipment Descriptions part
- . Issue Descriptions
- . Notes

Now we will dig deeper into each part one by one. As I explained before, it is the sure fire way to understand reading P & IDs painlessly. Ever heard about eating the elephant one bite at a time? Yes my friend, that is the strategy that we are going to be using – one bite at a time until all the big, huge, gigantic elephant is gone!

We all know the saying, but sometimes we struggle to apply this lesson in our lives. I am here to assist you to apply it and become a **Pro in reading P & IDs**. Your life satisfaction will probably be a lot higher if you view your life as a series of many small milestones, instead of one huge milestone that you may or may not ever achieve. So what am I saying? – I am saying we will break our P & ID into small parts and look at them one at a time, then at the end put it all together. The complexity is all going to disappear. So let's go ahead and eat our elephant starting with the Title Block area.

Area 1 – Title Block The Title Block of a P & ID is usually located on the bottom or lower right hand corner of the drawing. It contains all the information necessary to identify the drawing and to verify its validity. It is divided into several areas. Some of the areas you can expect to find within a **Title Block** are the drawing title, the drawing number, the location, the site, or the vendor. The drawing title and the drawing number are used for identification and filing purposes. Usually the number is unique to the drawing and is made up of a code that contains information about the drawing such as the name of the site, the system, *e.g.* cold water or hot process water systems, and type of drawing (P & ID, PFD, etc.). The drawing number may also contain information on the revision level. Drawings are often filed by their drawing number because the drawing title may be common to several prints or series of prints.

Other areas of the Title Block normally contains the signatures and approval dates, which provide information as to when and by whom the system was designed and when and by whom the drawing was drafted and verified for final approval. This information can be invaluable in locating further data on the system or component design or operation. These names can also help in the resolution of a discrepancy between the drawing and another source of information.

In Figure 3.1, the Title Block is area number 1. In Figure 3.2 below, I show you an enlargement of block number 1 from Figure 3.1. Figure 3.2 shows the kinds of information typically provided in the Title Block of a P & ID.

Be sure that you have the correct drawing for the area you are working on. Using an outdated drawing or a wrong drawing for the wrong area could result in an unsafe act or costly mistake. Unsafe acts in the Process and Power Plant fields will quickly get you out of work these days. I have seen it happen in my work life. A guy went into the field to take apart a valve on a live line instead of an offline line just because he used wrong P & IDs. What ended up happening was breaking containment of a live system which could have been very catastrophic. Had it not been the intervention of a diligent Plant Operator, we could be talking of something different right now. So be very careful to check the information in the Title Block and make sure you are working with the correct drawings.

Figure 3.2 – Title Block

Name Of Outside Engineering Firm (If Applicable)			
RPIDS MADE EASY PROCESS CO.			
RPIDS PLANT 01 - WATER TREATMENT DIV CAUSTIC STORAGE & SUPPLY SYSTEM PIPING AND INSTRUMENTATION DIAGRAM			
NOTICE This drawing has been prepared solely for the exclusive use of RPIDS Students. This Reproduction shall not be disclosed, used or reproduced either wholly or in part except as connected with such use, or with the prior written consent of Reading P&IDs Made Easy.	ISSUED FOR CONSTRUCTION		DATE
CONTRACTOR NAME - PID STUDENT	SCALE	DRAWING NO.	REV
CONTRACTOR DWNG NO. - RPIDS-001	NONE	077-47-097-200	7

FIGURE 3.2 - TITLE BLOCK The Title Block in Figure 3.2 above contains

the following information that is important for choosing the correct drawing:

- . Plant name
- . Process area covered in the diagram
- . Site the P & ID was originally issued and current issue number
- . Drawing number
- . Name of System
- . Vendor information

The best information that you can take away from this section is: Always be sure that you are using the correct and up to date P & ID for the job at hand. Check the title, issue number, and drawing number at the minimum. This is generally the information you will need to make sure you have the correct drawing. *Using a wrong drawing could lead to an unsafe act or costly mistake at work.*

Area 2 – Main Diagram The Main Diagram, also referred to as the Main Drawing, is the main body or main area of the drawing. The Main Drawing contains information that can be represented by symbols and lines. In Figure 3.1, the Main Drawing is area number 2. In Figure 3.3 below, the Main Drawing is the area number 2 which is shaded in blue.

Figure 3.3 - Main Diagram/ Drawing SHOWN SHADED IN BLUE

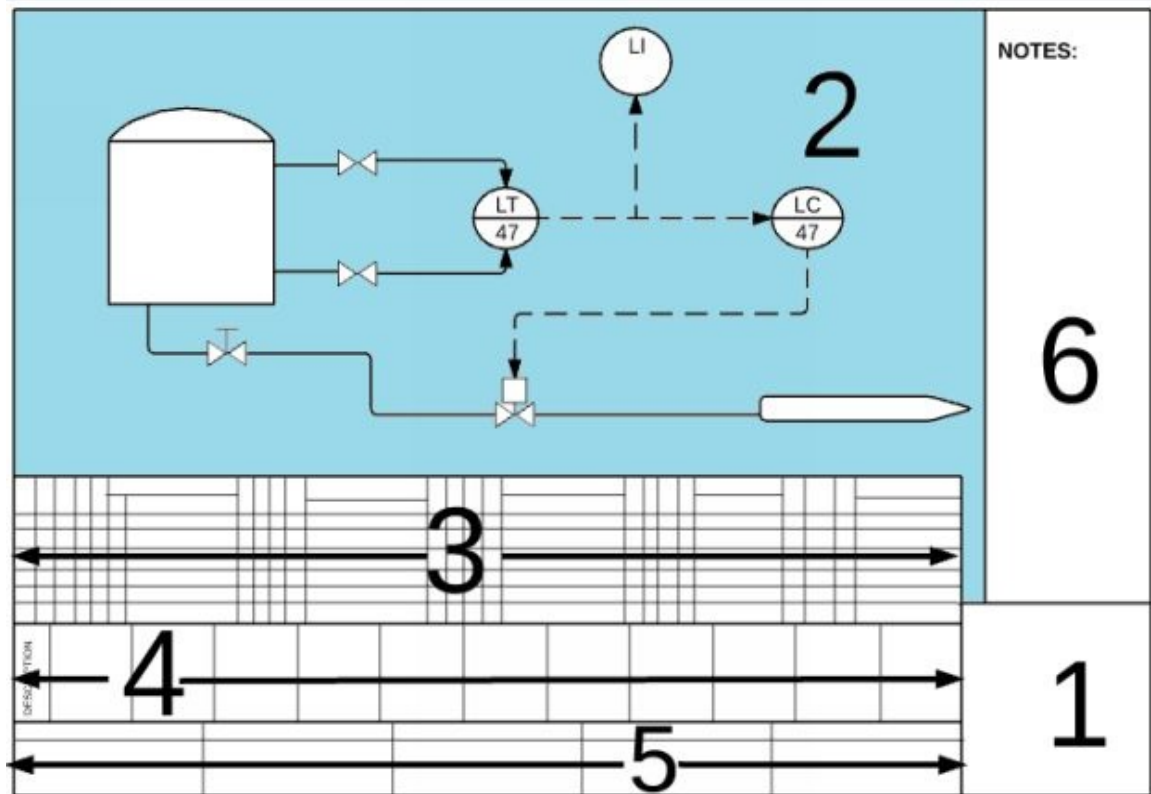


FIGURE 3.3 - MAIN DIAGRAM/ DRAWING SHOWN SHADED IN BLUE

List of Symbols Found On a Main Drawing

In the real world, the symbols that you are going to see in the Main Drawing will be for:

- . **Equipment** – Equipment is comprised of miscellaneous P & ID units that don't fit into the other categories. Examples are hardware like compressors, conveyors, motors, turbines, vacuums, and other mechanical devices.
- . **Piping connecting pieces of equipment** – A pipe is a tube that transports fluid substances. Piping can be made of various materials, including metals and plastics. The piping group is made up of one-to-many pipes, multi-line pipes, separators, and other types of piping devices.
- . **Vessels** – A vessel is a container that is used to store fluid. Sometimes it alters the characteristics of the fluid during storage. The vessels category

includes tanks, cylinders, columns, bags, and other vessels.

- . **Heat Exchangers** – A heat exchanger is a device that's designed to efficiently transfer heat from different areas or mediums. This category includes boilers, condensers, and other heat exchangers.
- . **Pumps** – A pump is a device that uses suction or pressure to raise, compress, or move fluids in and out of other objects. This section is comprised of both pumps and fans.
- . **Valves** – A valve regulates, directs, or controls the flow of a fluid by opening, closing, or partially obstructing passageways in a piping system. This category includes rotameters, orifices, and other types of valves.
- . **Instruments** – An instrument is a device that measures – and sometimes controls – quantities such as flow, temperature, angle, or pressure. The instruments group houses indicators, transmitters, recordings, controllers, and elements.
- . **Lines connecting instruments** – These are lines that connect instruments. They can be electrical, pneumatic, or hydraulic...etc.
- . **Instrument Control Loops** – These are at the heart of the control philosophy of the system and act as the brain power. More exciting stuff coming later in the course!

We will look at each of these types of symbols and lines in more detail later in this course. It is the meat and flesh of reading P & IDs. The juicy part, and once you master it, you will have immense powers at a Process or Power Plant that will endear you with your bosses and co-workers – that might mean job security and more money into the bank due to promotions. Who does not want a knowledgeable worker who does not need to be baby sat all the time just because

they can't read P & IDs?

For demonstrating other important concepts before we jump into the nine components of the main drawing listed above, we will make use of simple shapes - squares, triangles, circles as symbols in the drawings in the next few sections.

The Relative Size of The Symbols

Figure 3.4 - Relative Size of Symbols

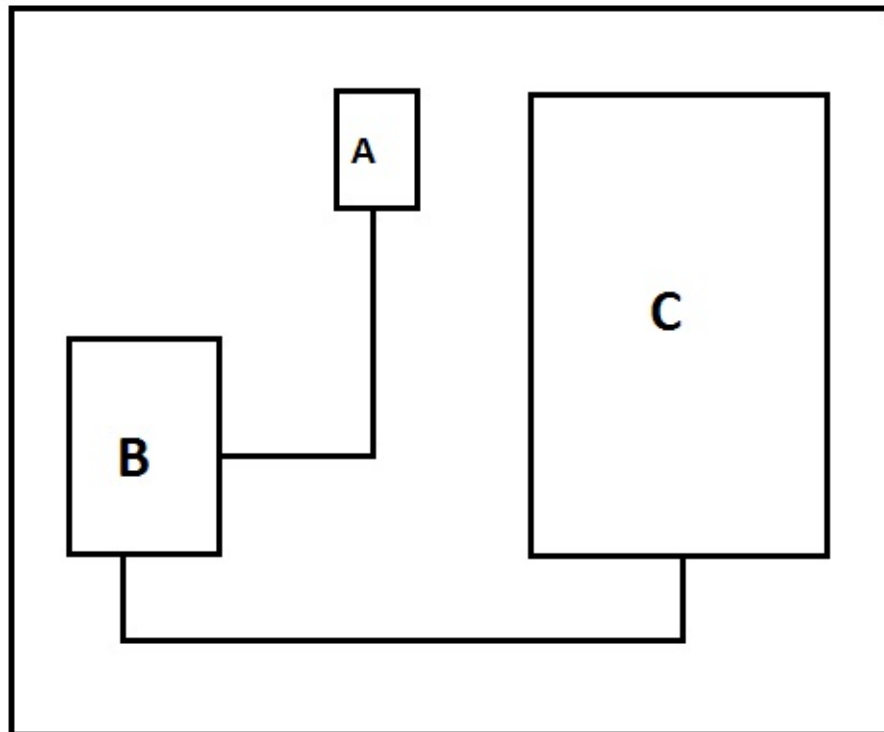


FIGURE 3.4 - RELATIVE SIZE OF SYMBOLS The **Relative Size of the Symbols** represents the relative size of the actual equipment out in the field. As Figure 3.4 above demonstrates, Square A is smaller than square B on the drawing. Therefore, the expectation is that out in the Plant, the vessel represented by square A will be physically smaller than the vessel represented by square B. Consequently, square C represents the biggest vessel of all three vessels in Figure 3.4.

The Relative Position of the Symbols

Another concept I want to bring to your attention is that of the **Relative Position of the Symbols**. The relative position of the actual equipment in the Plant area is represented on the P & ID by the corresponding relative position of the symbols. Figure 3.5 shows that the piece of equipment represented by symbol D would be below vessel C, which is represented by symbol C.

The word **Relative** is very important in this context. Always bear in mind that this is not a roadmap where you can expect the distances to be proportional to the actual distances between two geographical points. You cannot expect the distances on a P & ID to be proportional to the actual distances between equipment in the physical Plant. But if a valve or a fan is located under a vessel on a P & ID, you should expect the real valve or fan to be located somewhere under the real vessel. Always remember that the P & ID will never tell you how far away equipment is from each other.

Figure 3.5 – Symbols' Relative Position

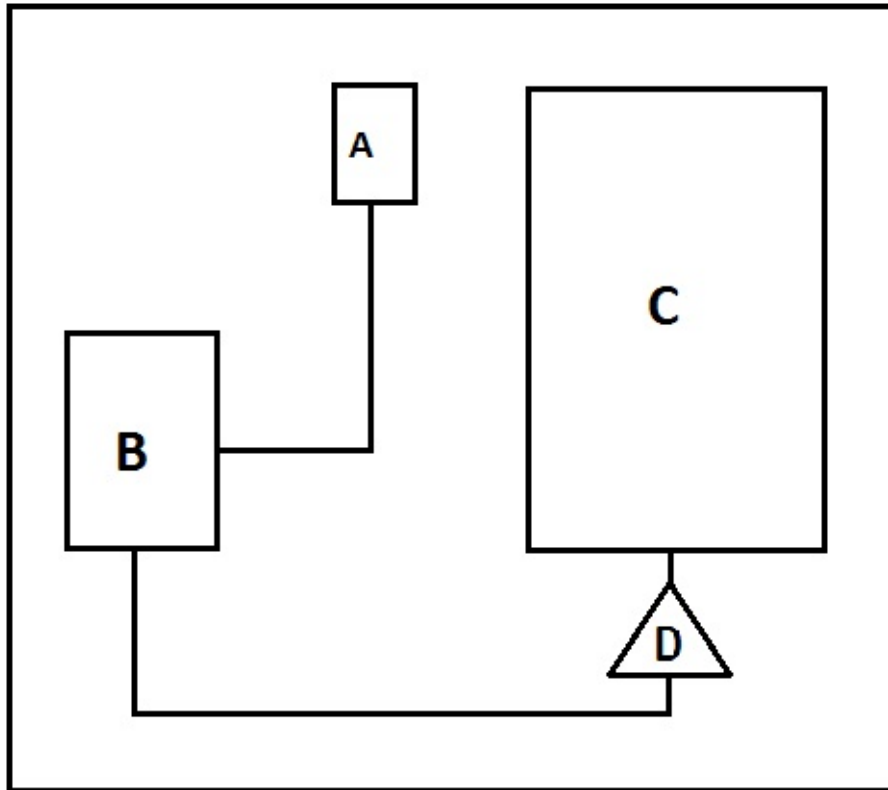


FIGURE 3.5 – SYMBOLS' RELATIVE POSITION The main point you should take away from Figure 3.5 is that **the positions on a P & ID are relative, but the distances are not in true proportion.** They never are!

Connecting Lines

The pipes and instrument lines in a process area are drawn on a P & ID as a line. Pipes and instrument lines that have a unique purpose are drawn as lines with distinct variations for each use. For example, how we show a pneumatic line on a P & ID is different from how we show a hydraulic line. More on that in future chapters in this course.

In the Plant, we all know that pipes and lines go in any direction. They can cross

over each other, go through walls, or just come to a dead end. Surprise surprise, this is also the case on a P & ID.

Figure 3.6 - Reading Connecting Lines

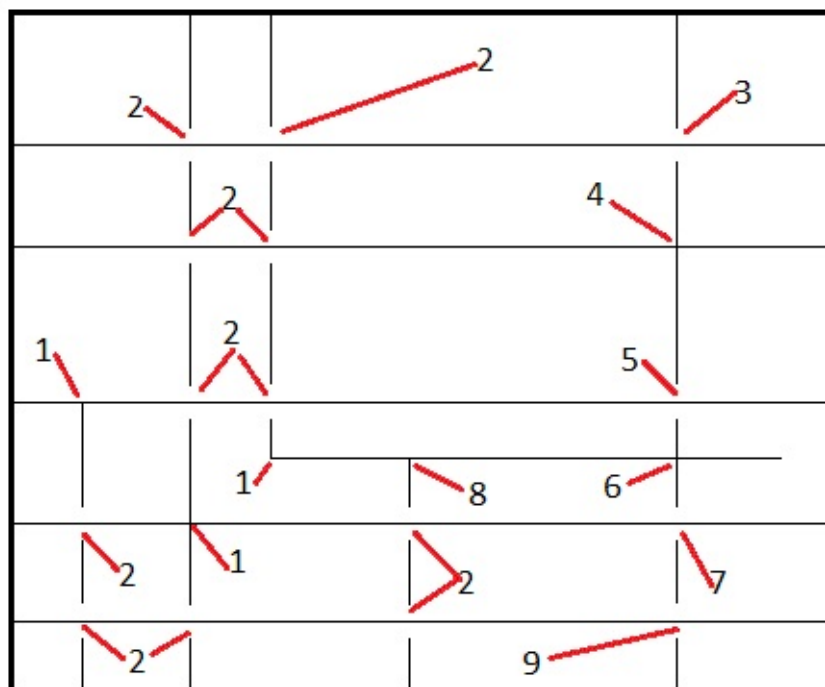


FIGURE 3.6 - READING CONNECTING LINES “1” – Physically Connected “2” – Not Physically Connected **If you see two lines on a P & ID cross over or make a corner without any break in the drawn line, it means that those two pipes are physically connected in the real Plant.** Figure 3.6 shows points labelled “1”, which are areas where the pipes are physically connected in the field.

When drawn lines cross over each other but show a break or gap at the crossover, these pipes are not connected in the Plant. The break in the drawn line may be a simple space, or a small, curved S-shaped or U-shaped symbol on each side of the break to show that the pipes are not physically connected. The arrows numbered “2” in Figure 3.6 indicate places where drawn lines for pipes cross over each other and **do not physically connect** in the field.

Corners or turns in pipelines on P & IDs do not necessarily represent bends in the real pipelines. Bends are often put in by the person drawing the P & ID to make lines fit in the space available on the drawing. Remember too that lines on

the drawing do not represent actual distances or actual locations, but only relative position (such as a line attached to the bottom of tank).

Figure 3.7 - Crossing Pipes Not Connected

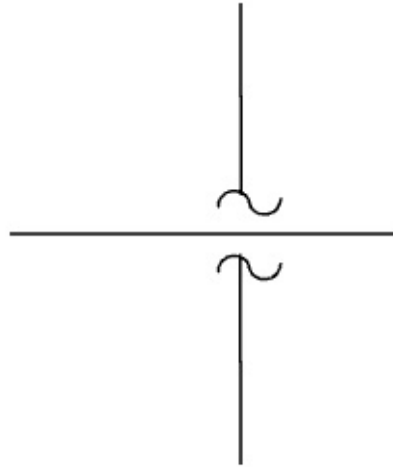


FIGURE 3.7 - CROSSING PIPES NOT CONNECTED An S-shaped symbol is sometimes used to show that crossing pipes are not connected. Figure 3.7, shows how pipes that cross each other but are not connected would be depicted on a P & ID.

Direction of Process Flow

We mentioned before that pipes carry fluids. That means these fluids flow inside the pipes in a certain direction. The P & ID shows the direction a material stream is flowing within a pipe. **The direction of flow is shown as a solid arrowhead on the line representing the pipe.** Arrows are usually shown for each segment of pipe. A segment being simply made each time another line crosses or connects to the line. This is a good thing, since after the pipes cross the arrows show which way flow continues.

Figure 3.8 - Process Flow Direction

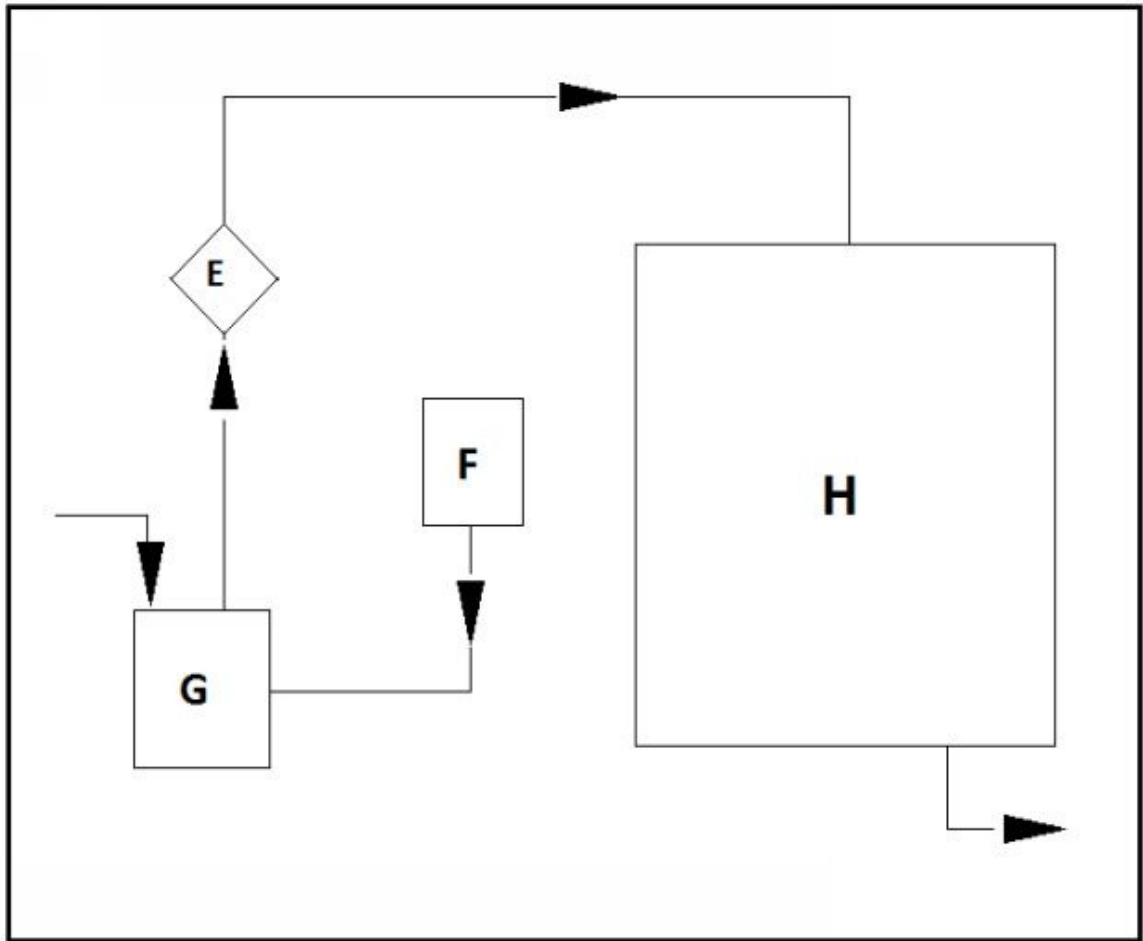


FIGURE 3.8 - PROCESS FLOW DIRECTION In the drawing above, Figure 3.8, the direction of flow is shown by the arrows with solid arrowheads. Flow into equipment symbol G is into the equipment from the top and from the right side. Then it flows out of equipment G from the top going into equipment E, where it enters from the bottom. Leaving equipment E, the flow exits from the top and enters into equipment H from the top as is clearly seen in Figure 3.8. The Process Flow finally leaves equipment H from the bottom.

Just as I have done above, you can trace a process stream's flow from where it begins, through piping, into equipment such as tanks and pumps, going through

valves, and out of the system on any P & ID. The drawing may show that the stream leaves the plant. It may alternatively indicate that the flow continues on another diagram. If you want to locate where the stream enters the current diagram, all you need to do is to trace along the line against the flow. Don't worry too much about this at the moment, we will look at it deeper later in this course, in Chapter 10.

Area 3 – Line Schedules Similar to equipment and instrumentation, every pipe on a P & ID requires a unique tag number so that it can be uniquely identified during design, or referenced in operating procedures. This unique pipe tag is the **Line Number**. It is what you will use to get more data about that pipe from the **Line Schedule**.

Block number 3 in Figure 3.9 is the Line Schedules area. The Line Schedule tells us important information about each pipe on a P & ID. Having said that, not all companies like to put the line schedule on their P & IDs. So it all depends on the company preferences. We can expect to get the following information about each pipe on the P & ID from the Line Schedule:

- . Pipeline number
- . Material flowing through the pipe
- . Where the stream flow is coming from and flowing to
- . Specifications, size, material of construction, and if insulation or tracing is on the pipe

In some cases, the Line Schedule block on some P & IDS gives additional information that relates to the process. This information may include parameters such as:

- . Pressure at which the stream is flowing
- . Temperature of the product in the line
- . The product flow rate in m³/hr or pounds/hour depending on preferred units of measurement

Figure 3.9 - Shaded Line Schedules Area

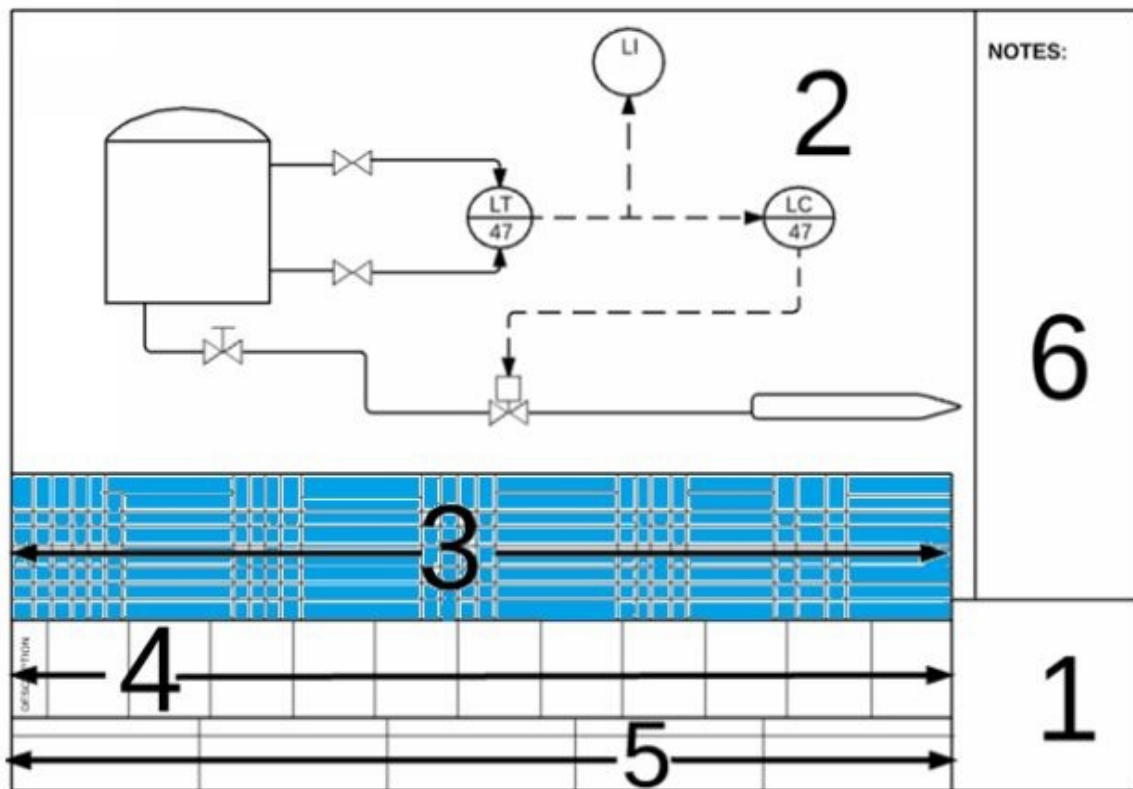


FIGURE 3.9 - SHADED LINE SCHEDULES AREA All you need to remember is that the Line Schedules give us specific information about the actual piping. The sample Line Schedule table in Figure 3.10 provides the following information:

- . Size or diameter of the pipe
- ii. Schedule (SCH) thickness or relative strength of the pipe – just remember that the higher the number, the stronger the pipe

- iii. The material which the pipe is made up of – such as stainless steel (SS), Teflon (TF), or carbon steel (CS)
- v. Details on pipe insulation or traced including how that is done

Figure 3.10 below shows typical examples of Headings and Information given for four different pipelines in a Line Schedule. A P & ID will obviously have many lines than this example. The Line Schedule list may cover most of the bottom of the page. Some companies just choose not to include line schedules on their P & IDs altogether. Regardless, we are going to learn how to apply the information from the Line Schedule when reading a P & ID in this course.

Figure 3.10 - Line Schedule Example

Line Number	Product	FROM	TO	Spec	PIPE				
					SIZE	SCH	MATL	INS	TRACE
LSAC-047-01	LIQUID ACID	1 - 25PRO01	SULFURIC ACID TANK	AC07	1.5"	80	SS	YES	YES
DWA - 047 - 03	DRAIN WATER	V01 - 097EP	SEWAGE PLANT	ST1	12"	80	CS	NO	NO
WWA - 047 - 77	WASTE WATER	V03 - 099AP	SEWAGE PLANT	ST1	6"	80	CS	NO	NO
LTOL - 047 - 97	LIQUID TOLUENE	7 - 200PRI	6"W - 15M - 7	CR03	3"	80	TF	NO	NO

Line Schedules you will come across on real P & IDs will most likely provide more information and contain more lines that are shown in this example. This example empowers you to handle any other form of Line Schedules in the future due to familiarity.

FIGURE 3.10 - LINE SCHEDULE EXAMPLE **NOTE:** **Spec** = *Specification*, **SCH** = *Schedule*, **MATL** = *Material*, **INS** = *Insulation*

Line Schedule Number

The Line Schedule Number is the number that is in the first column in Figure 3.10. Did you observe that the abbreviation for the material flowing in a pipe is included in the Line Schedule identification for that pipe? If not yet, well, now you know. In the Line Schedule Example in Figure 3.10, DWA stands for drain

water in the line, “DWA – 047 – 03.” *It is a good thing to be familiar with the abbreviations for the materials in your Plant Area.* You don’t have to memorize the abbreviations though, as you can look up this information in what is called a, “Legend/Mastersheet/Lead sheet.” We will be looking at this in tables covered in the next Chapter under Line Designations.

Area 4 - Equipment Descriptions

The Equipment Descriptions block is block number 4 shaded in blue color in Figure 3.11 below. This area on P & IDs gives descriptions of crucial pieces of equipment shown in the Drawing Area of that particular P & ID. The P & IDs may have the equipment information in the form of notes at the bottom of the Main Drawing. Sometimes you may find companies that will prefer to put this information above the Main Drawing. Regardless of how or where this information is put, the equipment descriptions may include the following information depending on the type of equipment and company preference:

Special equipment number – this appears on each piece of equipment and on the P & ID equipment symbols

Capacity of the equipment Size of the equipment Materials of construction for the equipment in question Temperature and

Pressure operational limits data for the equipment Horsepower of pumps The name of the Vendor who makes the equipment as well

as model number if this is deemed important

Figure 3.11 - Equipment Descriptions AreaA 4

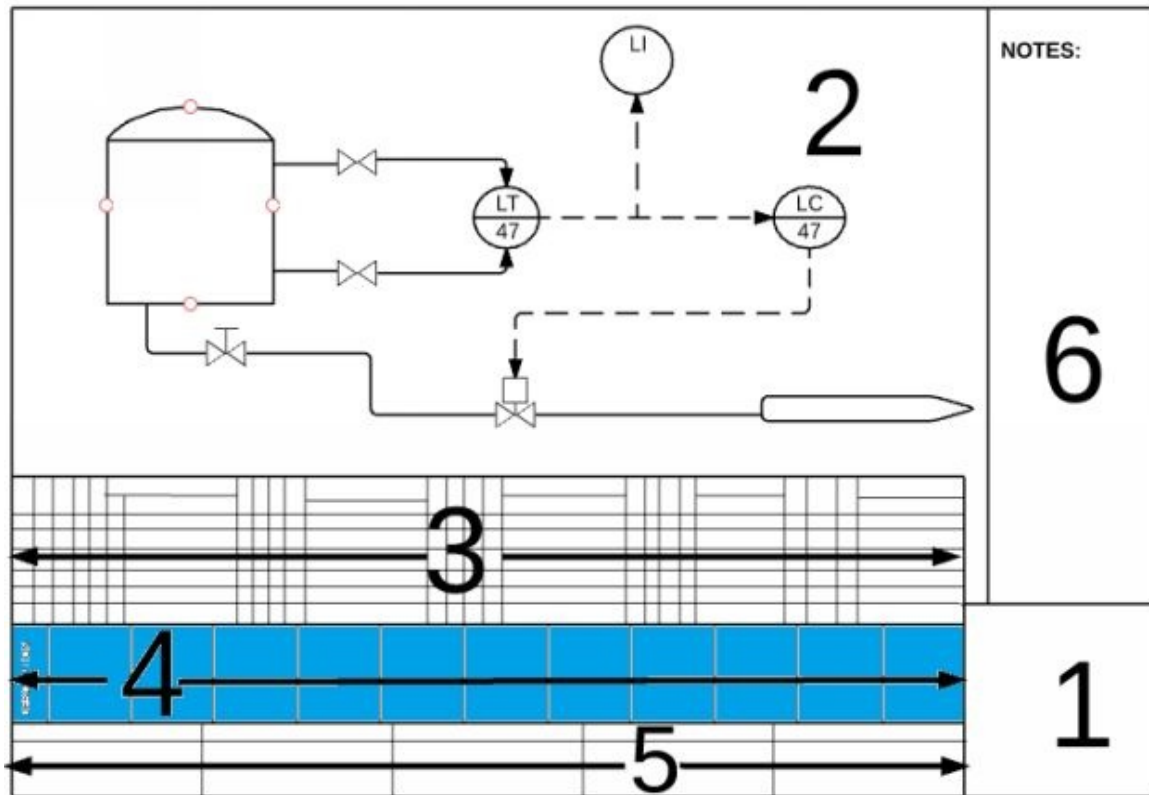


FIGURE 3.11 - EQUIPMENT DESCRIPTIONS AREA 4

The equipment number is a unique tag number. That means no other piece of Process Equipment should have that number in the plant. This Equipment Number is shown inside the equipment symbol or very near it in cases where the symbol is relatively small. Specific information about a tank, for instance, may also be written on the tank on site as shown in Figure 3.12 below:

Figure 3.12 - Tank Information Label

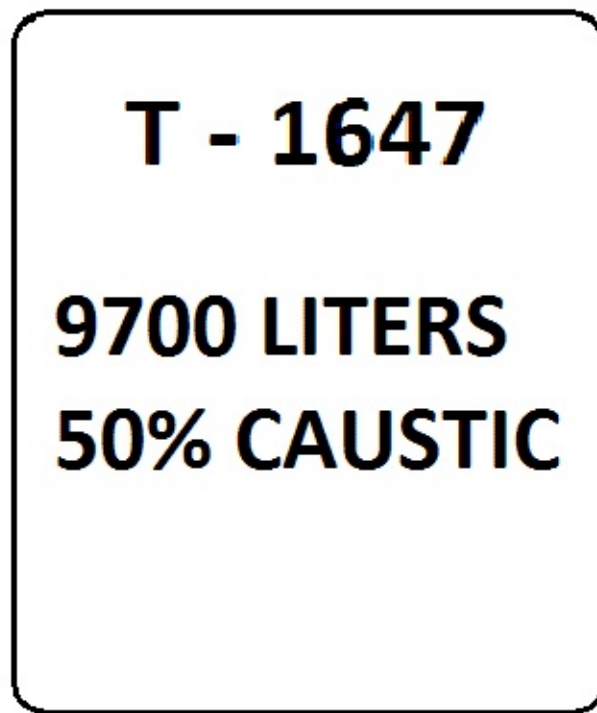


FIGURE 3.12 - TANK INFORMATION LABEL Next I would like to show you two examples of P & ID Equipment Descriptions. The samples are for a tank and its associated electric heater. The two items have tag numbers.

This is not standard from plant to plant, and is done depending on company preference. Again the Lead sheets will give you most of the clues regarding how to use your company's P & IDs. We will be looking at Lead sheets shortly. Just remember that equipment numbering will differ from site to site. For now consider Figure 3.13 below, which shows the two samples of equipment descriptions:

Figure 3.13 - Sample Equipment Descriptions

<u>H - 1647</u> CAUSTIC TANK IMMERSION HEATER CAPACITY: 60.0 kw(e) MATERIAL: ALLOY 625 TRIM: EQ-676 - 1647 - A6E - 50H	<u>T - 1647</u> CAUSTIC TANK (50%) WORKING CAPACITY: 315 m³ SIZE (ID x HEIGHT): 7.0 m x 9.5 m DESIGN PRESS. (MAX/MIN): 1.60 kPa(g) / -0.25 kPa(g) DESIGN TEMP. (MAX/MIN): 44 Deg C / -40 Deg C MATERIAL SHELL/LINER: CS +3 mm / NOT LINED TRIM 1: EQ-676 - 1647 - A6E - 50E
---	--

FIGURE 3.13 - SAMPLE EQUIPMENT DESCRIPTIONS The above sample Equipment Descriptions show typical information you could see on a P & ID. However, there is no standard way of the amount of information required. Therefore the amount of information will vary. In fact some P & IDs may not have Equipment Descriptions at all.

Area 5 - Issue Descriptions

I have already mentioned that proper P & ID updates is a requirement for maintaining useful and accurate information on P & IDs. The P & ID for an area is revised and reissued every time a change(s) is (are) made. Changes may be made during the design and construction of a process. Additions changes may be made to the plant system throughout the operating life of the plant. Figure 3.14 shows the issue description area shaded in blue color. This is often at the bottom of the page as shown in Figure 3.14 below, within block 5:

Figure 3.14 - Issue Descriptions Block

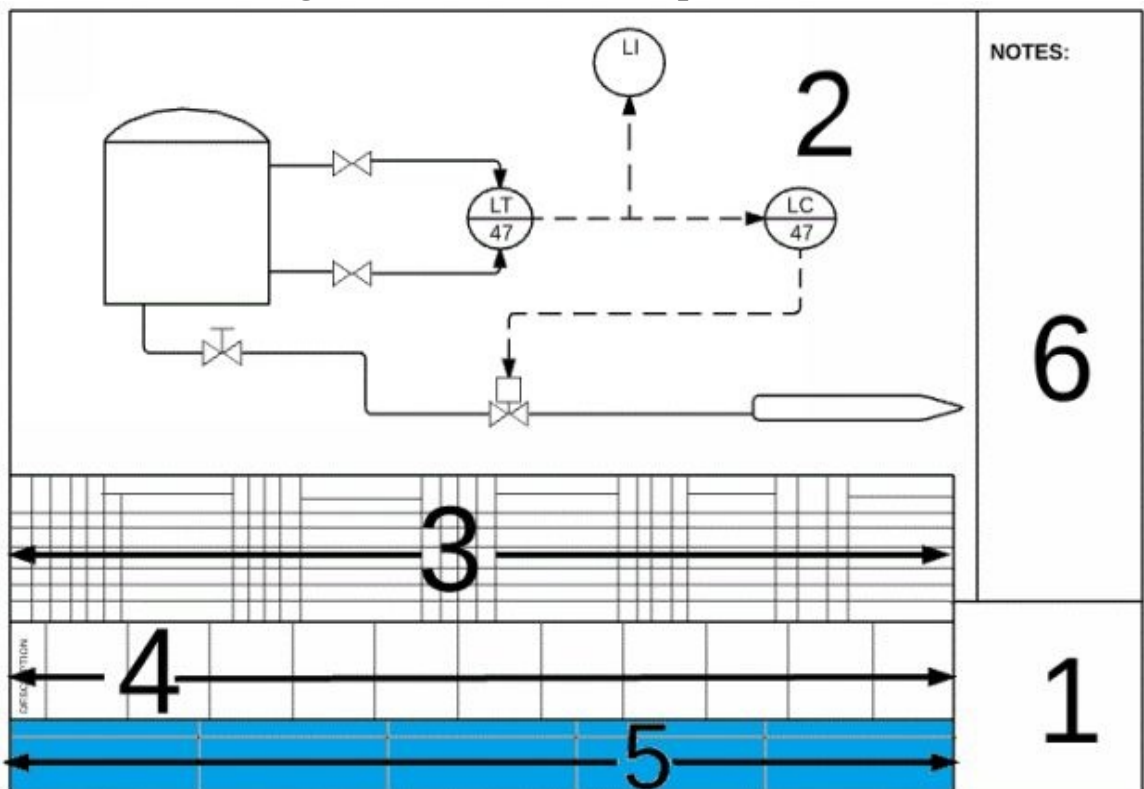


FIGURE 3.14 - ISSUE DESCRIPTIONS BLOCK Issue Descriptions tell you exactly what changes were made with each new issue number of the P & ID for the area. *The issue number (or revision number) for a P & ID is*

included in the Title Lock, area number 1 in Figure 3.14 above.

Issue Notes

Notes may be made in the main drawing to show where exactly a change has been made in the Process. *In some cases a “cloud” is sketched in the drawing to show where the new equipment is.* Since a P & ID might have several similar pieces of equipment, the cloud or other similar indicator makes the new heat exchanger easier to find. *In some cases you may see triangles on a P & ID.* A triangle is used to indicate that the number inside the triangle refers to the issue number for recording this change. Figure 3.15 below gives a sample of how a note marker, a hold cloud, and a revision change cloud with a revision triangle looks like on a drawing. We will talk about Notes in the next section. I include this example here so that you are familiar with how these markings would look like on a real P & ID. The Hold Marker is just a special bubble that shows that particular section is on hold and no work is to be done until further notice.

Figure 3.15 – revision change Cloud with revision triangle & NOTE marker as well as hold marker

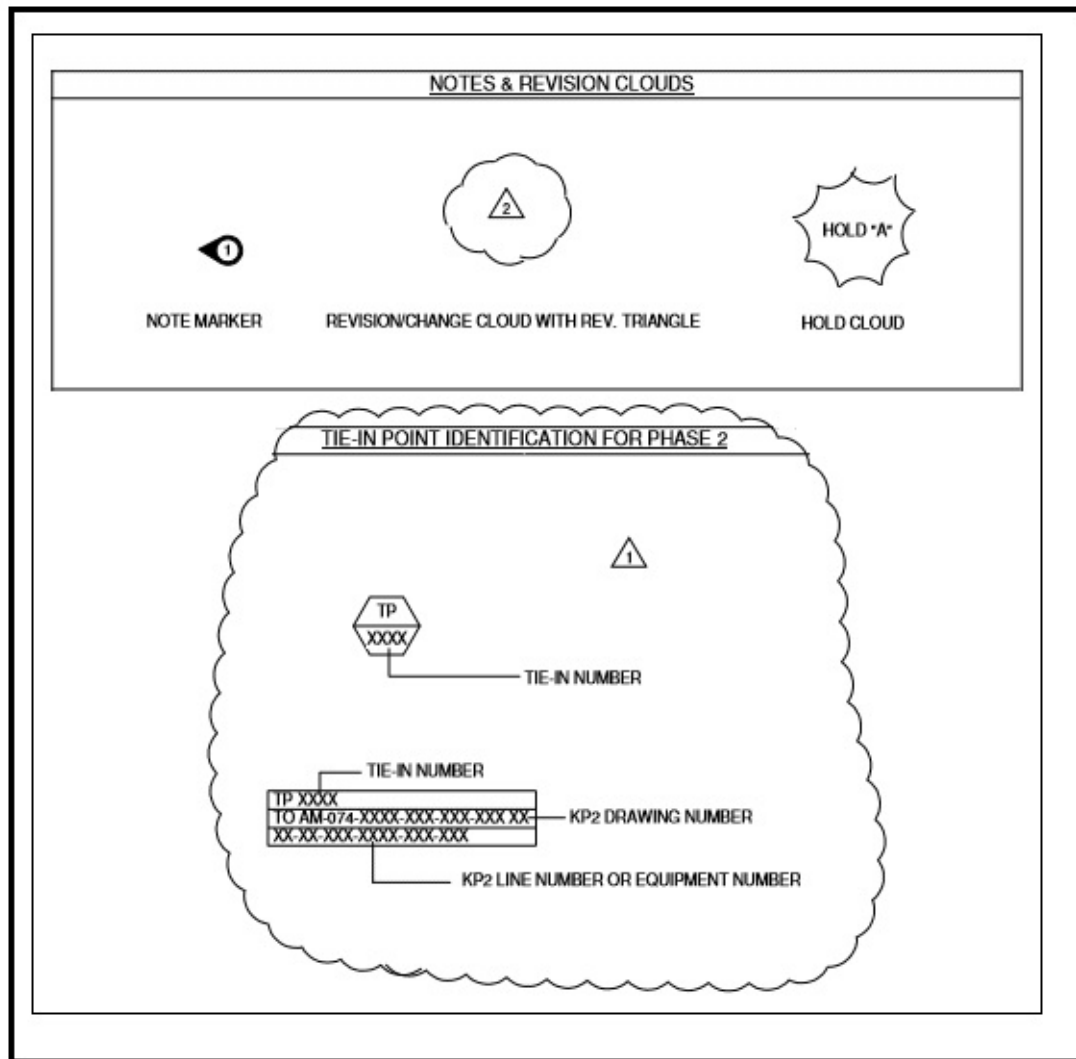


FIGURE 3.15 – REVISION CHANGE CLOUD WITH REVISION TRIANGLE & NOTE MARKER AS WELL AS HOLD MARKER The Issue Description references the number in the triangle to provide further details as to what are the changes made. So realize here that once you are familiar with the six P & ID areas, the whole puzzle of reading P & IDs becomes less intimidating.

So just to recap the special symbols and notes mentioned in this section, these may be in the main drawing to point out where changes were made in the plant. The triangle shown above in Figure 3.15 would be placed with the number of the current issue everywhere there is a difference with the previous P & ID issue for that area. A triangle with a new issue number would also appear in the equipment list next to a description of the new equipment as well as in the main drawing next to the equipment symbol. Some Engineers prefer to put a cloud as in the example above, or some sketch around all of the parts of the system that

have been altered with the current issue for easy identification.

Then from the above change markers, the Issue Description block at the bottom of the drawing summarizes the changes that have been made with each issue and give such things as date of work and person approving the change(s). It may look confusing right now, but once you lay your hands on a real P & ID and with the information that I'm giving you in this course, you will be home and dry.

Area 6 – Notes

Figure 3.16 below shows a typical example of Notes that would accompany a caustic tank P & ID. As explained before, Notes are found in block 6 as shown in Figure 3.16 below. It is the block that is to the right hand side of the drawing. If you want to refresh your memory, Figure 3.14 is the closest drawing that can show you block number 6, which is the Notes area.

In the notes area, many different kinds of information may be included at the discretion of the Engineers. More often than not, notes appear to the right hand side of the drawing. That is not always the case though. The fact is Notes may appear in almost any part of the P & ID, depending on company choice.

You should always pay attention to the Notes area, or any noted information for that matter. That is because Engineers who prepared the P & ID may have made a note about something that varies from the usual or something particularly important. You don't want to miss such crucial information. Hence the need to exercise due diligence when reading P & IDs.

Possibilities of information that could appear in the Notes area are several, which may include but are not limited to the following:

- . Interlock information – An interlock is a feature that makes the state of two mechanisms or functions mutually dependent. It may be used to prevent undesired states in a finite-state machine, and may consist of any electrical, electronic, or mechanical devices or systems.
- . Special symbol descriptions
- . Reference information for documentation or company standards used
- . Accommodations for special operating conditions
- . Safety information, information on how a vent is to be accessible in case of emergency
- . Installation information, and sometimes more details of a particular complex Control Loop

Notes are usually numbered as can be seen in the example that I have provided in Figure 3.16 below. For instance, a note may be made about interlocks because they are very important for safety reasons.

Figure 3.16 - Typical Notes that would accompany a Caustic Tank P

NOTES:

1. ALL EQUIPMENT AND INSTRUMENT TAGS ON THIS DRAWING HAVE THE FACILITY/SYSTEM PREFIX "1120-676" UNLESS SHOWN OTHERWISE.
2. CAUSTIC SPILLS TO THE CONTAINMENT AREA SHOULD BE REMOVED BY VAC TRUCK. BERMED CONTAINMENT AREA CONSTRUCTED WITH CONCRETE. VAC TRUCK WILL DISPOSE OF THE MATERIAL TO ETA.
3. VENT TO SAFE LOCATION.
4. CHEMICAL HANDLING TRUCKS WILL FILL THE TANK THROUGH TRUCK CONNECTION WHICH WILL BE UNIQUELY KEYED TO PREVENT UNLOADING OF WRONG CHEMICAL. UNLOADING WILL BE DONE WITH THE PROVIDED AIR UNLOAD FACILITY. COUPLING AND ISOLATION VALVE (MV-1630-02) TO BE LOCATED OUTSIDE THE TANK CONTAINMENT AREA. DRIPS AND SPILLS AFTER DISCONNECT WILL BE CAUGHT IN THE COLLECTION TRENCH OUTSIDE THE CONTAINMENT WALL. BERMED CONTAINMENT AREA CONSTRUCTED WITH CONCRETE.
5. FOR UNLOADING CAUSTIC TRUCK WITH AIR THE ELEVATION DIFFERENCE BETWEEN HIGH POINT ON CAUSTIC LINE AND BOTTOM OF TRUCK CONNECTION CANNOT BE MORE THAN 9.15 m (30 ft)
6. SAFETY SHOWER OUTSIDE BUILDING OR LOCATED NEAR CAUSTIC UNLOADING AREA.
7. PCV-1630-4 WILL BE LOCKED IN THE SET POSITION TO MAINTAIN CONSTANT PRESSURE.
8. VALVE PROVIDED FOR CONNECTION OF A TEMPORARY TANK.
9. EXTEND HEATER ACROSS CAUSTIC TANK, ABOUT 30 cm FROM OPPOSITE SIDE.
10. NOZZLE FOR LEVEL TRANSMITTER SHOULD BE HEAT TRACED.
11. A SPARE IMMERSION HEATER WILL BE PURCHASED BUT NOT INSTALLED.
12. PUMP SUCTION LINE WILL PENETRATE BERM THROUGH SLEEVE WHICH IS PROPERLY SEALED.
13. EACH SAFETY SHOWER HAS A HEATER.
14. TYPICAL SAFETY SHOWER AND EYE WASH STATION AS PER TDR 0569 REV 0.
15. WARNING HORN AND STROBE TO BE LOCATED AT UNLOADING STATION
16. ANY CAUSTIC TANK HIGH LEVEL ALARM SHALL ACTIVATE WARNING HORN AND STROBE.
17. HEAT TRACE AND INSULATE ALL DEAD LEGS, DRAINS AND VENTS. REFER TO WINTERIZATION PHILOSOPHY KP 76-74-015.

& ID

In Figure 3.17 below, I have provided an example of information concerning an Interlock. This example shows how the information may appear as a special note

on a P & ID. The Interlock symbol is diamond shaped and may be labelled with a letter ' I ' in the center as shown in the example in Figure 3.17 below.

Figure 3.17 - Example Note on INTERLOCKS

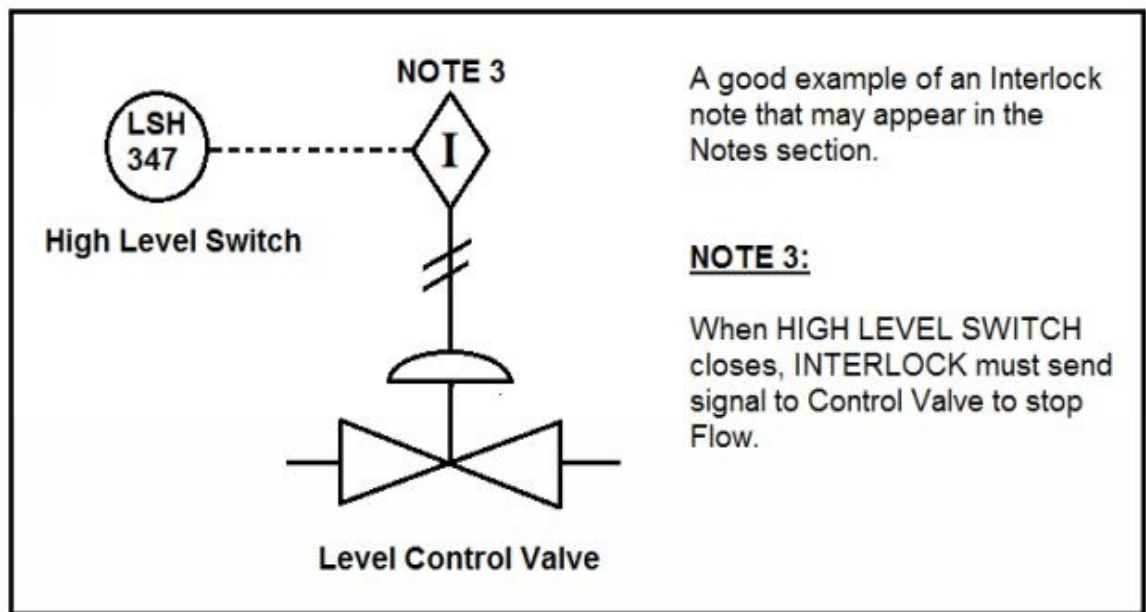


FIGURE 3.17 - EXAMPLE NOTE ON INTERLOCKS

Zone Numbers

To help locate some information on the Main Diagram, Zone Numbers are used on some P & IDs. These numbers work in a similar manner to a grid line on an ordinary map. So it should be pretty easy for you to figure out how this stuff works. On a P & ID, as shown in Figure 3.18 below, numbers run from left to right along the bottom of the drawing, and letters run from the bottom upwards along the right hand side of the drawing.

If you draw imaginary lines up from a number and across from a letter, you will

be able to locate a specific spot on the P & ID. Where the two imaginary lines meet is the location of the area you want. In the example below, the NOTES Header is located where lines **J** and **9** meet.

Figure 3.18 - Zone Numbers on a P & ID

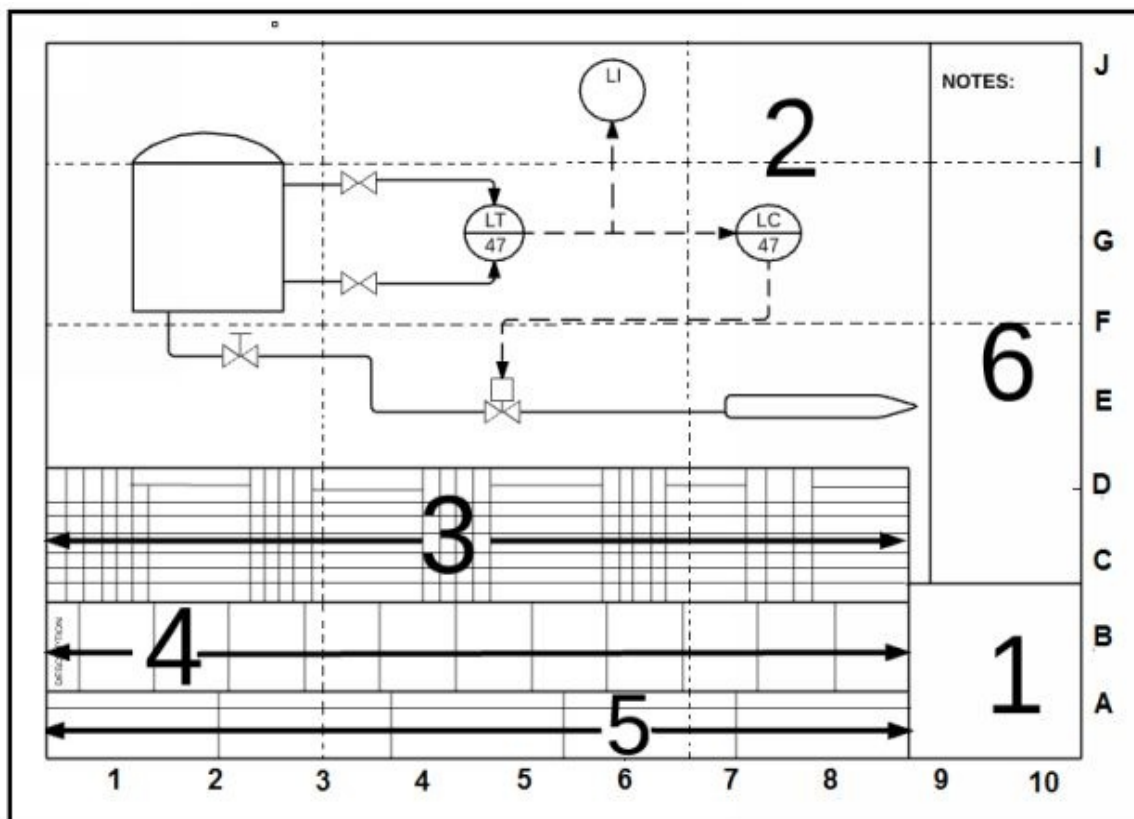


FIGURE 3.18 - ZONE NUMBERS ON A P & ID Not all P & IDs have Zone Numbers. This is dependent on the company standards, which obviously reflect on the company's preferences. One word of caution though, the dotted lines you see on the example P & ID in Figure 3.18 will not appear on a real P & ID. Therefore, do not confuse them with the many pipes and instrument signal lines that do appear on a real P & ID.

The imaginary lines in this example have only been drawn to demonstrate how to use Zone Numbers for locating a specific area on a P & ID. These dotted lines will never appear on an actual P & ID. As you will learn later in this course, dashed lines have a meaning when you see them on a real P & ID. This line symbol mean an electrical signal. This will be covered in Chapter 7.

Chapter Review:

The review questions are available at [ReviewQuestions.](#)

Chapter 4: The P & ID Legend Sheet/Master Sheet/Lead Sheet – The Key for Reading P & IDs

Chapter Goals:

At the end of this Chapter, you should be able to use a Master Sheet/ Legend/ Lead Sheet as a reference for identifying P & ID symbols and labels found in the:

- . Line Tables
- ii. Instrument symbols and designations tables
- iii. Graphic symbols tables
- v. The whole P & IDs pack

What a Legend Sheet/Mastersheet/Lead Sheet is and how IMPORTANT it is to reading a P & ID:

The Legend, also called Master Sheets or Lead Sheets are used to define the equipment and device symbols, tags and other notations, abbreviations and sometimes esoteric conventions that companies use to develop P & IDs for any project they execute. I bet if you compare the Master Sheets from a few dozen companies out there, you will observe that ninety percent of them are pretty much copy and paste. For the remaining ten percent, there can be distinct differences and company-specific conventions used that are not obvious on P & IDs. Therefore, *it is good to refer to the Master Sheets in your company so you can track down the meaning of that pipe service symbol or some other obscure symbol.*

This course does not try to cover all the possible equipment and line combinations that can appear in P & IDs. That being the case, with the skills taught in this course, you should be able to look at any P & ID and figure your way out. You can do this by simply using the Master Sheets/Legend Sheets/Lead Sheets to look up any symbols and line identifications that you either don't know, are in doubt with, or are just not familiar with.

As I mentioned above, the meanings of various symbols used on P & IDS (aka symbology) are defined on separate drawings that are called by the three names:

- . Legend Sheets
- . Lead Sheets
- . Master Sheets

These are your “*secret decoder rings*” to P & ID symbology interpretation. Every company that builds process plants should have a set of these sheets customized to their particular ways and means. Having laid my hands on a number of Legend Sheets over the years, I can tell you that most of them are just variations on a core set of generally accepted symbols and notations that engineers and industry organizations have settled on as defacto standards over the years.

The Legend Sheet should come with the set of diagrams for a Process area. It is printed on the same kind of paper and with the same kind of ink as the P & IDs.

It should also be on file with them. These sheets are the key to what symbols and labels mean on the set of P & IDS for your company. How this information is recorded and what is included will vary from company to company. For this course, an acceptable example of a Legend Sheet would have four parts as follows:

- 1. Table I – Line Designations
- 1. Table II – Instrument Symbols
- . Table III – Graphic Symbols
- . Table IV – Process Equipment Symbols

Some companies have from two to six or even seven Lead Sheets. Probably a few with more. The number of Lead Sheets is not that important. What is important is that they are logically organized so that the symbols and tags can be located and read easily. You will agree with me that poorly organized and/or incomplete Legend Sheets will just frustrate folks who turn to them for help. **So it's very important to keep Master Sheets neat, concise and logical.**

Even though major equipment is also included on the Legend Sheets, it is easy to remember without referring to the sheets. It's good to have Lead Sheets for that kind of stuff. I am not going to say otherwise. Nonetheless, I have observed that:

It is almost always self-evident what a symbol represents for major equipment, and Even if it's not apparent, the major equipment is *always* tagged and named with some general specifications provided along one edge of the drawing.

For Operations Folks here in attendance: Keep in mind that reading and understanding P & IDs is a core topic of Operator Training. That training should happen long before you step onsite. In fact, everyone should know this stuff before they enter the room as a team member on a Process Hazards Analysis. Most Process Engineers at heart view Operations as their number one client and work hard to make sure that they fully understand the plant and its procedures. When Operations personnel understand the plant and its procedures, they can safely and efficiently meet the plant's objectives. That all starts with understanding the stuff we teach in this course. I will make you a simple promise – so long you go through all the material covered in this course, you will definitely walk away from this training with a solid, and functional

understanding of P & IDs. If you don't, call me and I will refund your money, with no questions asked!

This course will give you practice of the skills needed to use a typical Master Sheet reference. That will help you understand and use a typical Mastersheet during your entire career. All you need to remember is that whenever you encounter something you don't know on a P & ID, refer to the Master Sheet. You will help yourself and look more self-reliant that way vs. jumping to seek help from others. They will likely refer themselves to the same Master Sheet anyways.

Mastering Line Designations:

Flow lines should be labeled to show pipe size, line service identification, line number, line material, piping class and the line pressure rating. The Line Schedule in the previous unit, Figure 3.10 – LINE SCHEDULE EXAMPLE, gave us several pieces of important information about each pipeline. Here is the thing, the material flowing through a pipe is given in the line schedule and in the line identification number as an abbreviation. In the example line designation we used in Figure 3.10, “LSAC” stands for Liquid Sulfuric Acid. For you to know what these abbreviations mean, you would go to the Line Designations section of the Legend Sheets.

Below is a sample table for Line Designations, Table 4.1. This is just an example and is by no means exhaustive. It is just serving the purpose to show you how a Line Designations Table looks like.

You do not have to memorize all the abbreviations in the line designations table. I recommend that you become familiar with the abbreviations that refer to lines in your work area. If you need to consult a P & ID before beginning a task, and you run into a situation where you don’t recognize the material code for what is in a line, you should check the table. If it still is not clear or you have questions, always ask your Supervisor or a subject matter expert for your area.

There is no absolute standard for defining how line designations will be written. Be sure to check carefully all the time. You are at work, the company pays you to do proper work, so do it properly and avoid mistakes that could cost your company a lot of money. One letter can make a big difference. Be sure that you know what it is in a line before you perform any work on a line. If you are still not sure after looking at the Master Sheets, ask your Supervisor. Notice how one letter makes an important difference in the following list: **AA** is Acetic Acid **AC** is Acetylene **AD** is Ammonia Drains This alone should be enough to warn you to be very careful with reading details on a P & ID and its associated sheets. You can avoid a lot of mistakes by being careful. Even a lot of embarrassment.

Figure 4.1 - Line Designations

Table 4.1 - Line Designations

A Compressed air (wet)	EA Equalizer line
AA Acetic acid	ES Exhaust steam
AC Acetylene	FG Fuel gas
AD Ammonia drains	FO Fuel oil
ANS Ammonia nitrate solution	G Gasoline
ATV Atmospheric vent	H Hydrogen
BD Boiler blow down	HCN Hydrogen cyanide
BG Burner gas	IA Instrument air
C Condensate	LA Liquid ammonia
CAT Catalyst	M Methane
D Drains	MA Methanol
EA Exhaust air	MG Mixed gas and steam

This is part of a typical Line Designations Table. I need you to take note of the fact that line designation letters may be the same as instrument designations in some cases. Under such cases, if the letters are on a line, their meaning can be found on a Line Designation Table. If they are in an instrument symbol, their meaning can be found on an Instrument Designation table. For instance, "PV" means **pressure valve** when it is an instrument symbol but it means **pressure vent** on a line. so be cognisant of the right table for the right item. If you just exercise due diligence, you will have fun with P & IDs!

FIGURE 4.1 - LINE DESIGNATIONS

Mastering Instruments Designations:

Under this section we will kick off with what has traditionally been viewed as the “hardest part” of P & IDs interpretation. Anyone could guess that it is of course Instrumentation and Controls. This is the area that gives newbies the most grief, at least judging from my experience. Trust me my friend, it’s not that hard. Besides, once you have this area mastered, everything after that is stupid simple. The learning curve will skyrocket, assuming that a learning curve with a steep start actually represents rapid progress.

Table II on the Master Sheet gives abbreviations for instrument designations. Some Plants may call Instrument Designations Instrument Tags. In this section we will look at instrument designations in great depth. After going through this section, you should have it easy reading P & IDs because this is the hardest part for most people. You will find that it’s not even hard. Especially with the system that we are using of breaking the P & IDs in small parts before attempting to read them in full.

The main symbols used for Instrumentation and Control (I & C) are shown in Table 4.2 below. When you spot one of these on a P & ID, you will be able to discern three things from it. These three things answer the following three questions:

- . **What is that device?**
- . **Where is it located?**
- . **Why is it there?**

Now here is a little trick: the ‘what’ and ‘where’ parts is determined from the shape of the symbol. The ‘why’ part comes from the text that is placed inside the symbol that is made up of two parts that forms the “Tag Number”. The two parts that form the Tag Number comes from:

- . **An abbreviation for what the device is** (based on ISA S5.1 Standard which contains tables and examples for creating letter abbreviations that are used for instruments on P & IDs. Most P & IDs follow this standard to some degree), **combined with a**
- ii. **Loop Number based on your company’s preferred numbering system**

I will provide a couple of simple Tag Number examples as a lead in before I dig into this topic more heavily. By the way this is my forte. Pressure indicators have the abbreviation **PI** and temperature indicators use the abbreviation **TI**. It follows from logic that flow and level indicators will use the abbreviations **FI** and **LI**, respectively.

Many Plants can have many instruments of the same type, a unique number is applied so that each instrument can be individually identified. This number is often referred to as the “**Loop Number**”. Thus, *the device abbreviation plus the loop number become the unique “Tag Number”*. While the device abbreviations are largely based on accepted standards (ISA S5.1), the loop numbering system is company specific.

If you are in a company that happens to use a four digit numbering system, typical tag numbers for pressure and temperature indicators in your Plant may be PI 1730 and TI 1747, respectively. You could even reuse the Loop Number “1747” to define other types of devices, such as a level indicator. Such a level indicator would have a tag number LI 1747, or flow indicator, FI 1747. The same holds true for Loop Number “1730”. It may be used for PI 1730, LI 1730 and HS 1730 (where HS stands for Hand Switch).

The key point is that the abbreviation plus Loop Number must be unique for each device, failure of which it cannot be uniquely identified. Most companies get creative and apply special prefix (or Suffix) numbers to the tag number when they want to reuse the same tag. I have seen that happen in cases where there are redundant devices but you don’t want them to have different loop numbers. For instance redundant Temperature Transmitters on a steam header. They could be labelled, TI 1747A, TI 1747B, TI 1747 C, and TI 1747D. These would be measuring the same variable in a redundant setup.

Table 4.2 - Instrumentation and Control Symbols

Instrumentation and Control Symbols				
Where What	In the Field Locally Mounted	On a Main Panel Or Screen	On A Subpanel or Remote Location	Inaccessible, Hidden Or Back/Inside Panel
Instruments & Devices				
Graphics on a Computer Screen				
Computer Functions (Seldom Used)		I have decided that it is reasonable to remove these solely because the symbols that would normally go here do not provide any real clarity on P & IDs in my opinion. The limited use of the two symbols at the left hand side can be adorned, as necessary, to refer to specific computers and/or PLCs functions. The functional description will help clarify computer functions and control logic.		
PLC/DCS Functions (Seldom Used)				

Color Code

 Most commonly used symbols, always present

 Used in most cases, maybe not all

 Used from time to time, but will be absent sometimes

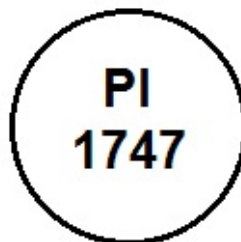
 Not usually needed unless there is a good reason

 Use of this symbol can be avoided most of the time

My Review Notes

FIGURE 4.2 - INSTRUMENTATION AND CONTROL SYMBOLS

What is that Instrument Symbol?



If you refer to the first row in Table 4.2 above, you will notice that a circle symbol is quite simply any physical instrument or device in the field or on panel. It doesn't matter if it is a flow transmitter, level transmitter, pressure gauge or some other type of indicator. If it is a physical device that measure or displays something, it will be illustrated by the use of a circle on a P & ID. Notice too, how the Tag Number, PI 1747, is placed inside the symbol. The common practice is to place the device function abbreviation on the top line, with the Loop Number at the bottom.

When the physical device is ordered and a stamped tag is requested, it should match the Tag Number placed inside the symbol on the P & ID.

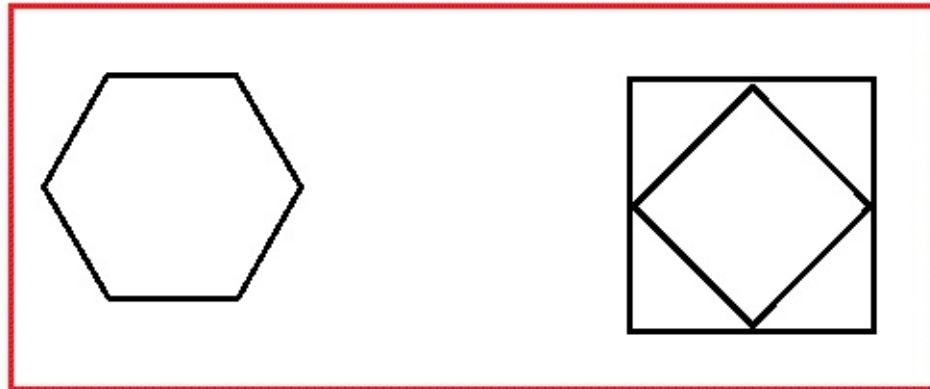
Aside: More often times you will hear folks refer to the symbols as instrument "bubbles". This is just jargon that is commonly used. When you hear it, they are simply referring categorically to the symbol shapes I am talking about in this part. I suggest you just act like you have been calling them bubbles for years and show no sign of confusion! Now next instrument symbol...



This time for the above instrument symbol, just move down to the symbols on the second row of Table 4.2 above. It is the ones that show a circle inside of a square. These are used to represent a graphic on a computer screen or control panel that you can see and possibly interface with via touch panel or a computer mouse. It might be used to show the level in a tank (as the Tag Number in the bubble shown here suggests) or represent a Hand Switch that you could click on with the mouse to start a pump (or a thousand other things!). The point is if you can see it on a control screen (most likely in the Control Room), it will be

represented as a circle inside a square on P & IDs. Don't ask me who decided this, all I know is that it wasn't me!

The last two rows are for symbols that let the reader know a computer is used to do some sort of complex processing. The hexagon means a "computer is used.



In the case of a square with a diamond in it, that means a Programmable Logic Controller (PLC) is in use. The venerable PLC – still hanging tough after all these years. Even before the Distributed Control Systems showed up at the plant. My friend, don't get intimidated, even if you are not familiar with control computers or PLCs, don't sweat it. Just know that these symbols really represent software instructions that Control Systems guys write to define the automated behaviour of the Plant. For example, code that tells an electric motor that drives a pump to automatically stop when the tank it is pumping from runs low. Remember we talked about interlocks in the previous chapter. This case about the electric motor here would be a so-called low level interlock type function that would exist as instructions inside a PLC.

In this case, a level element provides the input and the computer runs a set of instructions that say 'stop the motor' if tank level is low. These symbols are often left off of P & IDs because they really don't provide any usable information that you could get out of just looking at the symbol. For example, in the simple example that I just provided, how could you describe the low level interlock using a symbol that look like a square with a diamond in it? I bet you couldn't!

You would need to supplement the P & ID with a written description of what the Plant is supposed to do with all of the input it receives. I hope that you can see that the symbols would just take up space and clutter the drawing for no good reason other than perhaps to provide some pointer via a Tag Number to coded instructions. **But remember always that the P & IDs serve the Process, and not the Programmer so we can't have that!**

Color Code in Table 4.2

Now about the arbitrary color code rating that I gave all of the symbols in Table 4.2 – Instrumentation and Control Symbols. Folks, this is not published by ISA (as if I had to qualify this...) but it is my way of explaining the frequency and importance of these symbols in most cases. Here goes.

For each symbol, I rated it based on how often it typically shows up on drawings I have worked on over the years. Every Plant is different but there is a general theme here. I view symbols with the red color code as pretty much useless because the abstract concept they are trying to illustrate simply can't be done effectively with just symbology.

Blue color code symbols have value but may not show up very often or at all in many cases, depending on the type of Plant and its design. Anything that is black, brown or green is a celebrity in our P & ID feature course. We are talking Arnold Schwarzenegger, whereas the red color coded symbols are akin to the nondescript ensign killed in the first five minutes of a Star Trek episode.

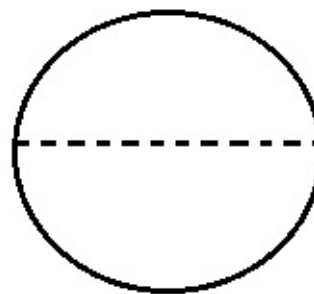
Where is the device located?

If you glance back at Table 4.2, you will see that there are four columns that provide the 'Where' part of a symbol. **Now, as we discussed earlier on in this course, P&IDs generally aren't good at showing you where something is located in the field. We aren't talking about that kind of 'where'. In this case, we are using where as a relative reference. Relative location is indicated via the presence of a centered, horizontal line (or lack thereof), a dual centered horizontal line, or a dashed centered horizontal line placed inside the symbol;**

- . **Single horizontal line** - located on a main control panel near the control room or some computer screen in the main control room
- . **No horizontal line** - located somewhere in the field, probably close to the general area shown on the P&ID
- . **Double horizontal line** - on some secondary (satellite) local panel in the field
- . **Single dashed horizontal line** - inaccessible or not generally located where it can be easily accessed or viewed. May also be used for hidden or password protected areas of a control system

Notice in the above items, no specific location information is provided, only that the device or graphic is associated with a relative, general location. In many cases, it's not hard to figure out where something is just from where the symbol is at on the drawing. But there are limits to what the symbol can convey.

From experience, I find that the dashed line symbols can cause confusion so I want to speak on those a bit more. When you see a symbol such as the one shown below, that simply means that you can't normally see it or work with that device in the field. It might be installed behind or inside of a panel so that it is normally not in view (i.e. inaccessible to the operator). So for the symbols shown here, a circle with a dashed line in the middle means it is an instrument or device that you can't normally see or get to.



More On The Dashes

If you are an operator, it is probably something you do not need to get to but it might still be vitally important to the Plant Control System, so we show it this way on P&IDs. In similar fashion, a graphic display symbol with a dashed line

in the middle simply means that this portion of the Control System is password protected or hidden from normal view on a screen or operating panel. You can't get to it unless you know the secret access code. It's not that people are keeping secrets from you (or maybe they are...wink wink); it's just that it might contain important settings that nobody should ever need to mess with.

Why is that device here?

You've come a long way towards understanding Control Symbology. You can now identify what a Control Symbol represents and its relative location in the plant. But you probably still don't know why it's there. It's not helpful to know how to identify a Control Symbol type if you cannot explain what purpose it serves in the plant. *The textual abbreviations placed inside the symbols explain what purpose it serves in the plant.* We touched on this a bit above. Let's now cover the essence of what you need to know - and keep in mind, come of this is the way I like to do things, which doesn't necessarily mean it is the best or only way. Refer to Figure 4.3 below entitled "Instrument Symbol Tag Identification". A Control Symbol will typically contain two lines inside it, as follows:

- . **Upper Line (or ‘the letters part’)** - an abbreviation for the functionality it provides (based on the ISA 5.1 standard), and
- .. **Lower Line (or ‘the numbers part’)** - a Loop Number that corresponds to the equipment or area it is associated with (or based on your company's preferred standard).

The upper line text abbreviation, along with the lower line Tag Number makes up the unique symbol identification tag. It is important that each symbol have a unique tag so that it can be individually identified within the whole Plant. In this example, the symbol would be referred to as PDIT1747 in a Process Document or Operating Procedure. There may be a bunch of other symbols with 1747 in them, but they must have a different text abbreviation before the 1747 or you won't be able to uniquely identify it.

Figure 4.3 - Instrument symbol Tag Identification

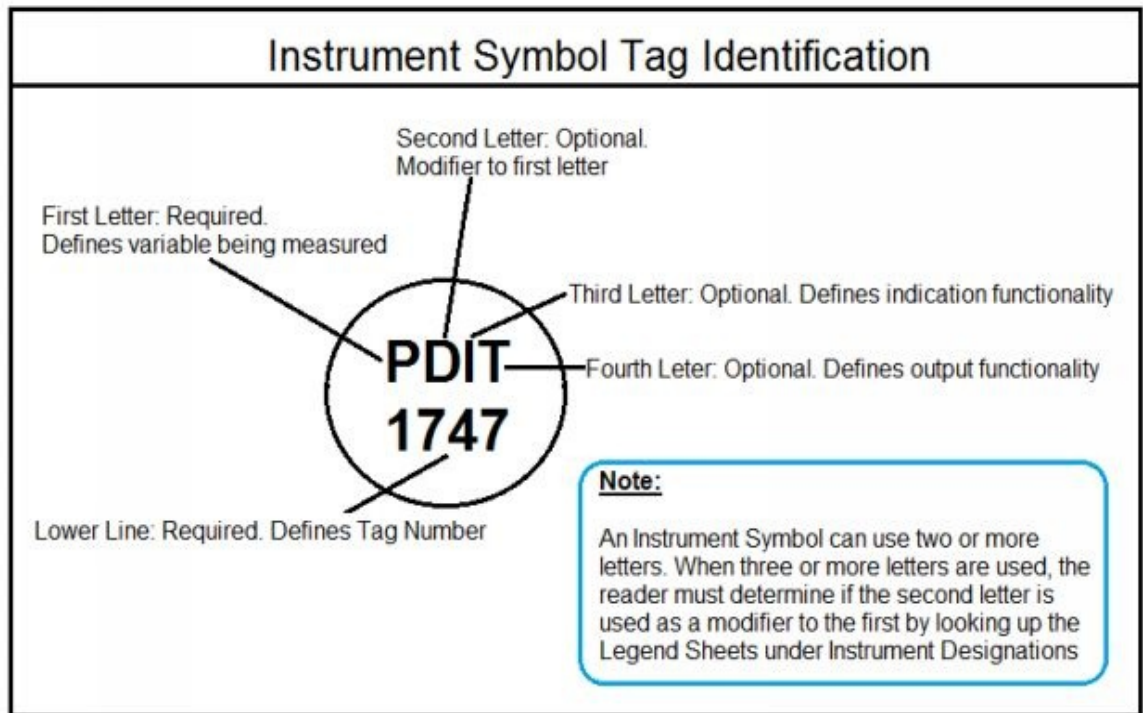


FIGURE 4.3 - INSTRUMENT SYMBOL TAG IDENTIFICATION The letters on the first line are in accordance with [ISA Standard S5.1](#). Each letter provides unique information. We can use the table in the Mater Sheets to determine that this symbol represents:

- . "P" - First Letter stands for "Pressure"
- . "D" - Second letter is a modifier for the first and stands for "Differential"
- . "I" - Third letter stands for "Indicating"
- . "T" - Fourth letter stands for "Transmitter"
- . 1747 is the loop number

Most companies base loop numbers off the associated major equipment. I do too. That's just me, and I think it makes good sense. But if your company uses a different technique, roll with it by any means. Now is not the time to be a renegade creator of new Tagging Systems. Fight your battles but win your wars! So in this case, we have a **Pressure Differential Indicating Transmitter (PDIT)** installed on equipment 1747. You might see such a device across a filter inlet and outlet to let you know what the pressure drop is across it so that you can clean it when it gets high.

Common Instrument Abbreviations

There are a number of Instrument Letter Combinations that you are likely to come across a lot. A few of these are listed in the [Figure 4.4](#) titled "Common Primary Device Symbols". These examples will help you get some practice understanding the abbreviations used for Instrumentation and Control symbols. You can compare the examples to the table on Lead Sheets to get the hang of it. These examples all represent field-mounted devices. We know that because they are all simple circle symbols with no horizontal lines. I told you this was pretty straight forward, and you would be pretty good at it soon!

The hardest part in deciphering the abbreviations inside Instrumentation and Control symbols is figuring out what the letters designate when there are three or more letters used. The following are a couple of rules of thumb:

- 1. [In the case of abbreviations with four letters, the second letter is a modifier to the first.](#)
- 2. [When only three letters are used, the second letter probably is not a modifier.](#)

Please remember that as with any "rule of thumb", your mileage may vary, so if in doubt, look it up using the Instruments Designation Table on your company Lead Sheets. Figure 4.4 below will ensure that you will never run into problems with identifying Common Instrumentation and Control Symbols. So make sure to spend enough time practising deciphering what each symbol mean. This alone will guarantee you that you are ahead of 95% of your peers out there. It's a great start...

Figure 4.4 - Common Primary Device Symbols

Table 4.4 - Common Primary Device Symbols

AI 1747	LI 1747	TI 1747	PI 1747	Indicates only
AT 1747	LT 1747	TT 1747	PT 1747	Transmits Only
AIT 1747	LIT 1747	TIT 1747	PIT 1747	Indicates and Transmits
ADIT 1747	LDIT 1747	TDIT 1747	PDIT 1747	Indicates and Transmits and Includes first letter modifier D for Differential

Other Common Common Examples

XV 1747	Actuated Valve	ZSC 1747	Limit Switch (Close)
SV 1747	Solenoid Valve	ZSO 1747	Limit Switch (Open)
SC 1747	Speed Controller	VS 1747	Vibration Switch
HS 1747	Hand Switch	PS 1747	Pressure Switch

Line Symbols

Figure 4.5 – Key Line Symbols below, shows the key line types you will encounter when dealing with P & IDs. By far, the most common line type is the solid line, which as you might guess, is used to represent a pipe. Although not shown below in Figure 4.5, a process line with long dashes means the pipe is existing or is outside the battery limits (OSBL) of the plant. A battery limit is a defined boundary between two areas of responsibility, which may be physical (e.g. a flange on a pipe); or represented by a map coordinate; or some other means (for example a demarcation fence).

Other common line types that you should be able to identify are for electrical signals (anywhere electrical conducting wires are employed), instrument air to control valves/devices (labeled as pneumatic signal in Figure 4.5) and software or data link which includes "virtual" communication such as what occurs inside a computer program or PLC ladder logic. The software can include anything that happens inside a computer. But you need a functional description to actually know what that is, as we discussed earlier in this course. Just be aware that when you see a software line, it means computers are at work linking the devices in some meaningful way that relates to the Control System.

Figure 4.5 - Line symbols

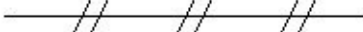
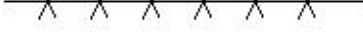
Table 4.5 - Line Symbols	
	Connection to process
	Instrument Air Supply
	Hydraulic Signal
	Pneumatic Signal
	Capillary Tube
	Electric Signal or 
	EM, Sonic, or Radioactive
	Mechanical Link
	Software or datalink
Notice The Difference In The Below Two:	
	Guided Wave (Electromagnetic signal)
	Unguided Wave (Electromagnetic signal)

FIGURE 4.5 - LINE SYMBOLS

Mastering Graphic Symbols:

We have identified the symbols that contain instrument abbreviations and numbers. Since all we see on a P & ID is many connecting lines and various symbols, we are going to cover the other symbols and what they stand for in the remaining sections. **As a rule of thumb, always refer to the Master Sheet that accompanies your employer's P & IDs when in doubt what something means or stand for.** Even before you seek help from someone else. Self-reliance is a very valuable and respectable attribute in industry. So strive for it, as long as you are not sacrificing safety in the name of self-reliance.

Figure 4.6 below shows Graphic Symbols for use on flow diagrams. It contains most of the smaller symbols you will see on a drawing of a process system. You should always make it a point that you are familiar with the symbols for the equipment in your work area. In case you come across a symbol you are not sure about, check the Legend. It is the master key to all the P & IDs. Chances are anyone you ask for help will refer to the Legend as well, if they are not sure about anything on the P & IDs. Note that in Figure 4.6 below, many symbols are similar. That should warn you that an extra line or slight difference between two symbols can mean a different type of equipment. So always look carefully and check the Legend if you are not sure exactly what kind of equipment is represented.

Figure 4.6 below is a sample of the Graphic Symbols for use on Flow Diagrams. This is not exhaustive as more information can always be obtained from the relevant Master Sheets at your establishment. Also note that some P & IDs may have differences in how they show specific pieces of equipment depending on company preferences. If anything is not clear, consult the Legend Sheets. If that doesn't help, ask your Supervisor.

Figure 4.6 - Graphic Symbols for Flow Diagrams

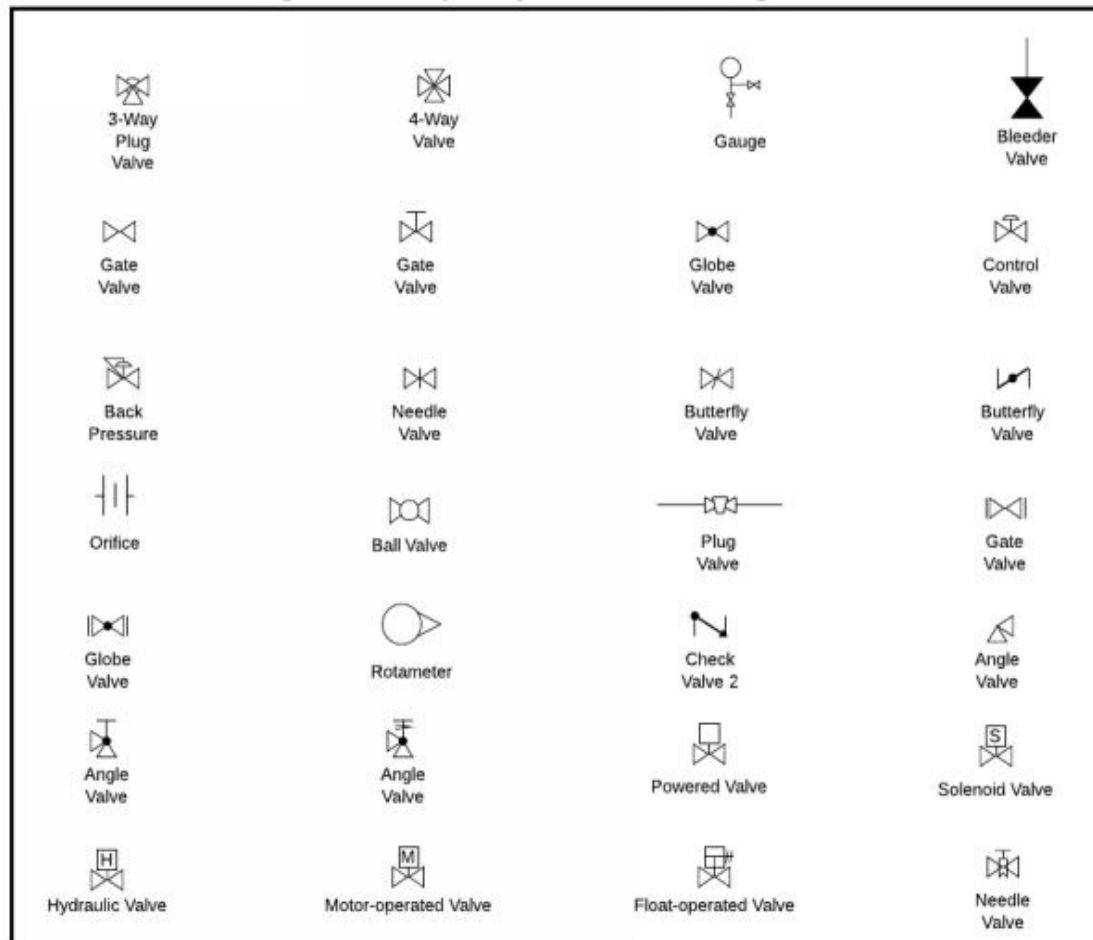


FIGURE 4.6 - GRAPHIC SYMBOLS FOR USE ON FLOW DIAGRAMS Figure 4.7 below is a sample of the Process Equipment Symbols. These are often some of the largest symbols that you will see on a P & ID. A more complete and relevant list of equipment symbols should be found on your company's Master Sheets.

Figure 4.7 - Process Equipment Symbols

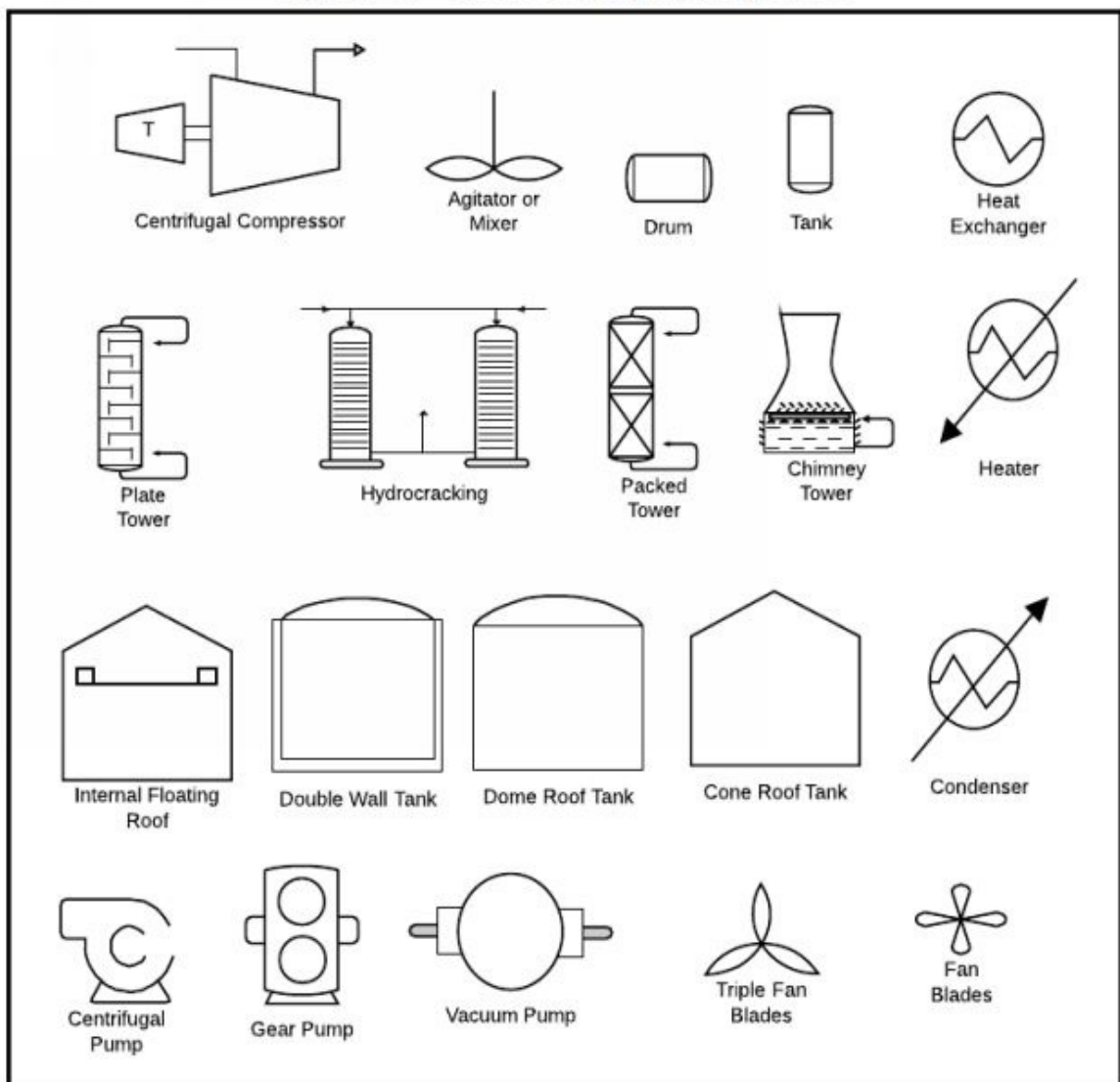


FIGURE 4.7 - PROCESS EQUIPMENT SYMBOLS

Chapter Review

The review questions are available at [ReviewQuestions.](#)

Chapter 5: The Symbols and Meanings for Common Items Found on a P & ID

Chapter Goals:

At the end of this Chapter, you should be able to:

- . Identify the symbols for selected vessels, heat exchangers, pumps, compressors and blowers, other equipment found on P & IDs, and piping
- ii. Interpret typical numbering systems used for labelling equipment on P & IDs
- iii. Refer yourself to the Master Sheet if you come across Graphic symbols that you are not familiar with

Vessels:

A vessel is a container that is used to store fluid. It may also alter the characteristics of the fluid during storage. The vessels category includes tanks, cylinders, bags, *etc.* At this point the expectation is you should now be able to tell what kind of equipment a symbol on a typical P & ID represents by using the Legend Sheets. I want you to note that equipment symbols usually contain an identification number.

At most sites, this identification number can tell you information about the equipment's location. It could be an area, building or even what floor in the building. Instead of me loading you with what might not apply in your case, I would rather recommend that you find out if your site equipment numbers are designed to give specific information about the piece of equipment. At the site where I work, equipment numbers are designed to give information on the area, system and function of the equipment.

An example of a special numbering system could be a tank in a Utilities area. Let's say the area number is 4700, and the tank is part of a system numbered as 037 (Water Treatment Plant). This information could appear on the P & IDs including the tank as shown and explained in Figure 5.1 – Special Numbering System Example:

Figure 5.1 - Special Numbering System Example

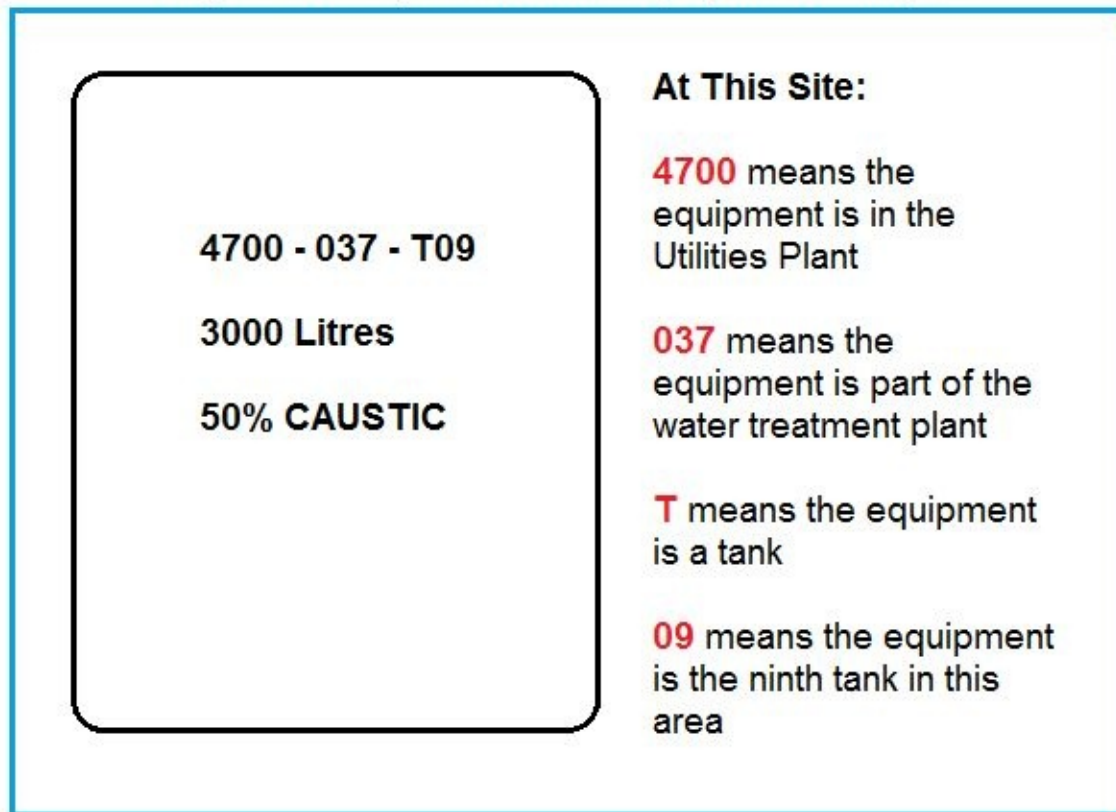


FIGURE 5.1 - SPECIAL NUMBERING SYSTEM EXAMPLE The P & IDs may show an additional number that appears on the real tank on the site as well as an identification number. Frequently used abbreviations in equipment numbers are: T or TA – Tank

R – Reactor

H or EX – Heat Exchanger

CN – Condenser

P - Pump

Size and Shape of Vessels:

Vessels come in many sizes and shapes. We use vessels to hold process liquids, gases or solids. Do not expect every vessel symbol to look similar to the actual equipment even though many do. Symbols for tanks and reactors on a P & ID have a shape that tells you of the real equipment in the field. These are usually

the large symbols on a P & ID. Also note that the main drawing does not show symbols drawn to scale, even though the relative size is shown. More specific information about a vessel is given under Equipment Descriptions. This is information such as actual size or capacity of the vessel.

Vessels Associated Equipment worth mentioning:

An **agitator** is a piece of equipment that is often associated with vessels. I felt it was necessary to mention it in this section because of that. An agitator agitates or mixes material contained in a vessel. The symbol below in Figure 5.2 shows a Mixing Reactor that includes an agitator. Agitators will normally have their own identification numbers and may be covered in the equipment descriptions as well. In some cases, even the agitator motor may have a separate equipment number.

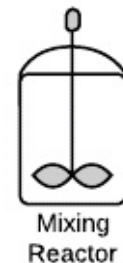


Figure 5.2 - Mixing Reactor with agitator

FIGURE 5.2 - MIXING REACTOR WITH AGITATOR Any important pieces of equipment and connections that are attached to the vessel will be shown on the symbol for the vessel. For example, nozzles on a vessel will be shown on a P & ID vessel symbol near their actual position on the real tank. Most nozzles are round because they connect to pipes. The diameter of each nozzle may be given near its symbol. If no size is shown, the nozzle generally is the same size as the pipe attached to it. Below, Figure 5.3 – Connections on a Vessel (Nozzles), shows what I am talking about: **Figure 5.3 - Connections On VESSELS (Nozzles)**

Figure 5.3 - Connections On A Vessel (Nozzles)

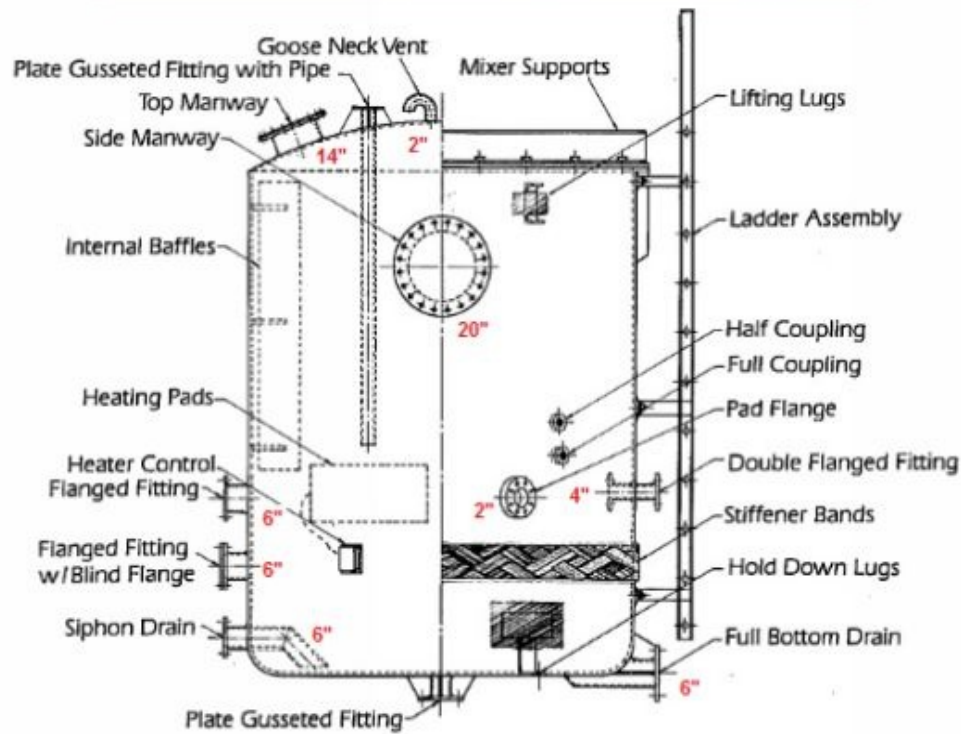


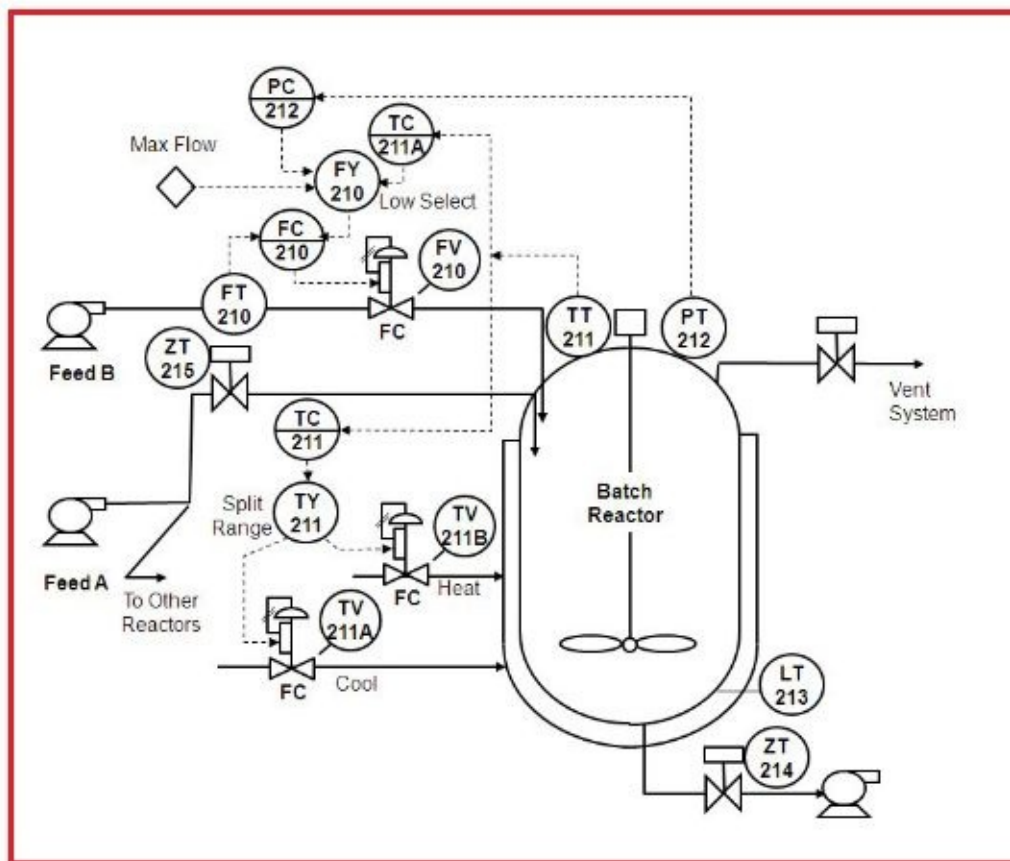
FIGURE 5.3 - CONNECTIONS ON VESSELS (NOZZLES) You are going to encounter variations of tank symbols on different P & IDs. Some P and IDs use symbols like the ones shown below for Vessels, Figure 5.4. In addition to the information you can obtain about a vessel from the identification numbers and the equipment descriptions, the P & ID will show you:

- . The equipment that is attached to the tank such as Nozzles
- . The locations where material comes into and out of the tank
- . The Control Loop(s) for the material coming into and out of the tank and how they control the material
- . How Process Variables such as temperature, pressure, flow, level, density, etc. for the tank are controlled

Figure 5.2 shows a Mixing Reactor. Reactors are a form of a vessel. **They are designed to contain processes that cause chemical change in one or more substances.** As you can see from Figure 5.2, the symbol for a reactor looks like

a tank. Reactors are normally made of special materials that can withstand the pressure and temperature of the chemical reaction. Reactors on P & IDs will often have numerous pieces of additional equipment associated with them for monitoring and controlling the process reaction. Figure 5.4 below shows a typical reactor and its control loops:

Figure 5.4 - Typical Reactor and its Control Loops

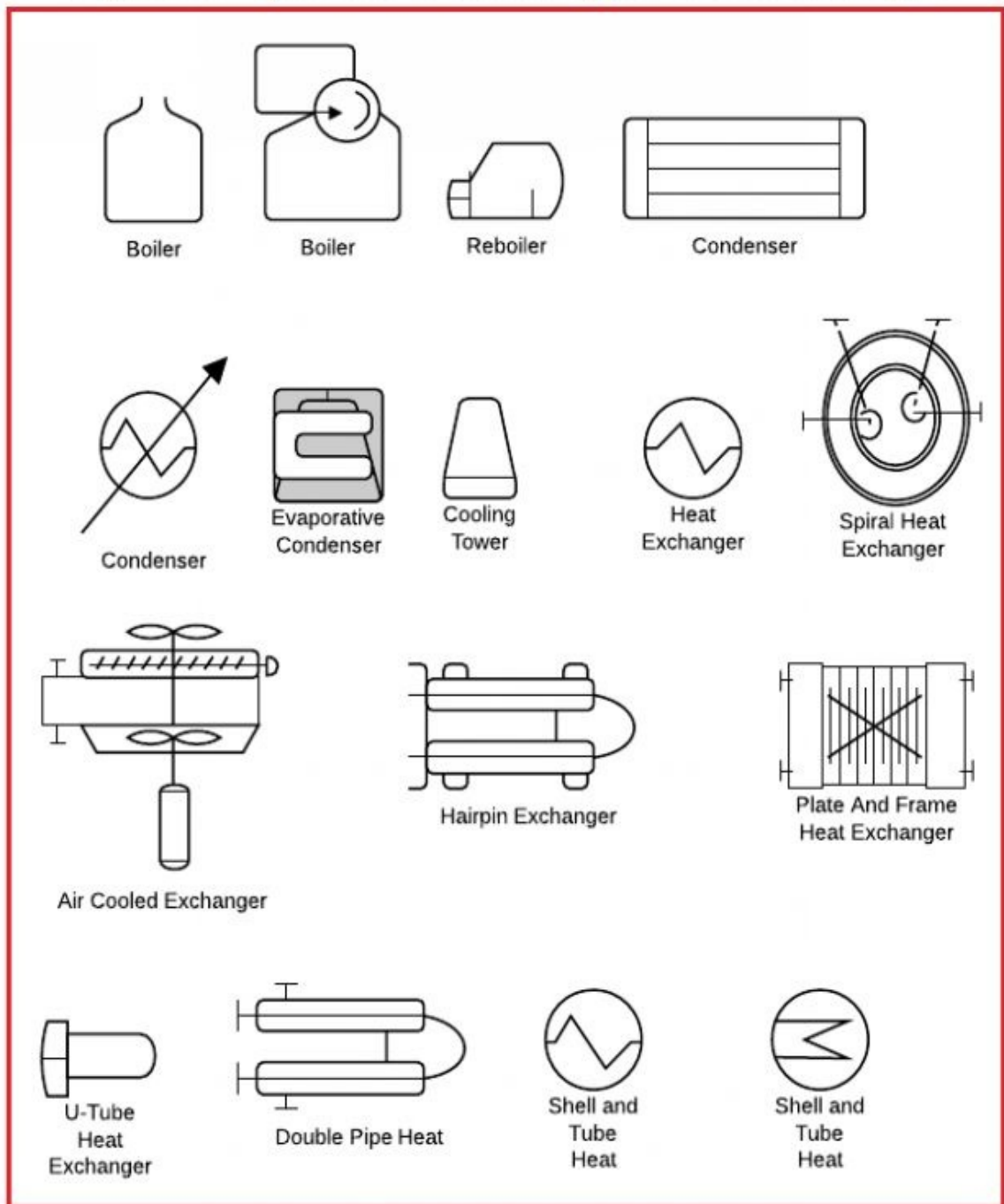


Besides the agitator and several nozzles, **instrument control loops** monitor pressure, flow, temperature and valve positions. The vessel has an **insulated jacket** around it.

Distillation columns are another type of vessel you will most likely find in chemical plants. The symbols for different types of distillation columns show parts that represent trays and columns with packing.

Heat Exchangers:

Figure 5.5 - Symbols For Various Types of Heat Exchangers



A heat exchanger is a device that is designed to efficiently transfer heat from

different areas or mediums. This category includes boilers, condensers, and other heat exchangers. In other words heat exchangers are frequently used in process systems to heat or cool materials. Heat exchangers may be connected to vessels, for example. Figure 5.5 above shows the various symbols for various types of heat exchangers. Heat Exchangers that are designed to cool materials are sometimes called coolers or condensers. The ones that heat materials may be called vaporizers or heaters.

Tracing Material Flow through a Heat Exchanger:

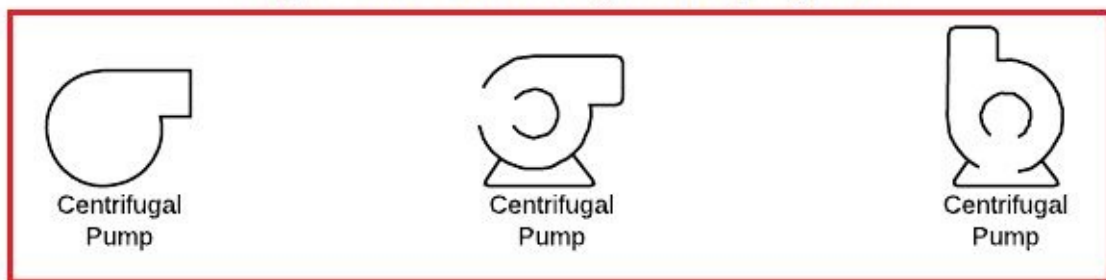
The P & ID will show you the location where the material to be heated or cooled flows into and out of a Heat Exchanger. It will also show you where the heat transfer medium flows into and out of the heat exchanger. If the function of the equipment is to cool the material. Then expect the material coming out to be cooler than when it went in. If the function of the equipment is to heat the material, expect the material to be warmer coming out than when it went in. You may be able to find additional information about specific Heat Exchangers on a P & ID from the Equipment Descriptions.

Pumps:

Pumps are devices that use suction or pressure to raise, compress, or move liquids in and out of other objects. One could simply say pumps move liquids. The equipment used to move gases on the other hand is called a **compressor**. In this course we will look at three different types of pumps, namely: Centrifugal Pump, Rotary, Gear, or Positive Displacement Pump, and a Vacuum Pump. One thing for certain is that pumps use energy to move the liquids.

Centrifugal Pump:

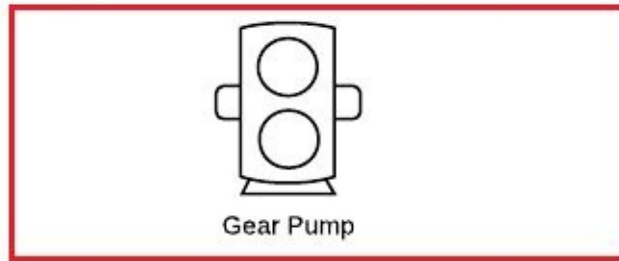
Figure 5.6 - Centrifugal Pump Symbol



Centrifugal Pumps are very common because they have a relatively low cost and require low maintenance. The basic shape of this symbol suggests the impeller of an actual centrifugal pump. The Centrifugal Pump uses the impeller to move liquids. The impeller and shaft are the rotating parts of the pump that converts driver energy into Kinetic Energy.

Rotary, Gear, or Positive Displacement Pump:

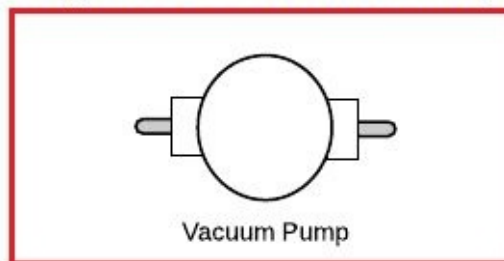
Figure 5.7 - Gear Pump Symbol



The symbol for this pump suggests the two gears that are important parts in this pump. A gear pump uses the meshing of gears to pump fluid by displacement. They are one of the most common types of pumps for hydraulic fluid power applications. Gear pumps are also widely used in chemical installations to pump high viscosity fluids.

Vacuum Pump:

Figure 5.8 - Vacuum Pump



This pump is used to create a vacuum (sub-atmospheric pressure) on its inlet side. It does this by removing gas molecules from a sealed volume in order to leave behind a partial vacuum.

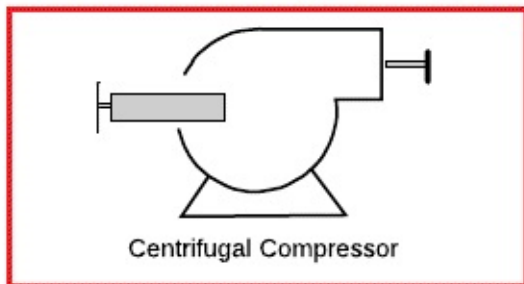
Tracing Flow Though Pumps:

Arrows indicate the direction of flow in piping shown on P & IDs. Using the direction of these arrows, you should be able to tell where material enters and exits the pump. As for pump identification numbers, these may be identified by a number similar to those used for other pieces of equipment such as tanks. As I promised you, there is no rocket science with reading P & IDs!

Compressors:

The equipment that uses energy to move a gas is called a compressor or a blower. The name comes from the way the equipment compresses the gas to a higher discharge pressure. Some compressor symbols are similar to pump symbols. That is for a reason. This is because certain pumps and certain compressors work in a similar way. Below, we will look at three examples in Figure 5.9 namely, Centrifugal Compressor, Rotary Compressor, and Blower:

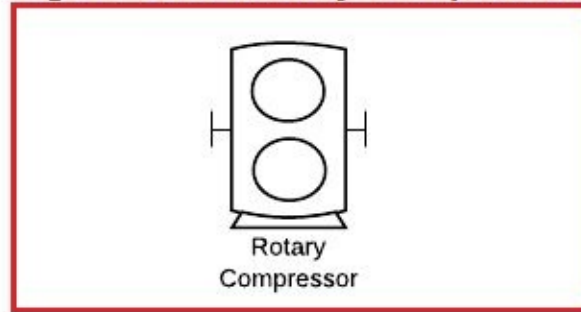
Figure 5.9 - Centrifugal Compressor



In a Centrifugal Compressor, Kinetic Energy is imparted to the air by the rotating impeller. The air enters from the center of the impeller, and is guided outward through the periphery by guide blades. That way the pressure of the air is increased in a Centrifugal Compressor.

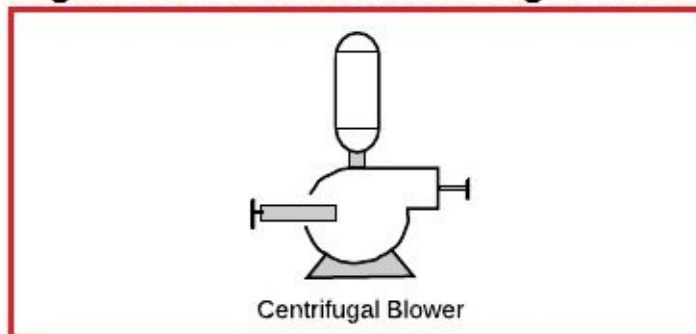
In Figure 5.10 is a Rotary Compressor symbol. In a typical rotary air compressor there will be two interlocking helical rotors contained in a housing. Air enters through an inlet valve and is then taken into the space between the rotors. As the screws turn, they reduce the volume of the air, thus increasing the pressure – which we call Compression.

Figure 5.10 - Rotary Compressor



The Blower basically blows air. Some call it a Centrifugal Fan or Centrifugal Blower. This is mechanical device for moving air or other gases. The terms **Blower** and **Squirrel Cage Fan** (because it looks like a hamster wheel), are frequently used interchangeably. These fans increase the speed and volume of an air stream with the rotating impellers. Figure 5.11 below shows the symbol

Figure 5.11 - Blower/Centrifugal Blower



for a Blower:

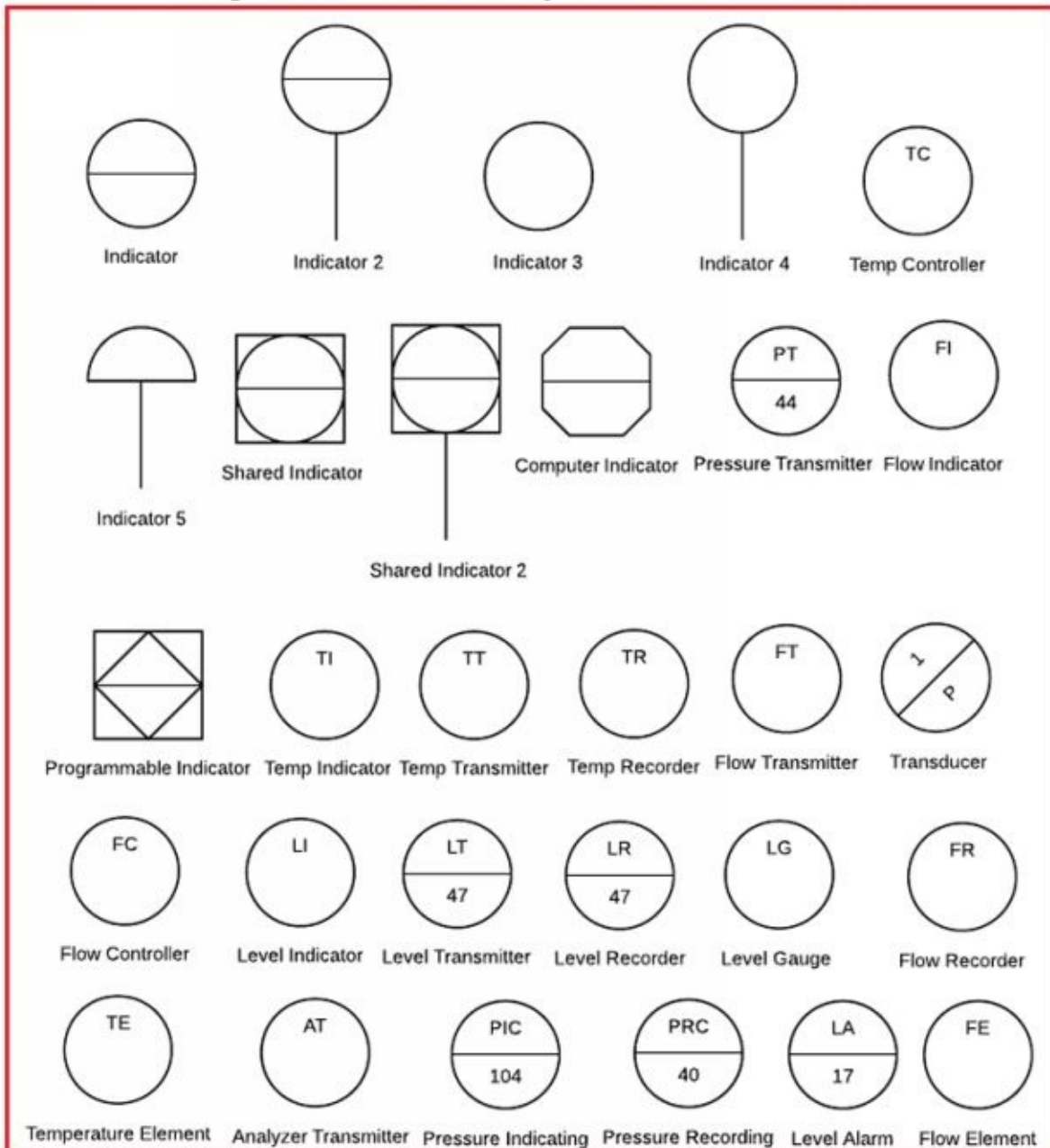
Tracing Flow through Compressors and Blowers:

You can trace the direction of flow for Compressors and Blowers the same way you do for pumps. Pumps and Compressors are crucial pieces of the process equipment that will require service or replacement. Similar to other pieces of equipment such as Tanks and Reactors, Pumps and Compressors may be identified by a number. All pipes that connect to equipment of this nature will be shown on P & IDs.

Instruments:

An Instrument is a device that measures, and sometimes controls measurable quantities such as flow, level, pressure, temperature, angle, density etc. The Instruments group will consist of Indicators, Transmitters, Recorders, Controllers, and Elements. Figure 5.12 shows typical instrument symbols found on some P & IDs:

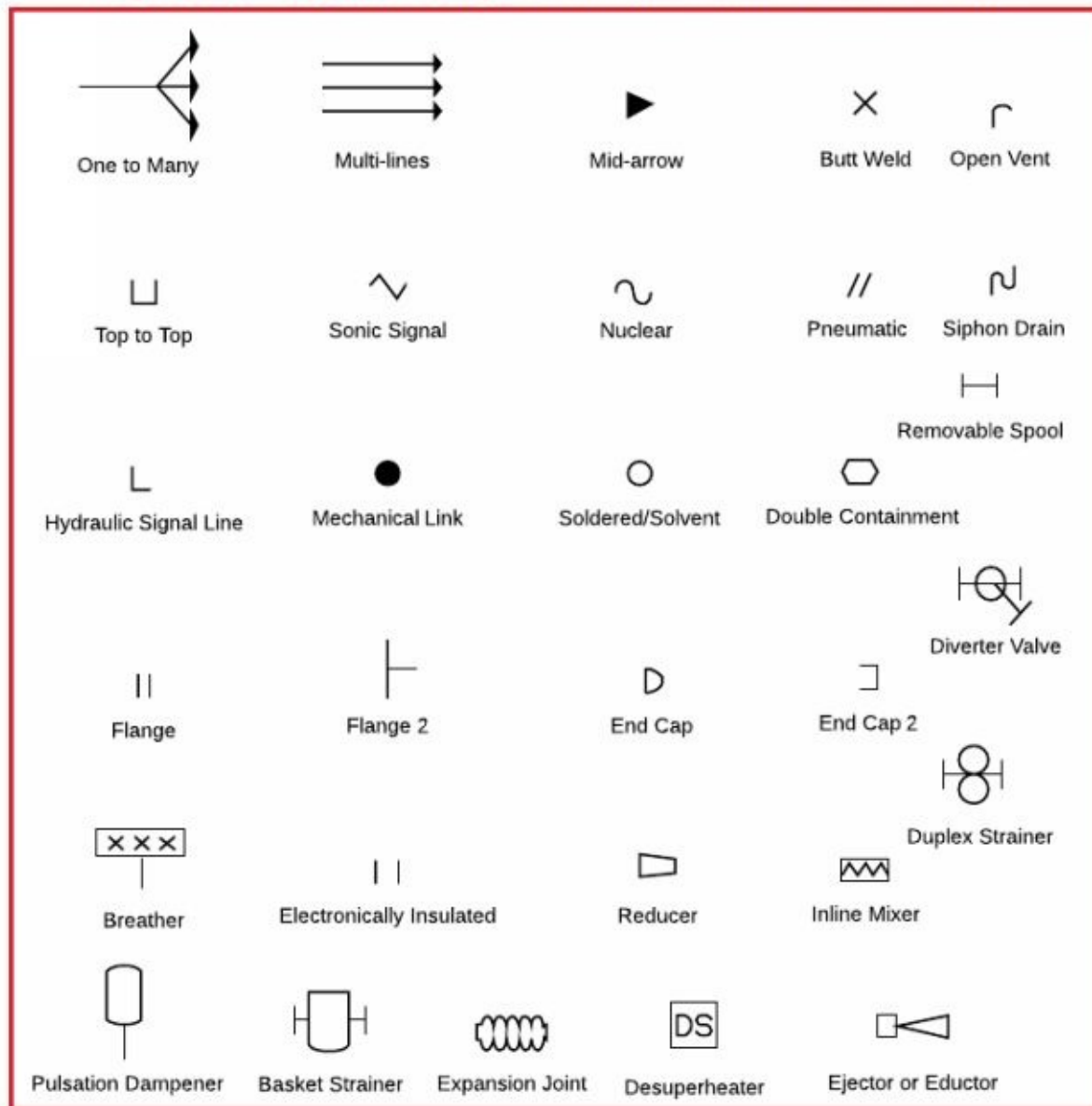
Figure 5.12 - Instrument Symbols on Some P & IDs



Piping:

A pipe is a tube that transports fluid substances. Piping can be made of various materials, including metals and plastics. Figure 5.13 shows typical piping equipment you could find on some P & IDs:

Figure 5.13 - Typical Piping Equipment Found on Some P & IDs

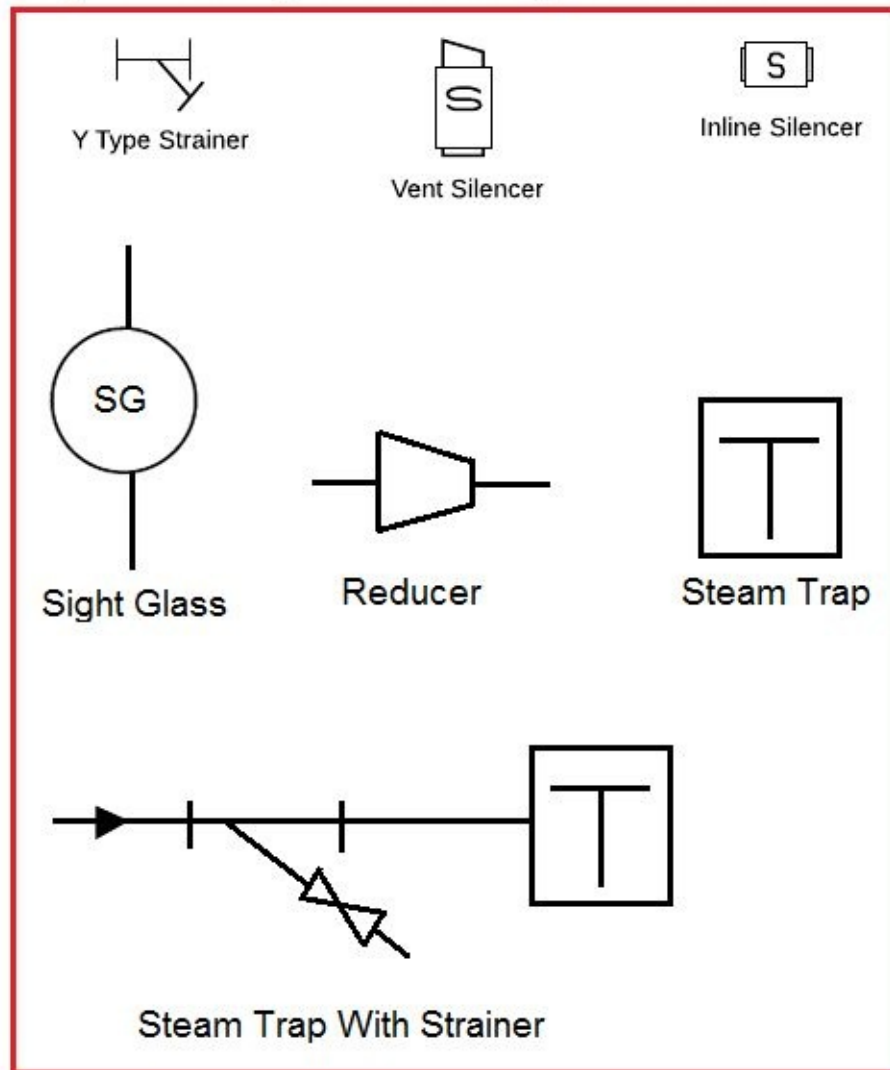


Other Symbols of Equipment Found on a P & ID:

In this reading P & IDs made easy course, we could never cover all the types of symbols that you will come across in your career. The best approach I'm using is to equip you with enough knowledge so you will know what to do when you run into unclear symbols or information: **Always consult your Master Sheets, and if you still have questions, then consider approaching your Supervisor or a subject matter expert.** The examples I try to give you are the common ones so that you can be ready for most P & IDS.

In this section we will look at some common fittings that I think you will most likely come across. Fittings are smaller pieces of equipment in a piping system. You will see them often during your entire career. Examples of the fittings commonly found on piping are strainers, sight glasses, and pipe size reducers. Figure 5.14 shows the typical P & ID symbols for these fittings, including Steam

Figure 5.14 - Symbols Of Fittings On Some P & IDs



Traps:

Steam Traps:

Above, in Figure 5.14 there are symbols for Steam Traps. Steam Traps are devices used to discharge condensate and non-condensable gases with a negligible consumption or loss of live steam. Most Steam Traps are nothing more than automatic valves. That is they open, close or modulate automatically.

You will likely find Steam Traps around steam piping, heat exchangers or heating coils. Steam Traps allow condensate to be released from the steam system while keeping the steam pressure up. Sometimes a Strainer is installed in the line in front of the trap to keep dirt, or scale from clogging the trap.

Chapter Review:

The review questions are available at [ReviewQuestions.](#)

Chapter 6: Valves in Control Loops and Primary Flow Elements as Parts of a P & ID

Chapter Goals:

At the end of this Chapter, you should be able to:

- I. Explain why Valves are an integral part of most of the Control Loops in a plant
- II. Describe how Valves are controlled
- III. State and explain Valve Actuator types
- IV. Identify Automatic Valve Fail Position from a P & ID symbol
- V. Identify Valve Actuator symbols typically used on P & IDs
- VI. Identify symbols for primary flow elements on a P & ID
- VII. Be aware of Transducers and what they do
- VIII. Explain why are Valves, instruments and Control Loops important

Valves and their role in the Plant:

In your plant, material will flow between pieces of equipment such as tanks and heat exchangers. This flow needs to be controlled if we are to stay in control of production and produce a consistent quality of product(s). **Valves are the equipment that controls this flow between equipment.** We say the valve is a Final Control Element. A Final Control Element is defined as a mechanical device that physically changes a process in response to a change in control system set point. Valves are not the only Final Control Elements relevant to actuators. The other Final Control Elements could be dampers, gates, burner tilts, and fluid couplings, *etc.*

Valves are always attached to at least one pipe and usually to two. One at each side. As we have shown before in this course, there are many different types of valves. We will mention them time and again in this course just to help refresh your memory. Common types of valves are ball, globe, check, diaphragm, plug or cock, back pressure control, and solenoid valves.

Valve Identification Numbers:

Currently, North America is the largest market in terms of valves consumption, while Asia leads in growth rate. With this growth, valve users continue to be challenged with properly identifying an increasing number of valves for repair, maintenance and validation requirements.

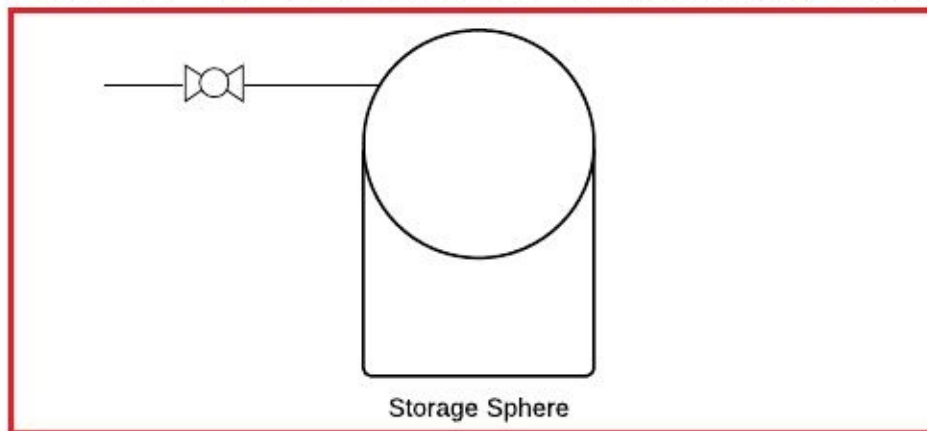
At refineries, for example, there may be hundreds of control valves and a few thousand manual valves in complex units and off-site configurations. There are many types of valves that need ongoing repairs and maintenance, including solenoid, gate, plug, check, butterfly, pinch, diaphragm, ball, globe, *etc.* Proper identification of these valves is a must if errors are to be avoided. Industry uses valve tags for identification purposes.

Valve tag placement is not explicitly required by the [American Society of Mechanical Engineers](#) (ASME) or the [American National Standards Institute](#) (ANSI). What both codes require is the proper marking of a piping system. Valves are a part of a piping system, and the code is generally interpreted to mean that valves must also be properly labeled.

The tag itself should identify the valve, usually by showing the valve number. The type of valve and the system the valve is part of, are typically identified as well. **The type of valve is specified based on its function—not the design of the valve.** For example, the valve tag might read “**1300-MV-1747**”. This identifies the valve as **Manual Valve** number **1747** in the **1300** system line. Sometimes manually operated valves are identified by a circle containing a number and the letter “V” or “HV”.

Figure 6.1 below shows a ball valve drawn on a line that goes into a spherical tank. Note that valve symbols may be drawn in any position on a line. What matters is that the valve symbol is correctly depicted. For instance, in this case the valve is a “Ball Valve”.

Figure 6.1 - Ball Valve on a Pipe Line into a Storage Tank



How are Valves Controlled?

The valves on the P & IDs are all controlled by either of two means. Control can either be manual or automatic. When you look at the P & IDs, this is information that you will be able to read from the drawing. For manual valves, they would be drawn simply as the valve symbol for its type on a P & ID. No actuator will be shown. Figure 6.2 shows 3 manual valves, namely Globe, Gate and Ball valves. We know they are all manual valves because no actuator is shown connected to them. An actuator is the part that controls (moves) the valve.

Figure 6.2 - Showing 3 Manual Valves, namely Globe, Gate, and Ball Valves



For automatic control, there must be an actuator to move the valve to the desired position. In my experience, most symbols for automatically controlled valves will usually show the actuator as a square. There are always exceptions to many things in life. The exception with square symbols for actuators is the pneumatic actuator. This one has a semi-circle on top of the valve stem.

The symbols for five actuator types for controlling automatic valves are shown below in Figure 6.3. In the drawings, the square part above the valve is the part that represents the **Actuator**. This square part also tells you how the actuator operates. Five ways of actuator operation shown below are; Solenoid, Pneumatic Diaphragm, Piston, Hydraulic Piston, and Electric Motor actuators.

Figure 6.3 - Valve Actuator Symbols

Solenoid Actuated Valve - The valve will open and close when an electric signal is sent to the actuator. The solenoid works by opening or blocking a pneumatic or hydraulic line that goes to provide the motive power to actuate the valve	
Pneumatic Diaphragm Valve - An air signal, referred most commonly as a pneumatic signal, actuates the valve. What actually does the actuation is a diaphragm connected to the valve, that is in turn controlled by the air signal	
Piston Actuated Valve - The Valve is also actuated by a pneumatic (air) signal, except it has a piston in the place of a diaphragm. That differentiates it from the Pneumatic Diaphragm Valve	
Hydraulic Piston Actuated Valve - This Valve is actuated using a control signal carried by Hydraulic Fluid instead of air. This is normally used for applications where a lot of power is required to move the valve	
Electric Motor Actuated Valve - The Valve is controlled by an Electric Motor. Some kind of gear system will be involved, but the electric motor provides the motive force	

Identify Automatic Valve Fail Position from a P & ID symbol:

Automatic Valves will at some point during their operation, fail. Control valves may fail in various positions namely; **open, closed, locked, or indeterminate**. The position of a failed valve can have a significant impact to the process and associated equipment. Consequently, it is of great interest to operations personnel.

Valve fail action often is discussed and agreed upon during P&ID review meetings. It is natural and efficient for Engineering to document the agreed-upon action on the 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

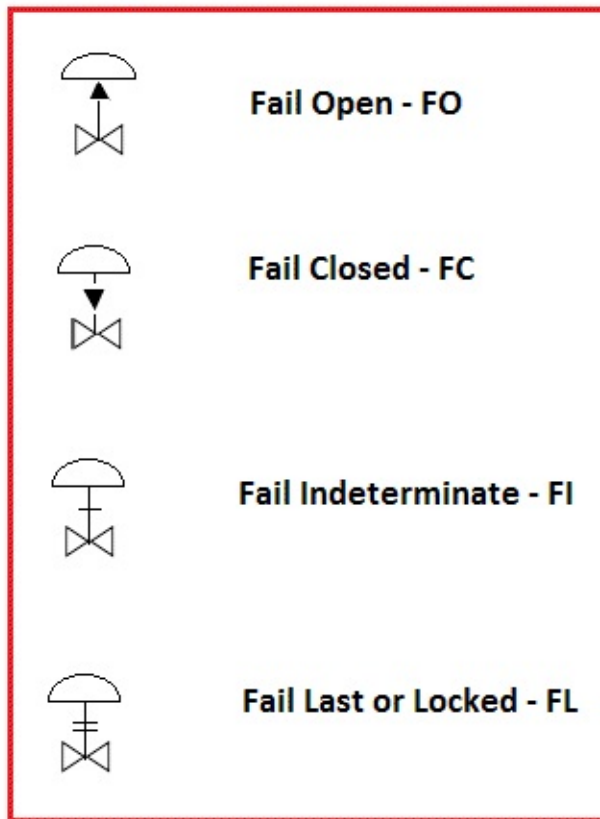
"Power" medium is instrument air. **Power does not refer to the signal, unless the signal is the medium that moves the actuator.**

The fail positions may be identified on the P&ID using letters below the valve symbol:

- I. **FO** for Fail Open
- II. **FC** for Fail Closed
- III. **FL** for Fail Last or Locked
- IV. **FI** for Fail Indeterminate

There is another method of indicating the fail position of control valves. Looking at Figure 6.4 below, **an arrow up signifies the valve fails open. An arrow down indicates the valve fails 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. From now on when you see **FO, FC, FL, or FI** on a P & ID automatic valve, you know what it stands for and what it means. If you forget, just come back to this section. Figure 6.4 shows exactly what we just discussed in this section:

Figure 6.4 - Symbols For Control Valve Fail Positions



The four ways valves will fail can be put in a word for easy remembering: **COIL**. That stands for closed, open, indeterminate, and last.

Primary flow elements on a P & ID:

Primary flow elements are the sensors that sense the flow in the process. There are various ways flow sensors work with pros and cons for each application. What we will discuss here is the symbology you will likely see on P & IDs. These symbols are nothing more than graphic illustrations that complement the control bubbles to help readers of the drawing more easily identify the type of flow element being used. The most common types are shown in Figure 6.5 – Primary Flow Elements.

Figure 6.5 - Primary Flow Elements

	ORIFICE PLATE WITH FLANGE PIPE TAPS OR VENA CONTRACTA		ORIFICE PLATE IN QUICK-CHANGE FITTING		AVERAGING PITOT TUBE
	TURBINE OR PROPELLER TYPE		PITOT TUBE		POSITIVE DISPLACEMENT
	VENTURI TUBE		ROTAMETER		VORTEX SENSOR
	FLOW NOZZLE		MAGNETIC		WEIR (V-NOTCH SHOWN)
	ULTRASONIC (DOPPLER)		CORIOLIS		FLUME
	TRANSIT TIME				

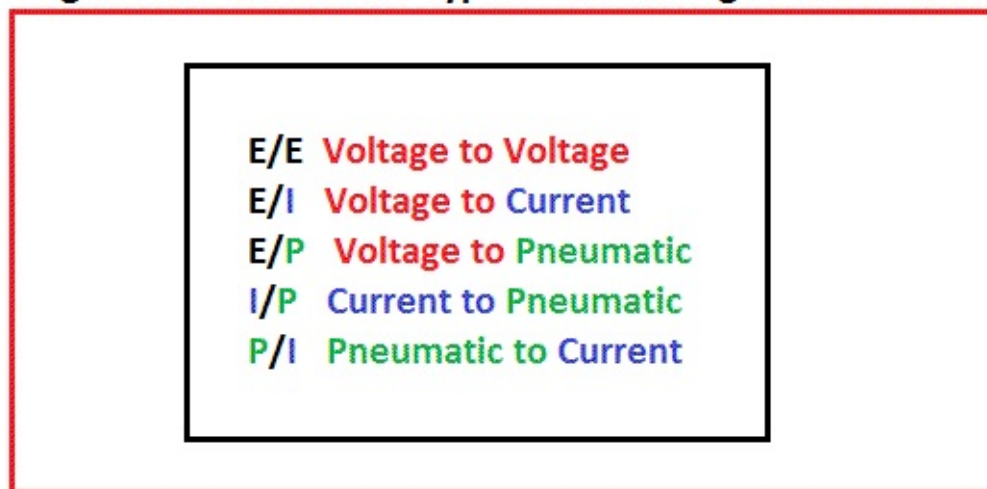
Transducer Functions:

When we talk and think about transducers, all we are doing is defining signal conversion. I think Electrical Engineers (EEs) are the nerds that get excited about this stuff, and we really do not need to focus too much on this as non EEs. As a matter of fact, I included it in this chapter as a last minute idea. I almost skipped it but I just know that if I did someone would ask. So I decided to get this out of the way before someone convinces you that you are missing a lot if you don't know a bit about this electrical stuff.

I will do exactly what you paid me to do - Simplify this thing for you. A transducer is something that takes a signal in one form and converts it into another form so that it can be used by a downstream device. Take for example, a control valve that needs air to actuate it. The signal that is sent from the controller to tell it to move may be electrical.

I hope you see that we have a problem here. The controller is speaking electrical signal language and the valve on the other hand speaks pneumatic signal language. For the two to communicate they need some form of an interpreter who can convert the electrical signal language into the pneumatic signal language so the valve can know what it's required to do. **The interpreter is the signal transducer.** There are various types for signal transducers and are named according to the types of signals that they convert. See Figure 6.6 below for the

Figure 6.6 - Transducer Types Based on Signal Conversion



details:

In the valve situation that I mentioned above, an I/P (current to pneumatic) transducer would be necessary so that the valve can be positioned to any desired position with an electrical signal from the controller. This is the most common transducer function used in many plants. The others listed in Figure 6.6 are comparatively rare. There you are, you can Master it and fast track your way to Master Ninja in P & ID Reading.

Why are Valves, Instruments and Control Loops important?

Valves, as we mentioned in this chapter, form a constituent part of Control Loops because they are a final control element (FCE). Whatever the control loop decides to do, the action is done through actuating the FCE. In most cases it is the valve, even though the valve is not the only FCE. Maintaining safe operations is extremely important. Control Loops do a good job in making sure we do this automatically. We need control loops to:

- I. Maintain Process Variables (PVs) within safe operating limits
- II. Monitor and detect potentially dangerous situations as they develop
- II. Initiates alarms to alert the Operators of conditions getting out of desired ranges
- V. Shut down the process if certain defined conditions exist

So in order to maintain plant process operations within safe limits, the control loops monitor the process variables using instruments. It's like the instruments are the feelers and the advisors to the control loops of what is going on in the process. With that information the control loop will decide what action is needed, if at all. If action needs to be taken, the control loop will command the final control element to do something in the process. Therefore, we can say the control loop is the Master, and the instruments and the final control elements are the slaves.

A process variable is a physical characteristic of a process that can change. Hence the need to monitor it and provide a means to force it back to where we want it in the system. Thus control loops help to ensure that a product meets specified quality standards and cost objectives. **The P & IDs for an area will show the lines, valves, instruments, and equipment that monitors and controls each process.** Do you now see why knowing how to read P & IDs means you get significant insights into how your process operates? In the next chapter we talk about Line Designations on a P & ID. At this stage, we have covered more than half this course.

What about Pipe fittings?

In case you are wondering (you probably were), pipe fittings are generally not shown on P & IDs. When we talk of pipe fittings, we mean fittings such as elbows, tees, unions, Victaulic couplings, *etc.* They will not include all the various flanged connections that might actually exist in the plant. These are details that show up on Piping Plans/Sections, Isometrics and Fabrication Drawings. So, unless it is important to the Process Design for some reason, fittings and extraneous flanged connection are generally not shown. If you need to get a fitting take-off, look elsewhere! Figure 6.7 reminds us that we shouldn't expect to find fittings information from P & IDs:

Figure 6.7 - Generally Fittings Are Not Shown on P & IDs



Chapter Review:

The review questions are available at [ReviewQuestions.](#)

Chapter 7: Line Designations on a P & ID

Chapter Goals:

At the end of this chapter, you should be able to:

- I. Easily identify piping on P & IDs
- II. Read specific information on a P & ID about a pipeline mainly the material in the line, size of the pipe, line number, and whether or not the line is insulated or heat traced
- III. Identify signal lines for major process piping, minor/instrument piping, electrical signals, capillary tubing, software or data link, mechanical link, pneumatic signal, hydraulic signal, guided wave and unguided wave

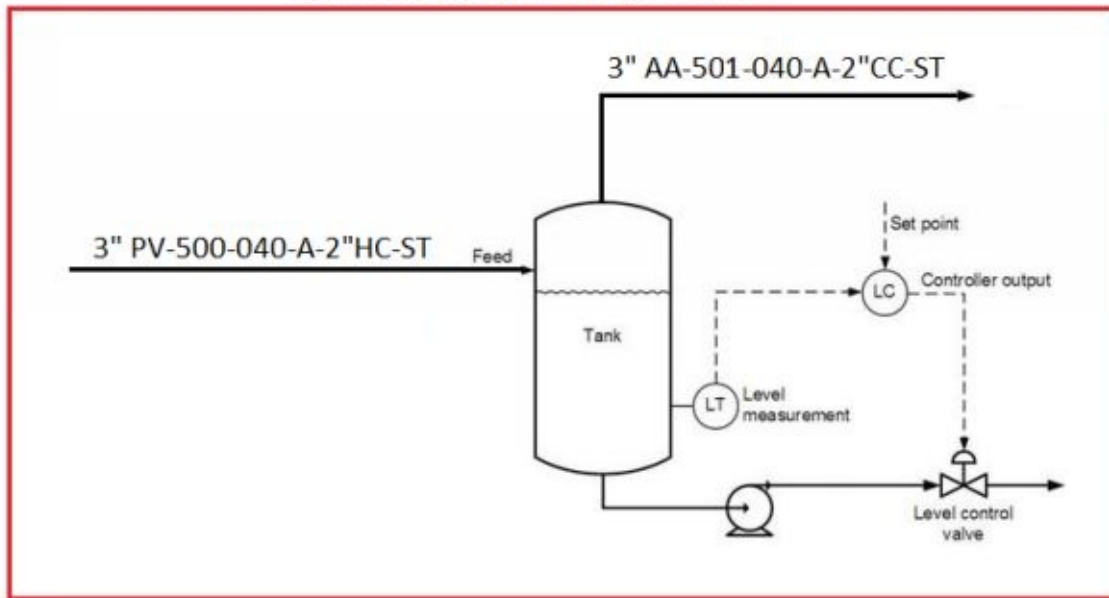
Understanding Piping information on a P & ID:

We have gone quite some ways regarding symbols and designations for equipment and instruments. For piping on a P & ID, equipment symbols will be connected with numerous drawn lines that represent piping and instrument lines. In previous sections we discussed how information is given in the main diagram that show lines that are physically connected and those that are not physically connected. We also spoke about how arrows show flow direction. If you want to refresh your memory about pipelines, please go back to previous units and review the material. That will help to reinforce the material into your brain.

We also talked about how specific information for each pipe may be given in the Line Schedule. Some information will be in the main diagram to identify each pipeline. Remember that pipelines are drawn as a solid line on a P& ID. Figure 7.1 below shows several pipelines, including one that feeds on the side of the tank. We will use this line as a Line Numbering example for this section.

Line Label Example:

Figure 7.1 Line Numbering Example



A typical Line Number aka, Line Label or Line Designation would be as shown on the line that goes into the tank from the side, labelled **3"PV-500-040-A-2"HC-ST**. In this example, the constituent parameters mean the following: 3" is the nominal diameter of the line

PV is the Service Classification

500 is the Line Number

040 is the Pipe Schedule

A is the ANSI Pressure Rating

2"HC = Coating or Insulation thickness and function. This example shows 2" insulation for the purpose of heat conservation. Other examples might be CC for cold conservation, FP for fire protection or PS for personnel safety.

Some coatings might be C for cement lined pipe, F for fiberglass, G for galvanized, P for plastic. This is an optional item and is typically left off if there are no entries on it.

ST is the Type of heat tracing to be used. This example shows steam tracing as the type of heat tracing. Other examples might be ET for electrical heat tracing.

The line designation on a P & ID tells us the following information at the minimum:

- I. The size of the pipe
- II. Gives us the letters that stand for the material in the pipe
- III. Tells us an identifying number, usually associated with the pipe's point of origin, where it begins. This would be the numbers 500 and 501 in the lines in Figure 7.1 above.

Helpful Hints on Line Designations:

1. Each company follows its own set of rules when assigning line numbers and line designations. This section has general information related to numbering lines. The line number should be continuous from one piece of equipment to the next. This would not be applicable if the piping class does not change. One line number may indicate more than one line size but not more than one class. Whenever the piping class changes, a new line number should be assigned.
2. If the specification of a line changes downstream of a control valve or control station, a new line number with a lower piping class should be assigned downstream of the valve. The higher piping class should be carried through the control valve up to the outlet of the downstream block valve and downstream of the bypass valve.
3. If lines with different numbers and piping classifications join at a valve, the block valve should be given the higher class. This is to ensure that the valve provides safe shutoff without violating ANSI Classifications. Otherwise more work will be created to manage Spec Breaks at this joint, and the valve will not be good for the higher rated line.
4. Headers will have line numbers separate from each branch.
5. Short connections such as vents or drains can be included under the same valve number of the line from which it ties into.

Heat Trace and Insulation on a P & ID Explained:

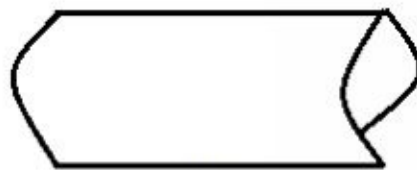
Pipes are sometimes covered and /or heat traced, especially in cold environments or anywhere just to avoid heat loss which would be an energy loss. As explained before, the Line Schedule information block will give you this information if that is the case. The type of heat trace used will be stated on the P & ID. A real life example of where heat tracing would be required would be a pipe carrying material that must be maintained at a certain temperature. Say Caustic which presents problems at or under 12 Deg C. This material would have to be heated to maintain a temperature higher than the atmospheric temperature if it is too close to 12 Deg C, or below. The material may be heated with an electrical coil, a steam jacket, or an oil jacket. Figure 7.2 shows how that would be shown symbolically on a P & ID.

Figure 7.2 - Heat Tracing and Insulation



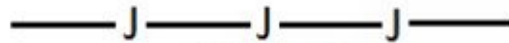
(S)

Steam Traced & Insulated



(E)

Electrically Traced & Insulated



Oil Jacketed

Instrument Lines on a P & ID made easy:

Chapter Review:

Chapter 8: Insights into How Process Operations are controlled

Chapter Goals:

At the end of this chapter, you should be able to:

- I. Show understanding of Control Loops on P & IDs
- II. Identifying and Explaining Functions of Instruments in a Control Loop
- III. Describe, from a P & ID of the process, how a Process Variable is measured and controlled
- IV. Describe and Explain what Interlocks are and how they work
- V. Understand Management of Changes for P & IDs

Understanding the importance of Control Loops on a P & ID:

Modern manufacturing and process industries are often largely run by Distributed Control Systems (DCSs), with minimal input from Operating Personnel. This has largely been made possible by the evolution of computer and controller hardware and software.

The basic building block of a Process Control System is the Process Control Loop. Process Control Loops use sensors, transmitters, calculations or algorithms, processing systems, and actuators or outputs. Their ultimate goal is to help a process run in a stable, predictable, consistent manner. Some common examples of process variables that are controlled by Control Loops include tank levels, liquid flows, air temperatures, and steam pressures.

Control Loops are sometimes called Instrument Control Loops. They are needed for the safe and efficient operation of a process. Instruments perform the following functions:

1. Instruments monitor process variables
2. Instruments inform the Process Operator what is going on in a process
3. Instruments allow the control of a process

A large industrial processing facility, like an oil refinery or paper mill, utilizes thousands of process control loops. This type of facility also typically utilizes a Data Historian to store data related to their control system or systems, plus other significant data. This data contains a wealth of information that can be used as a powerful troubleshooting or optimization tool. The trick is knowing how to use it.

Tables on the Mastersheet give the meaning of the abbreviations commonly used for the different types of instruments. Instruments in the same control loop will all have the same identification number. Different types of lines across the circle give us information about the location of each device. An instrument in a control loop may actually be located a considerable distance away from where a variable is measured even though it is shown on the same P & ID.

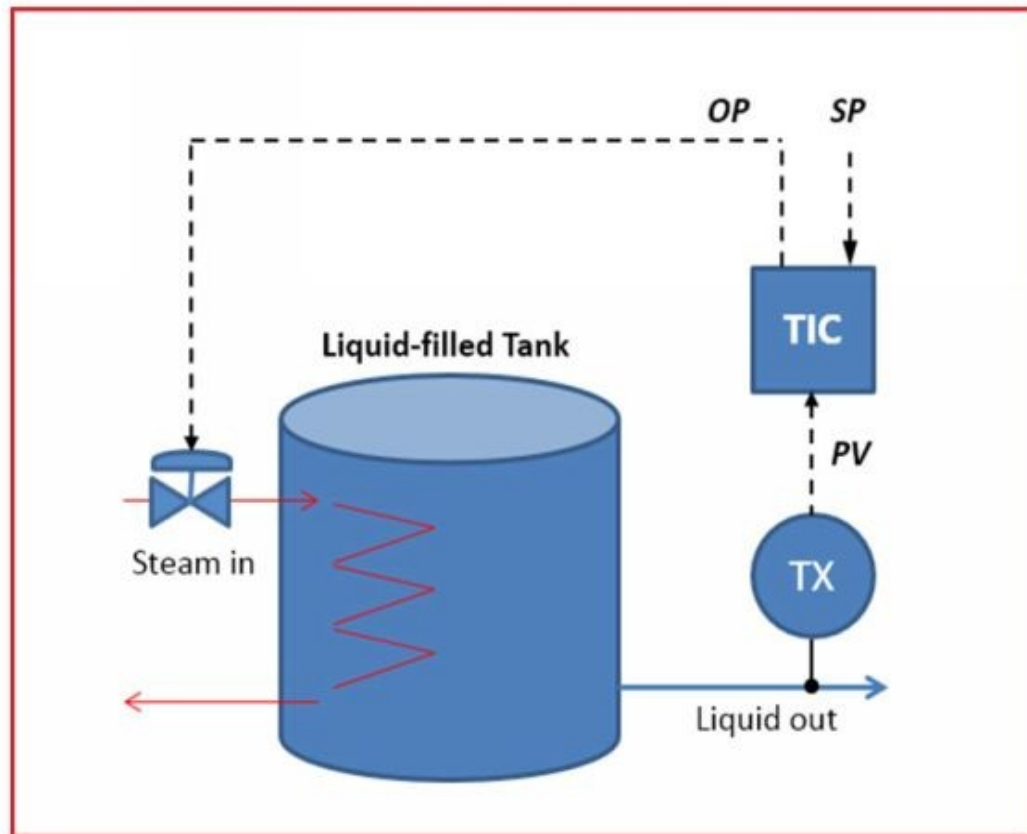
What is a Process Control Loop?

A Process Control Loop is a process management system designed to maintain a process variable at a desired set point. Each step in the loop works in conjunction with the others to manage the system. A basic Control Loop will have a Process Input, a Process Output, a Setpoint, and a Controller. Below is an explanation of what these terms mean;

- I. Process Input - An outside variable that affects a process. In a control loop, you must be able to control and manipulate this variable. For example, the steam flow into a tank (provides the heat to the steam heater shown within the tank) could be the process input in a control loop controlling the fluid temperature out of a tank. (Note that the process input is sometimes referred to as the “input variable.”)
- II. Process Output - A characteristic of the process that affects the outside world. In a process control loop, this must be measurable and vary in a consistent way with the process input. In the tank temperature control example, the temperature of the fluid exiting the tank would be the process output. (The process output is sometimes referred to as the “output variable.”)
- III. Setpoint - The desired value for the process output. In the tank example, this is the desired temperature of the fluid.
- IV. Controller - The hardware and software which compares the measured process output to the Setpoint, and calculates if the process input needs to change and by how much. The controller then sends a signal to an actuator to make an adjustment to the process input, if necessary. In the tank temperature control loop example below in Figure 8.1, this could be an actuator on a control valve on the steam line to the tank.

Describe, from a P & ID of the process, how a Process Variable is measured and controlled

Figure 8.1 - Tank Temperature Control Loop



The Temperature Indicating Controller (TIC) compares a Process Variable (PV) to a Setpoint (SP) value, and calculates and sends an Output (OP) signal to the steam flow Control Valve.

The process data associated with the tank temperature Control Loop above would include the following:

- I. **PV or MV** - The process variable or measured variable. This is the measured value of the process output – in this case, the temperature of the fluid exiting the tank. This value is transmitted from the sensor to the controller as an electronic signal as can be seen from the dashed line that connects the two.

- II. **SP** - The Setpoint value, is the desired value for the process variable (PV). The desired Setpoint value can be entered by an operator, or it can be calculated or based on a signal from an outside source depending on the control philosophy.
- II. **OP** – This is the output from the controller. The output signal is transmitted from the controller to an actuator to make an adjustment, if necessary, or it can be sent to another controller (this is out of the scope of this course). In this case the controller output would tell the steam valve to open or close depending on the desired temperature on the liquid out line. If the temperature was lower than the Setpoint, we would expect the controller to command the steam valve to open more and let in more steam to heat the product and raise the temperature, and vice versa.

Mode - This determines when and how a controller works. The three most common controller modes are Automatic, Manual, and Cascade.

In **Automatic mode**, the controller receives the Setpoint value (SP) and the measured value of the process variable (PV), and calculates and sends an output signal (OP) to the actuator.

In **Manual mode**, the controller is overridden, allowing Plant Operators to send the output signal (OP) directly to the actuator.

In **Cascade mode**, which is similar to Automatic mode, except the controller receives its Setpoint (SP) from an outside source, usually another controller. To help illustrate this concept, imagine in Figure 8.1 if the temperature controller sent an output (OP) signal to a steam flow controller instead of a valve actuator. The steam flow controller would receive a Setpoint (SP) from the temperature controller, plus a PV signal from a flow meter on the steam flow into the tank, and calculate and send an output signal (OP) to the actuator. This “Cascade” control strategy would improve the temperature control response because it would largely remove outside influences, such as variations in the steam supply or any control valve non-linearity. (Note that you should not worry too much about this stuff in this course.)

Identifying and Explaining Functions of Instruments in a Control Loop:

A typical control loop will have the following functional parts:

- I. Sensor
- II. Transmitter
- III. Switch
- IV. Alarm
- V. Controller

The function of an instrument is the work it does. A Control loop does not have to have all the parts listed above. For instance, in Figure 8.1 the control loop did not include a switch and an alarm. I will explain below the five parts of a Control Loop and show you where they fit in that loop.

- I. **Sensor** – The sensor is the part of the loop that first detects or measures the process variable. The sensor, which for a temperature control loop would be labelled TE for Temperature Element on P & IDs, may be separate or part of a transmitter.
- II. **Transmitter** – This is the part that will send out the information about the variable being measured. In Figure 8.1, TX is the Temperature transmitter.
- III. **Controller** – The transmitter sends information about the temperature of the product to the Controller. The controller is TIC In Figure 8.1. In this example, the controller sends a signal to the pneumatically operated diaphragm valve on the steam line. This valve physically controls the flow of steam in the line into the liquid filled tank.
- IV. **Switch** – In Figure 8.1, if we needed to be sure that the temperature of the product does not go above a certain point, a switch would do that job for us. A switch (TSH for Temperature Switch High) would be connected to the temperature transmitter. If the temperature of the product in the line exceeds a high set point, the switch will send a signal to the alarm, say TAH (Temperature Alarm High).
- V. **Alarm** – The alarm alerts us of the temperature reaching a certain Setpoint, high or low depending on the loop settings. The alarm may be visual, such as a red light, or audible, such as a buzzer or bell. For a high temperature alarm, it would have the designation TAH.

A P & ID will generally not give specific information about specific instrumentation. If you need more detailed information to perform a job, you should check other sources such as specification or data sheets. As a last option, ask your boss. Remember as well that the degree of detail provided on different P & IDs can vary. Control loops generally show only the functional logic of how information about a variable moves from one instrument to the next.

Mastering Interlocks for reading a P & ID:

An **interlock** is a feature that takes the state of two mechanisms or functions and makes them mutually dependent. It may be used to prevent undesired states and is very important to the safe operation of a Process System. It may consist of any electrical, electronic, or mechanical devices or systems. Therefore, we can say that **the function of an interlock is to isolate or shut down the system if a dangerous situation develops.**

In most applications, an interlock is used to help prevent a machine from hurting the operator, plant personnel or damaging itself by preventing one element from changing state due to the state of another element, and [vice versa](#). [For instance, elevators](#) are equipped with an **interlock** that prevents the moving elevator from opening its doors, and prevents the stationary elevator (with open doors) from moving.

Although both are [idiot proof](#) strategies, an **interlock** should not be confused with a simple safety switch. For example, in a typical household [microwave oven](#), the switch that disables the [magnetron](#) if the door is opened is not an interlock. Rather, it would be considered an interlock if the door were locked while the magnetron is on, and the magnetron were prevented from operating while the door is open. **Interlocks** may include sophisticated elements such as [infrared](#) beam curtains, [photodetectors](#), a [computer](#) containing an interlocking [computer program](#), [digital](#) or [analogue](#) electronics, or simple physical [switches](#) and [locks](#).

In this course we will mainly worry about the Process Control of things on the process industries side. One thing to note is that one or more interlocks may be connected to a Control Loop. Your company P & IDs may show switches that activate interlocks controlling pressure, flow, temperature, or even level. Switches connected to an interlock sometimes may be manually operated. Things such as auxiliary electrical relays and other components of electric interlock systems may not be shown on a typical P & ID. The symbol for an interlock is a diamond as shown in Figure 8.2 below:

Figure 8.2 - Symbol for an Interlock

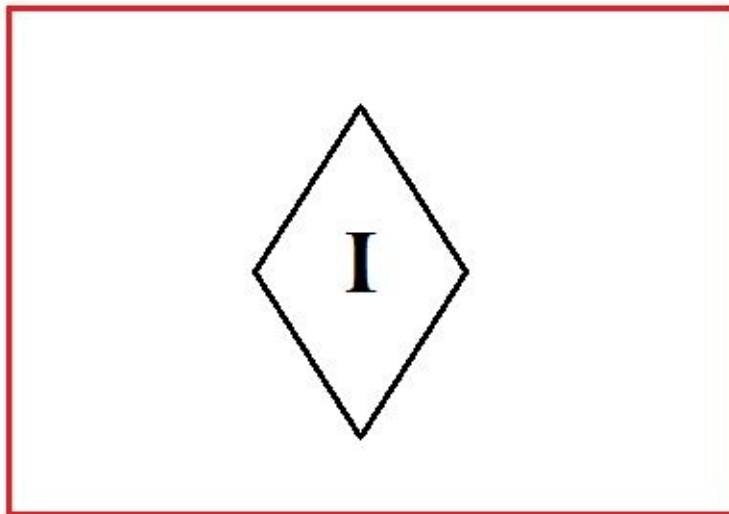
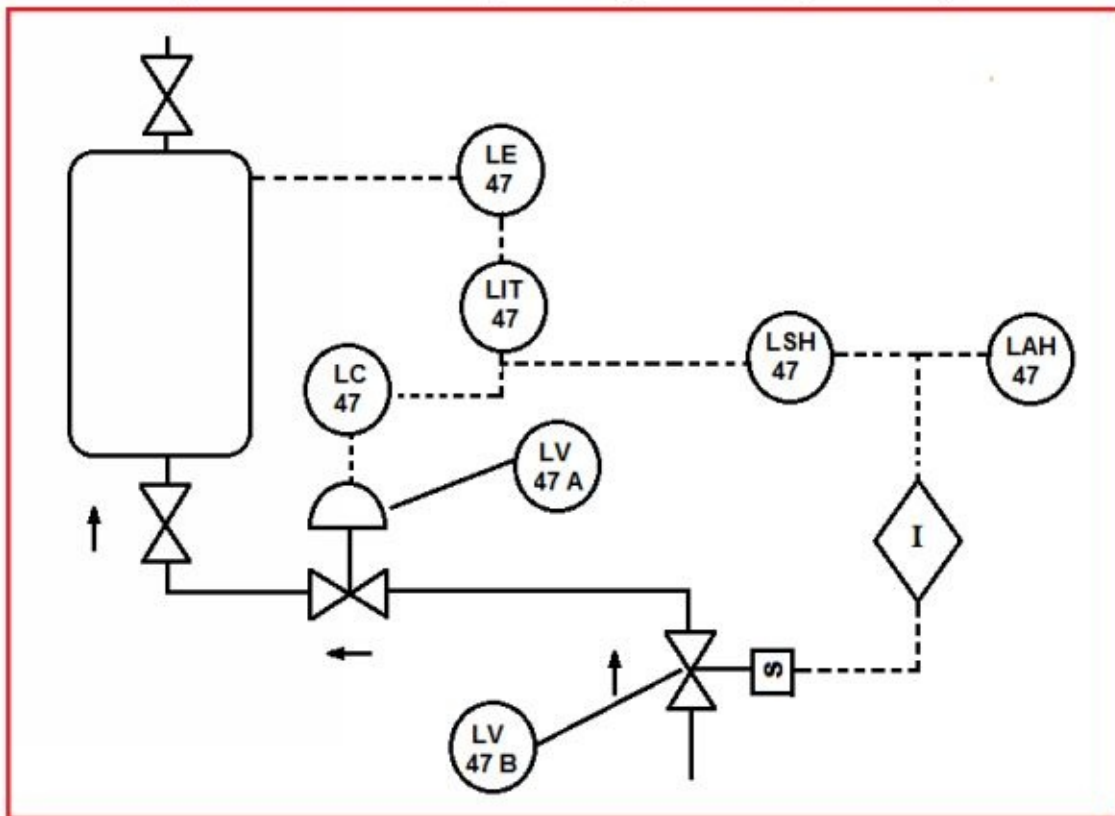


Figure 8.3 shows an example of a control loop with an interlock:

Figure 8.3 - Control Loop Showing Interlock Symbolically



Consider the above, Figure 8.3:

1. The Level Element, LE 47, senses the level inside the tank and lets the Level Indicating Transmitter, LIT 47, do the rest of the work
2. The Level Indicating Transmitter, LIT 47 sends a signal to the Level Switch, LSH 47 and Level Controller, LC 47
3. The Level Controller, LC 47, sends a signal to the Level Valve, LV 47 A to control level by either stopping or letting the flow into the tank.
4. If the level in the tank is too high, Level Switch High, LSH 47, sends a signal to the Interlock and also sets off an alarm warning us that level has reached a high point.
5. The Interlock, once it gets a signal for a high level, sends a corresponding signal to the Level Valve, LV 47 B to close in order to prevent overflow of the tank
6. As a result, Level Valve, LV 47 B, is activated by the Interlock to shut off the flow in the line that feeds the tank

Management of Changes on a P & ID made easy:

Management of Change, or **MOC**, is a best practice used to ensure that safety, health and environmental risks are controlled when a company makes **changes** in their facilities, documentation, personnel, or operations. So for P & IDs, that means all the changes should be approved by a Professional Engineer or someone authorised by the company. There is often a requirement for following a clearly laid down company procedure. There is no rocket science to it. All you just need to do is follow your company rules on MOCs, and you will just be fine!

Chapter Review:

The review questions are available at [ReviewQuestions.](#)

Chapter 9: How to Trace a Process Flow on a P & ID

Chapter Goals:

By the end of this chapter, you should be able to trace the flow of a process stream and:

- I. Explain why you need to know how to Trace Process Flows on a P & ID
- II. Identify and obtain the number of the P & ID from which a line comes from, before it enters into the current P & ID as a means to trace stream flow between 2 or more P & IDs
- III. Trace a process stream as it runs through pipes and equipment such as tanks, reactors, and heat exchangers in the current plant area as depicted by the current P & ID
- IV. Trace a process stream as it goes out of the P & ID by identifying and obtaining the number of the P & ID where the process stream continues to when required

Why you need to know how to Trace Process Flows on a P & ID:

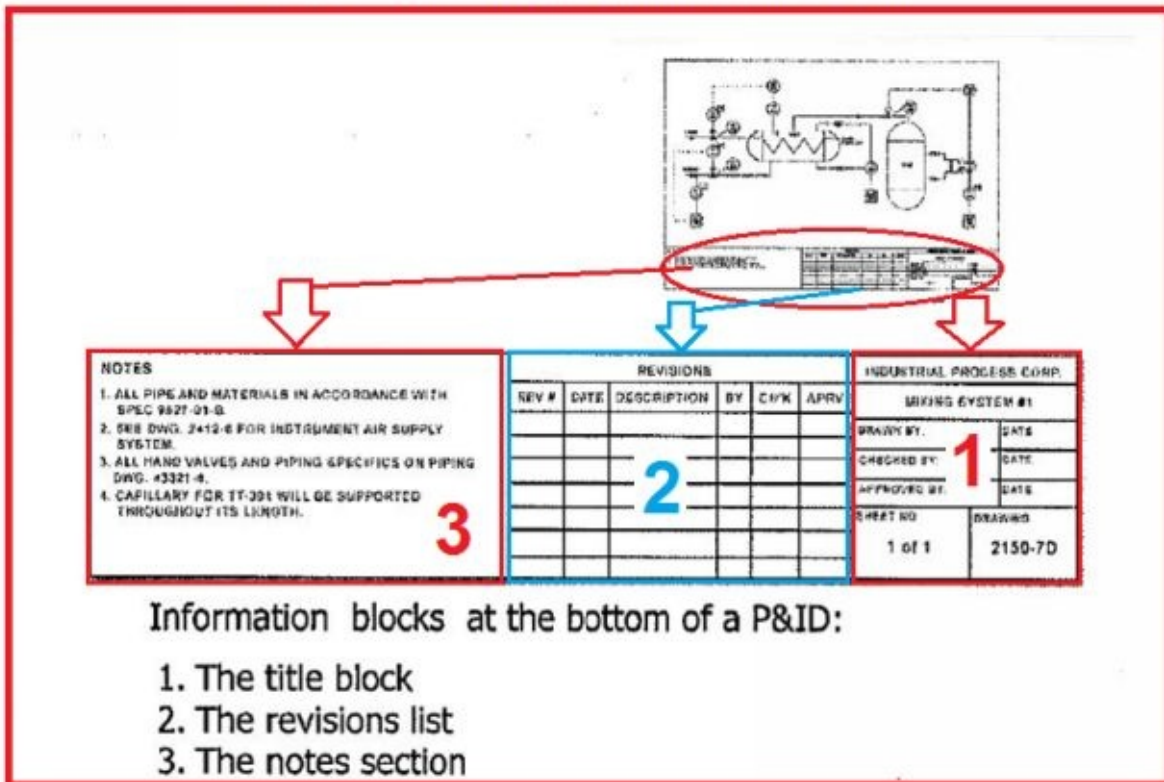
Process Industries and Power Plants processes will have more than one P & ID at any given time. Even though it is helpful to learn using examples that are presented using only one P & ID at a time, for purposes of going onto the job you need to know how to trace the process stream from one P & ID to the next. It's not unusual to find a process stream that passes through several P & IDs. This chapter seeks to show you how to easily trace such process streams. There is always a strong need to know how to find the correct P & IDS for the work that you are involved in. This chapter shows you how to do that.

Remember that each P & ID has an identification number as well as an area name and issue number in the Title Block. This Title Block and its information is in the lower right hand corner. All you need to do is check the Title Block to be certain that you have the correct P & ID that you need for the current job.

Look at the site name, P & ID Drawing Number, Issue Number, and Process Area covered.

Just in case you need me to refresh your memory on how a Title Block looks like, Figure 9.1 below shows a typical example of information that you find at the bottom of a P & ID. That includes a Title Block and the information that you can expect to find in it. The figure is not that clear but it serves the purpose for just showing you what typical information that you can expect to find in that area.

Figure 9.1 - Information Blocks At The Bottom Of A P & ID



How to find the beginning of a Process Line from Another P & ID:

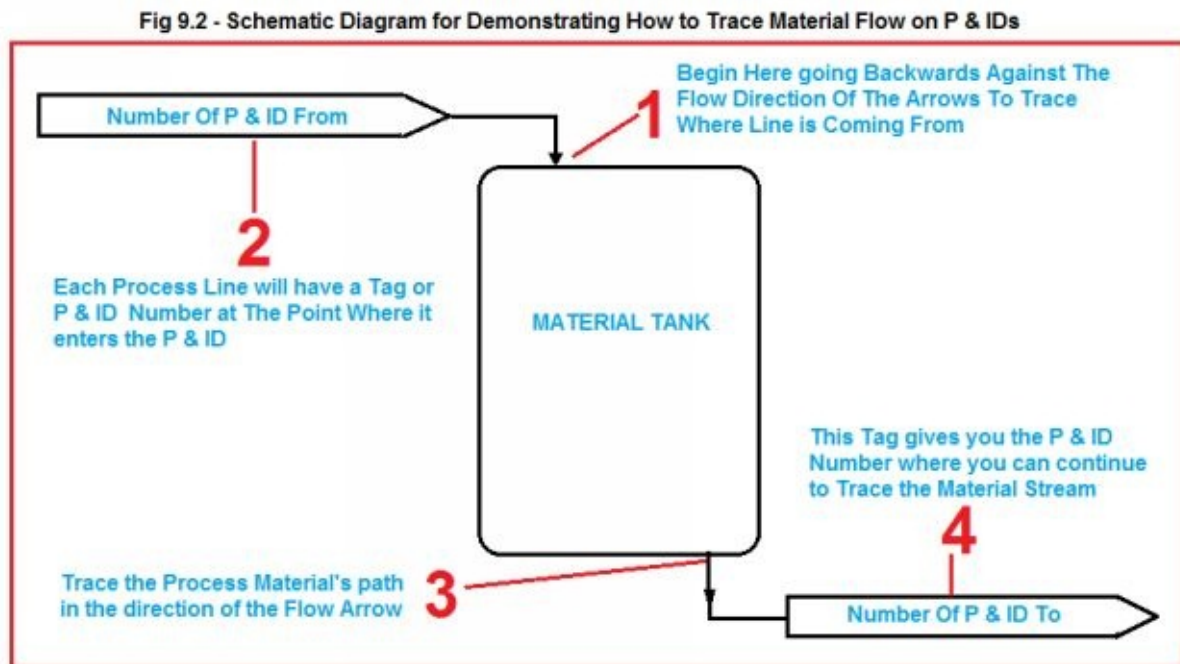


Figure 9.2 above shows point number 1. If you are trying to find the P & ID number for tracing back where this current stream flow is coming from, start tracing the process stream back from where it enters the tank against the flow direction of the arrow to the edge of the P & ID page. One word of caution though. These marker arrows and numbers are for our study purposes only. They might not appear on a real P & ID. Each process line will have a Tag or Label at the point where it enters the P & ID. Where I have worked, these tags provided us with the P & ID numbers for where the Process Stream is coming from.

Arrow #2 shows you where you can get this tag or P & ID number from. The identifying Tag or Number may be in a sausage shaped or rectangular box with an arrow point or be simply written on the line. You should always remember that there is no single way how P & IDs are drawn. Therefore, expect variations

from company to company. Anyway, let's not get distracted. The Identifying Tag we are talking about here carries the number of the P & ID from which the current process stream came. The Tag may also include the number of a piece of equipment where the material stream came from.

In Figure 9.2, we can see at the top of the tank that the line going into the tank on the current P & ID comes from P & ID number represented by the, “Number Of P & ID From” text. It also shows that the Process Flow continues after the tank to P & ID number represented by the, “Number Of P & ID To”, text. That is all you need for tracing the Process Stream Flow, in order to determine the P & ID where it's coming from.

How to follow a process line to Another P & ID:

You will run into a lot of situations whereby the material stream does not end at a piece of equipment on the current P & ID. In that case, it continues to an edge of the P & ID as in arrow #4 in Figure 9.2 above. At arrow #4, you can actually see that it ends with a Tag. In Figure 9.2 I labelled the Tag as “**Number of P & ID To**” for clarification purposes. On a real P & ID, this would be a drawing number or equipment tag number depending on your company’s conventions. The important point here is that this Tag Number gives you the number of the P & ID where you can continue to trace the material stream. So whether you see a P & ID number or an Equipment Number, either way you have information you can use to continue to trace the material stream. See arrow #4 in Figure 9.2.

Notice that I omitted the insulation and identifying labels for the material lines just to avoid overwhelming you with details in this example. Nonetheless, on a real P & ID all the information would be available. That means all the information that I’m teaching you incrementally will come on one piece. The strategy is to then use all the information you have learnt in this course to integrate everything on P & IDs and master them effortlessly.

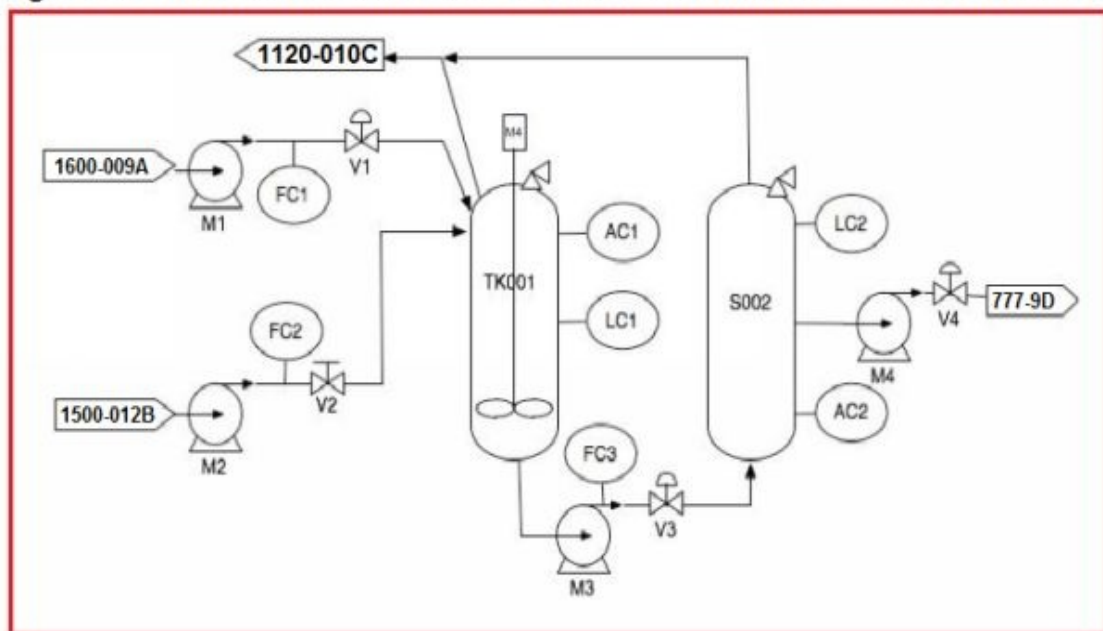
The other point I wish to make is that the example provided above only shows two pipelines. **You are likely to see multiple lines on a real P & ID.** Be they process or instrumentation lines, you will handle them the same way as explained above. Do not be overwhelmed by the many lines. Only pay attention to the numbers that concern the work that you are doing and pay close attention to all relevant details for the equipment that you are working on. The process lines may enter and leave the P & ID at any point around the outside edge of the P & ID.

How to Trace a Process Stream explained:

Using Figure 9.3 below, we can trace the Process Streams as follows:

1. The first stream to go into Tank TK001 is pumped through M1. The suction of M1 comes from P & ID number 1600-009A
2. The second stream is pumped into Tank TK001 through M2. The suction of M2 comes from P & ID number 1500-012B
3. M1 discharge and M2 discharge mix together in tank TK001 and exits as two material streams. One stream exits at the top and continues to P & ID number 1120-010C, and the second stream exits at the bottom. The bottom material stream is pumped by M3 into storage tank S002. This stream comes out of S002 as two streams, one at the top, and the second about the middle of the tank.
4. From S002, the stream that comes from the top goes on to mix with the stream from TK001 and continues together to P & ID number 1120-010C
5. The second stream that comes on the side of tank S002 is pumped by M4 and continues to P & ID number 777-9D

Figure 9.3 - How To Trace A Process Stream From Entrance To Exit On A P & ID



I have tried not to put too many details to avoid convoluting this example. My point was to demonstrate how you can trace material streams. Hence no need to overwhelm you with extra details that could serve no purpose in this demonstration for tracing stream flows. From the above explanation, you can see that if you follow a process stream from left to right respecting the direction of flow, you will easily be able to trace material flows. Even if the stream continues to a different P & ID, the number of the P & ID is always provided at the point where the stream exits the current P & ID as explained before.

Chapter Review:

The review questions are available at [ReviewQuestions](#).

Chapter 10: Demonstration Exercise – Reading a P & ID

Chapter Goals:

CONGRATULATIONS FOR GOING THROUGH THIS COURSE ...!!!

Now that you have gone through the course, it would be very beneficial for you to demonstrate ability to integrate all the material we have covered. You should do this by practically demonstrating application of the concepts to reading real P & IDs for your Plant. Below is a checklist for the items that you need to pay attention to:

1. Explain the Title Block information:
 - a. Where is the Title Block?
 - b. Did you check that the current P & ID is the right one for the work area?
 - c. What is the P & D Number
 - d. What is the Issue or Revision Number?
2. Demonstrate the ability to find and Interpret general information on the P & ID:
 - a. What changes were made with the current issue?
 - b. Identify the items that have changed on the main drawing with this issue number.
 - c. On the current P & ID, identify and list the major pieces of equipment.
 - d. Find Line Schedule Information for 6 Process Lines.
 - e. Locate, describe and explain any special notes given on the current P & ID.
 - f. How comfortable are you looking at P & ID packed with all the information?
3. Using the Master Sheet for the current P & ID, check the following:
 - a. If you are using the correct Master Sheet for the current P & ID.
 - b. The meaning of six Line Designations on the current P & ID.
 - c. The meaning of six Instrument Designations on the current P & ID.
4. Utilize the current P & ID:
 - a. With reference to the accompanying Mater Sheets if needed, identify approximately twelve symbols including equipment, instruments and other symbols.
 - b. For all major equipment pieces on the current P & ID, locate the Equipment Descriptions.

- c. Trace a Process Stream from the point it enters the P & ID to where it no longer exists (mixes in a reactor, for example) or leaves the current P & ID.
 - d. Refer to 'c' above, and identify all Graphic Symbols and Function along the line.
 - e. For 'c' above, explain the Function of Instruments in Control Loops along the line.
 - f. Trace a Process Stream from the point where it exits a piece of equipment to where it leaves the current drawing. Explain how to continue tracing the line.
 - g. For 'f' above, continue tracing the Process Stream to the next P & ID until the stream enters into a major equipment.
5. If you are doing this with a Trainer, go out in the field and select a Process Line. The Trainee should use the P & ID for the area to walk through the work area and identify all components on the line, describing direction of flow, and identifying where the material in the line leaves the work area or no longer exists.

*****When all tasks have been satisfactorily demonstrated, Congratulate yourself and treat yourself for a Job Well Done*****

*****If any of this information is not present on the P & ID, ask your mentor to explain theoretically how you would get it*****

The review questions are available at [ReviewQuestions](#).

Chapter 11: Review Questions, Practise Questions, and Practical P & ID Reading Exercises Resource Locator

For Review Questions that will ensure that you gain maximum benefits from this course, you will need to sign up to my list so I can send you the information on how you can access these.

The above mentioned resources can be accessed through this link: [please sign up here.](#)

Please don't forget to spread the love for this book if you found it helpful. Also, I would appreciate an honest book review on Amazon.

Thank you...!