Plant Design and Economics
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Lecture - 05
Piping and Instrumentation Diagram

Welcome to lecture 5 of Plant Design and Economics. So this is the last lecture of module 1. In this lecture, we will talk about piping and instrumentation diagram. We have already talked about block flow diagrams, as well as process flow diagrams in our previous lectures. Today we talk about one more very important flow diagram for chemical engineers known as piping and instrumentation diagram or popularly known as P&ID.

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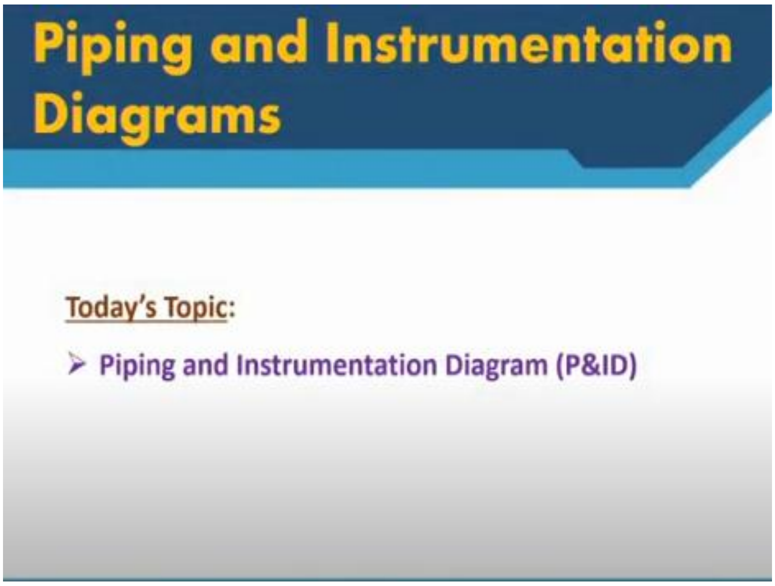

So today's topic will be piping and instrumentation diagram.

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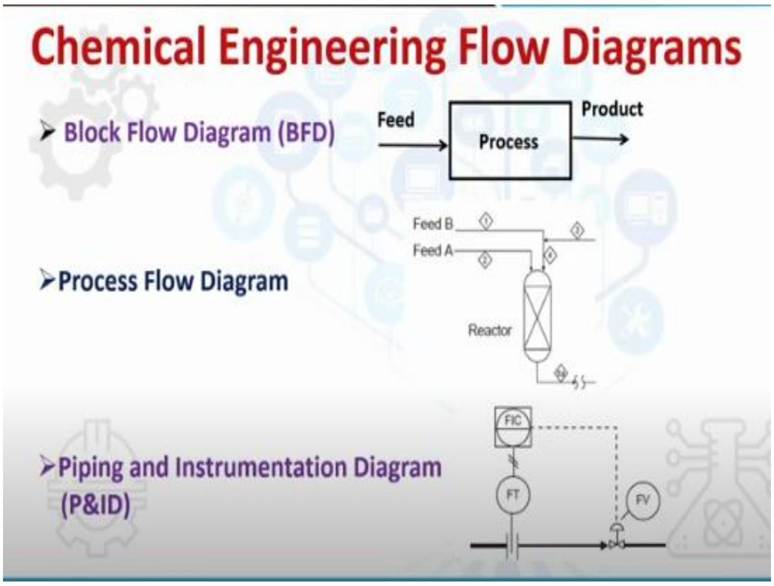

We have already discussed about block flow diagrams, process flow diagrams and now we are going to talk about piping and instrumentation diagram.

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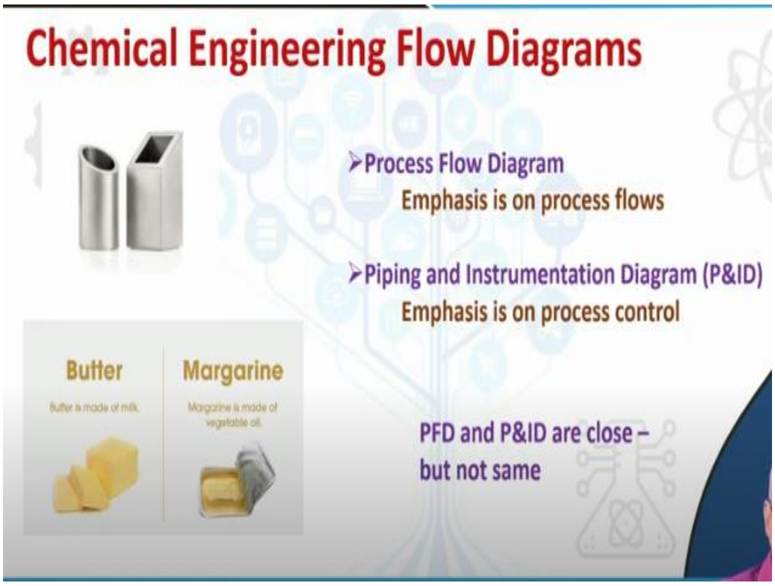

You have seen in process flow diagram emphasis is on process flows. Now today you will see that in piping and instrumentation diagram, the emphasis is on process control. So process flow diagram and P&ID diagram are close, but really they are not same. Process instrumentation and diagram involves much more detailed information.

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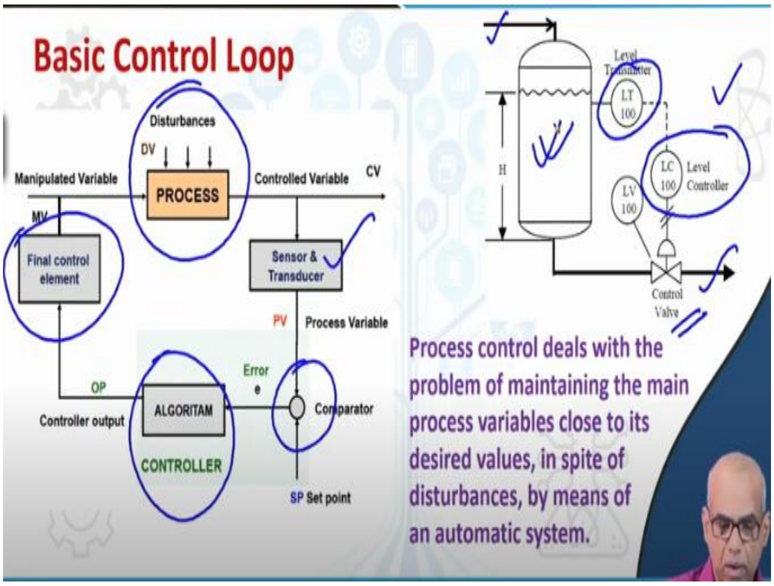

Now let us start our discussion with process control loop. A very basic control loop is shown here which you can quickly identify that this is nothing but level control of the tank shown. Now if this input flow rate and these output flow attain steady state and there is no disturbance then there would not be any need for process control. But you know that that is not going to be the case, there will be disturbances.

And process control deals with the problem of maintaining the main process variable close to its desired values in spite of disturbances by means of an automatic system. So what you do here is suppose you want to maintain the level of the liquid in the tank. So you measure the level using a level transmitter. Then you compare it with your target value. An error signal is produced.

And then the controller works on that error signal and decides what is to be done to the process. Whether the control valve, which is the final control element needs to be closed more or needs to be opened more. That decision then implemented and the process which is this tank here will be maintained at the desired liquid level.

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Modern processes use automatic process control to ensure consistent quality and quantity of products as well as it ensures safe and economic operation. Use of programmable logic control, distributed control system and centralized operation from control room are common in today's chemical process industry. Two images as shown here.

One shows the control room with analog instrumentation. And the other one shows a control room with digital instrumentation, which is more modern these days.

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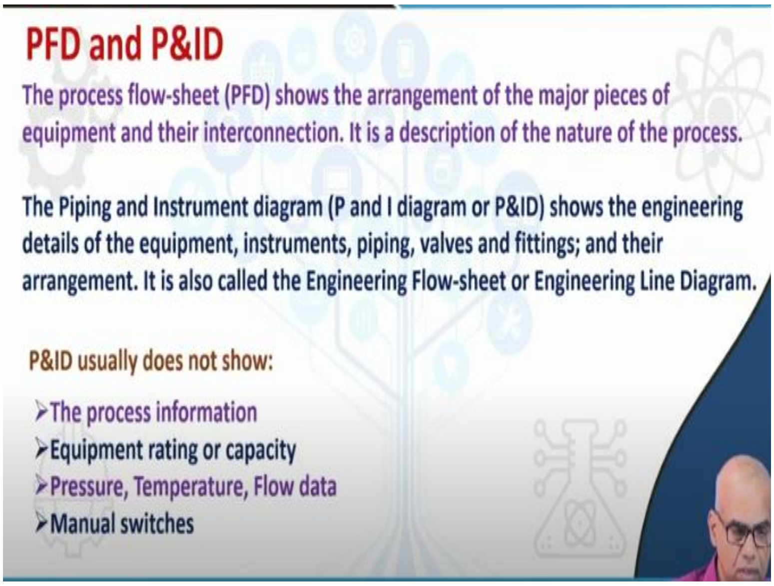

The process flow sheet shows the arrangement of the major pieces of equipment and their interconnection. It is a description of the nature of the process. The piping and instrumentation diagram shows the engineering details of the equipment, instruments, piping, valves and fittings and their arrangement. It is also called the engineering flow sheet or engineering line diagram.

However, there are certain things which piping and instrumentation diagram will not normally show. For example, piping and instrumentation diagram usually does not show the process information, the equipment rating or capacity, pressure, temperature, flow data, and manual switches.

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The process and instrumentation diagram is a key document for a chemical engineer. When you start working with the chemical process industry, you should start with the P&ID diagram. It will help you to learn how the process works, how the control and the safety protocols are in place in your industry.

The piping and instrumentation diagram acts as a directory to all failed instrumentation and control that will be installed on a process and thus is a key document to the control engineer. The piping and instrumentation diagram plays an important role in the design, installation and to day to day maintenance of the control system.

It is a key piece of information in terms of understanding what is currently being used in the plant for process control and safety. For example, the plant operator sees some malfunctioning with a piece of valve and reports to maintenance department that a valve on a piece of equipment is not functioning correctly.

Now the piping and instrumentation diagram is a directory to all fail instrumentation and control that are placed in the process system. So maintenance person will consult the piping and instrumentation diagram to identify the valve. And then he or she can learn how the valve is used in the control of the process and accordingly can take necessary action.

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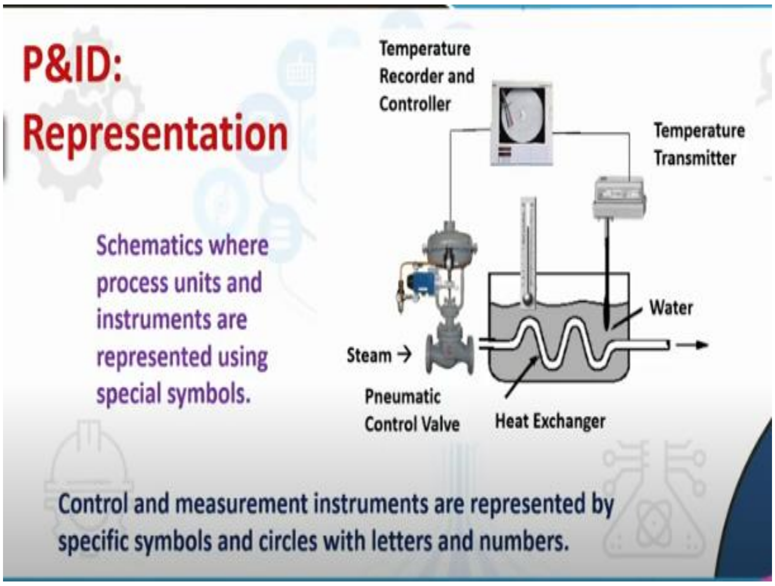

Again you can quickly identify that the schematic that you see is about control of temperature of the water taken in this reactor or beaker whatever you call it. So the elements in the control system such as temperature transmitter, temperature recorder and control and the pneumatic control valve which is the final control element are all shown using special symbols.

Now for a complicated process, it would not be possible to show all the elements of control loop using such symbols. Control and measurement instruments are represented by specific symbols and circles with letters and numbers. How it is done? We will see soon.

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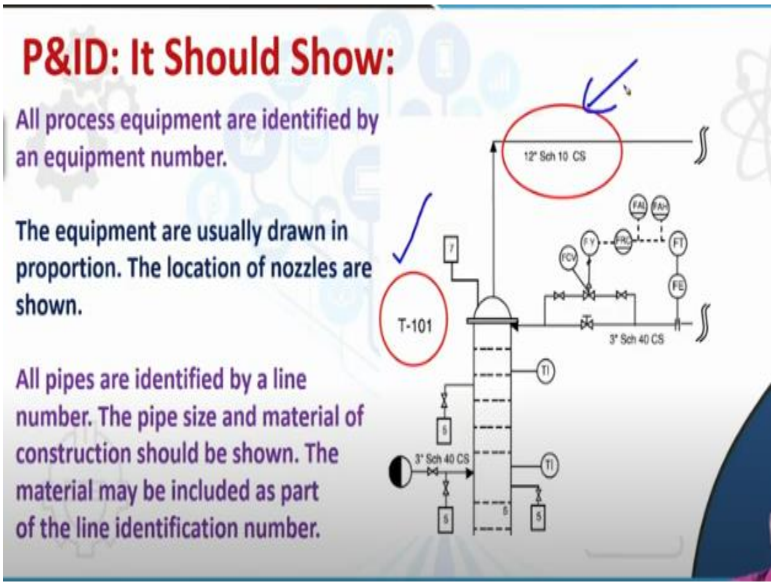

Now let us first see what does piping and instrumentation diagram show to us. Piping and instrumentation diagram will show all process equipment identified by equipment number. Look at the diagram, T-101 represents the tower. The equipment are usually drawn in proportion. The location of nozzles are shown. All pipes are identified by line number.

The pipe size and material of construction should be shown. The material may be included as part of the line identification number. You can see here the pipeline is identified as 12 inch schedule 10 made by carbon steel.

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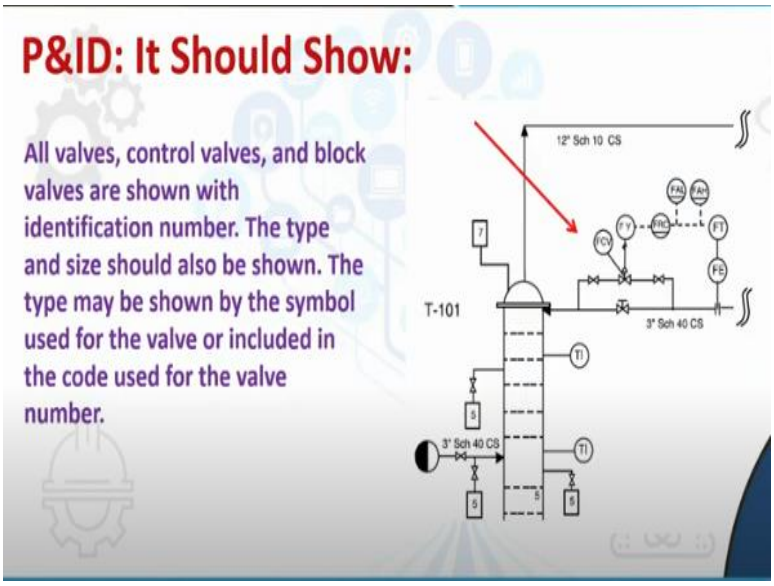

Piping and instrumentation diagrams should also show all valves, control valves, block valves with identification number. The type and size should also be shown. The type may be shown by the symbol used for the valve or included in the code used for the valve number.

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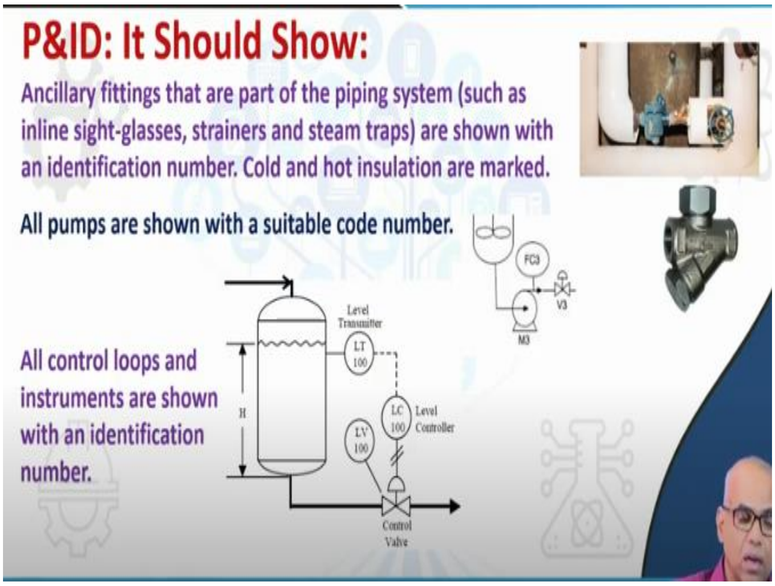

Piping and instrumentation diagram shows ancillary fittings that are part of the piping system such as inline sight glasses, strainers and steam traps with an identification number. Cold and hot insulation are marked. What you see is image of steam traps. Steam traps are valves that allow to pass through it condensed steam, but not the live stream. So that is how it saves live stream.

Wastage of live stream will be minimized. All pumps are shown with suitable code number in the piping and instrumentation diagram. You can see M3 has been used to indicate the pump. So there are M2, M1, etc. Maybe there will be M4 as well. All control loops and instruments are shown with an identification number. Once again consider the level control system.

Look at the instruments, which are represented by circles and numbers. The level transmitter, level controller, final control valve all are tagged with number 100.

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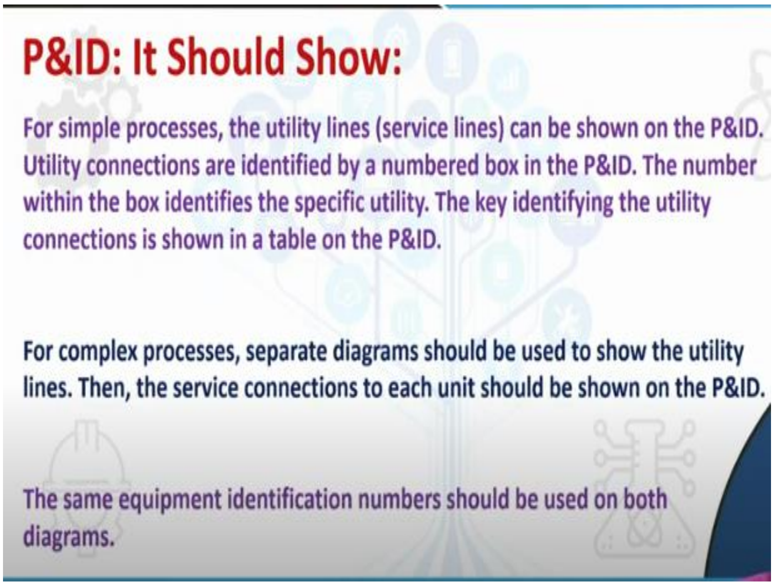

For simple processes, the utility lines, also known as service lines can be shown on the piping and instrumentation diagram. Utility connections are identified by a numbered box in the piping and instrumentation diagram. The number within the box identifies the specific utility. The key identifying the utility connections is shown in a table on the piping and instrumentation diagram.

For complex processes, separate diagrams would be used to show the utility lines. Then the service connections to each unit should be shown on the P&ID. The same equipment identification number should be used on both the process flow diagram as well as piping and instrumentation diagram.

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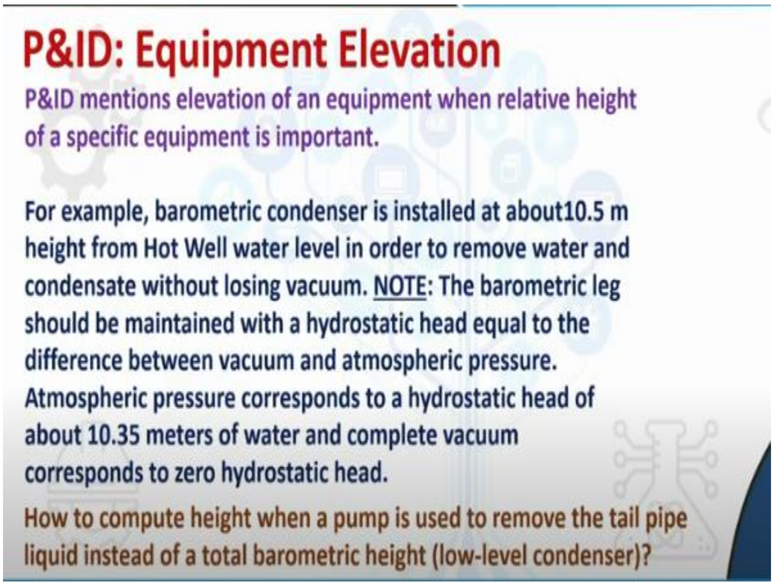

Piping and instrumentation diagram, oftentimes mention elevation of an equipment, when relative height of a specific equipment is important. For example, barometric condenser is installed at about 10.5 meter height from hot well water level in order to remove water and condensate without losing vacuum. If you have read about evaporator you must have known about barometric condenser.

The barometric leg should be maintained with a hydrostatic head equal to the difference between vacuum and atmospheric pressure. Atmospheric pressure corresponds to a hydrostatic head of about 10.35 meters of water and complete vacuum corresponds to zero hydrostatic head so in order to maintain vacuum, the barometric condenser installed at about 10.5 meter height from the hot well water level.

Sometimes, a pump is also used along with the barometric lake which is known as low level condenser. How to compute height of the barometric leg when a pump is used to remove the tail pipe liquid instead of a total barometric height? What you have to do is you have to subtract whatever head is being supplied by the pump from the barometric leg.

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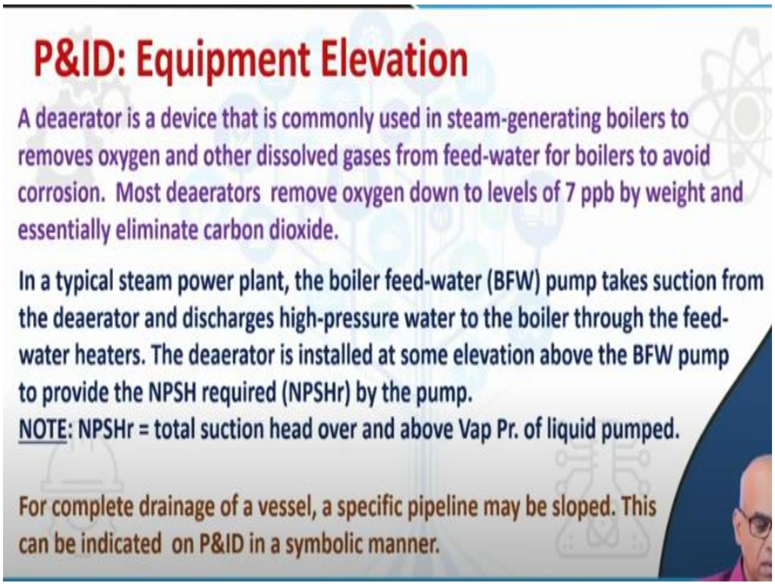

Another example when equipment elevation is important is the location of the deaerator in connection with the boiler feed water. A deaerator is a device that is commonly used in steam generating boilers to remove oxygen and other dissolved gases from feed water for boilers to avoid corrosion. You know that dissolved oxygen can corrode as corrosion property.

As well as dissolved carbon dioxide will be another source for causing corrosion. Most deaerators can remove oxygen down to levels seven parts per billion by weight. And deaerators essentially eliminate carbon dioxide from the water. In a typical steam power plant, the boiler feed water pump takes suction from the deaerator and discharges high pressure water to the boiler through the feed water heaters.

The deaerator is installed at some elevation above the boiler feed water pump to provide the net positive suction head required by the pump. Note that the net positive suction head required is equal to total suction head over and above the vapor pressure of the liquid being pumped. For complete drainage of a vessel, a specific pipeline, maybe sloped. This can also be indicated on P&D in a symbolic manner.

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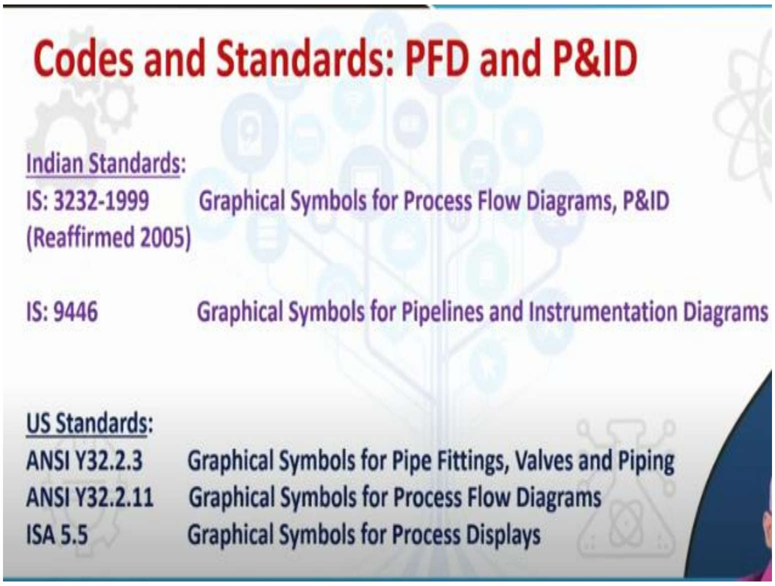

These are the codes that are used for creating process flow diagrams as well as P&ID. Indian Standards IS: 3232-1999, IS: 9446 are used for graphical symbols for process flow diagrams P&ID, graphical symbols for pipelines, and instrumentation diagrams respectively. Similarly, US Standards are there.

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British Standards BS: 1646 1 to 4 and German Standards DIN 19227 P1 to P3. So symbolic representations will follow these standards.

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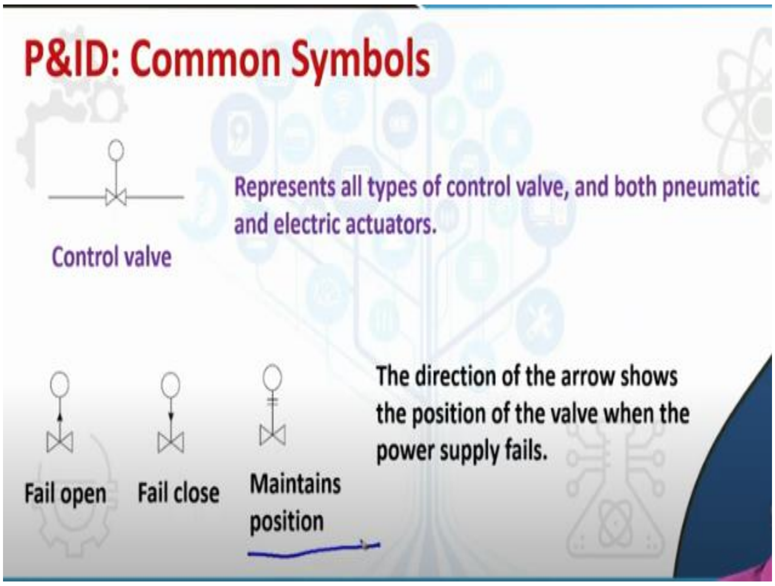

Now let us be familiar with the common symbols that are used to build process piping and instrumentation diagram. What you see is a representation of all types of control valves, both pneumatic and electric actuators. Fail open, fail close and this one maintains its position, stem position when the power fails. The direction of the arrow shows the position of the valve when the power supply fails.

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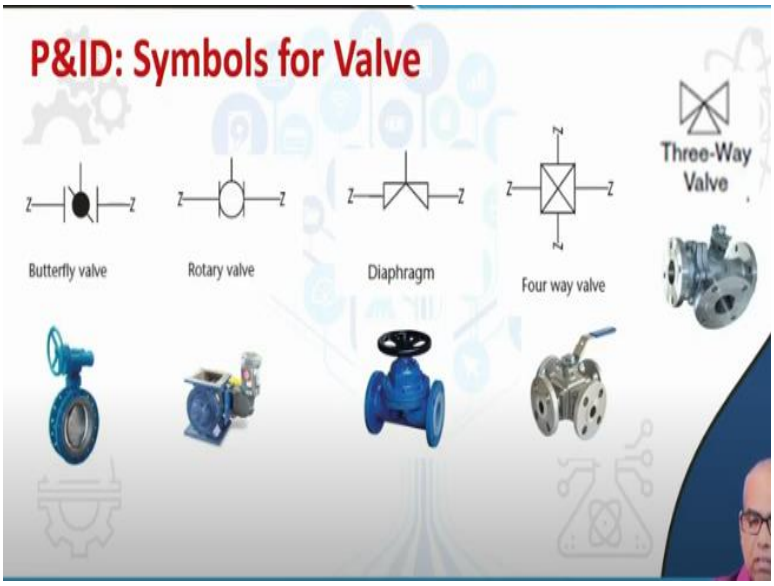

Again, here are some more symbols for valves along with images of some actual valves. Butterfly valve, rotary valve, diaphragm valve, four way valve, three way valve. So try to be familiar with the symbols for these valves.

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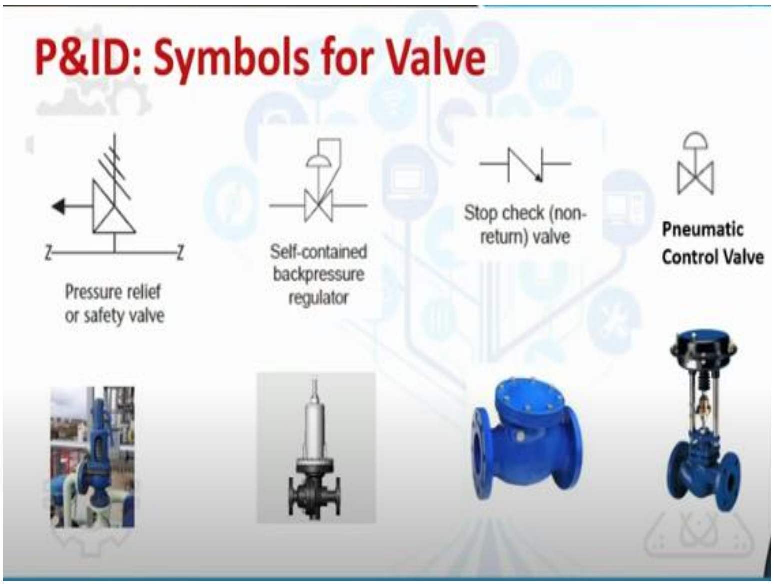

Pressure relief or safety valve, self-contained back pressure regulator, stop check or non-return valve, pneumatic control valve.

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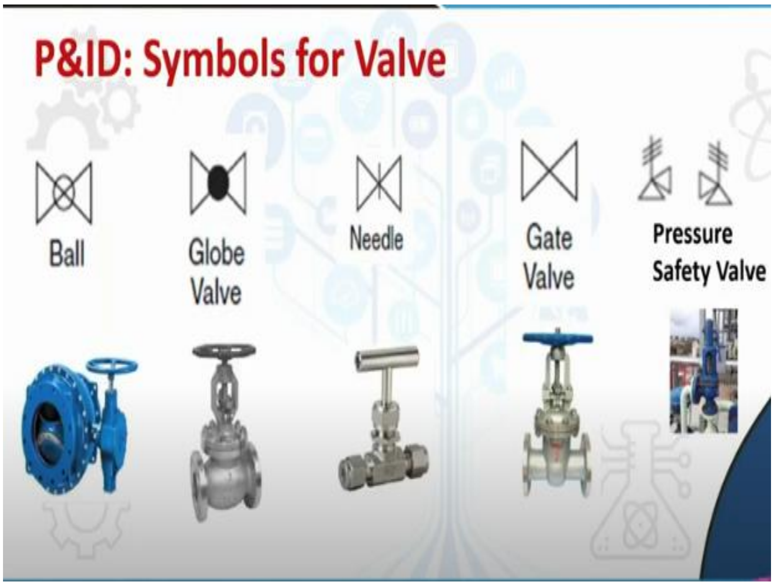

Ball valve, globe valve, needle valve, gate valve, pressure safety valve.

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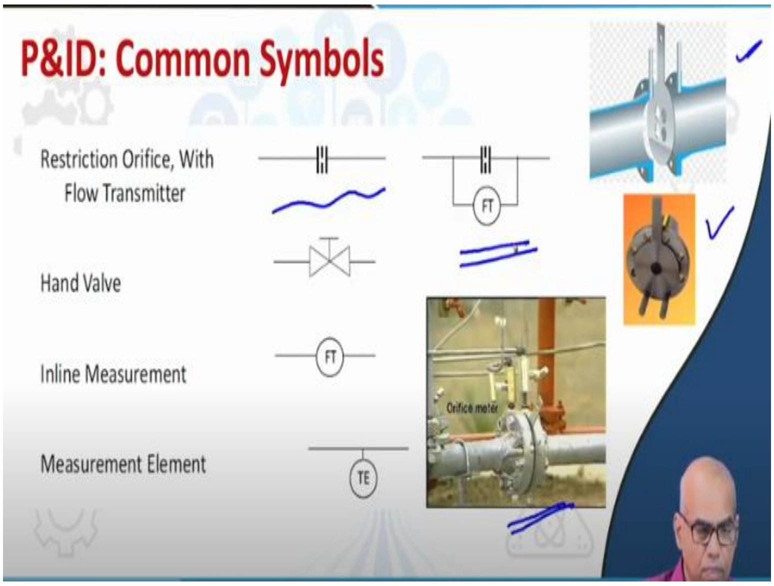

Some more symbols. This represents orifice. This image shows orifice installed in a pipeline. This is flow transmitter. You are measuring flow across orifice. Hand valve. Inline flow measurement and this is measuring element. TE is temperature measuring element. We will learn about nomenclature soon.

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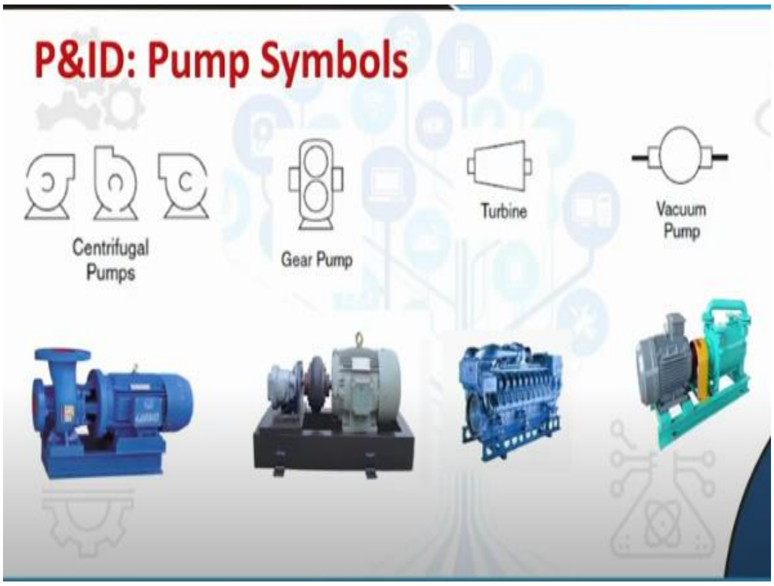

Here are some symbols for pumps. Centrifugal pumps, gear pumps, turbine, vacuum pump.

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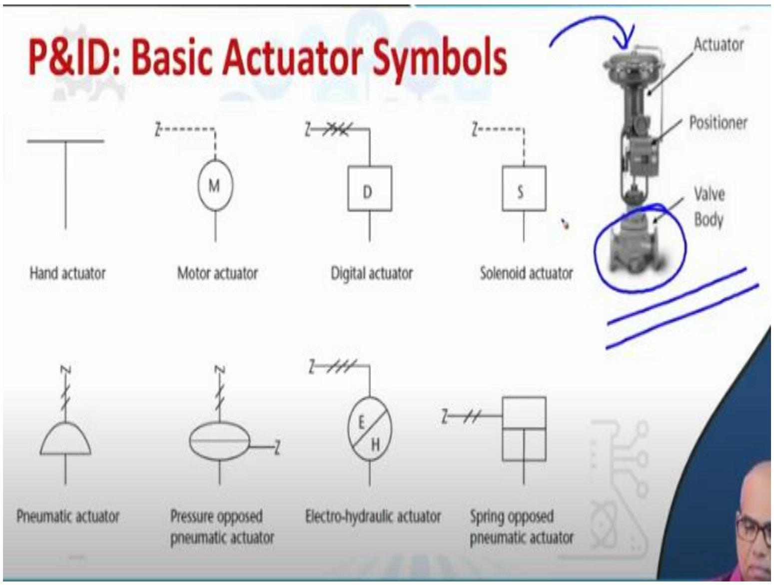

Here we have symbols for various basic actuators. This is an image for a pneumatic control valve. So inside there is a diaphragm. If we apply pressure here, the diaphragm is connected to a stem. When I apply pressure on the diaphragm, the diaphragm will push the stem down and the valve opening maybe closed. Now the actuator is responsible for this movement.

So actuator receives information from the controller. It receives the signal and then accordingly places the valve position. Now there are various actuators. Hand actuator, motor actuator, digital actuator, solenoid actuators, pneumatic actuators etc. And we use various symbols for various actuators. So these are some basic actuator symbols, which you may try to be familiar with.

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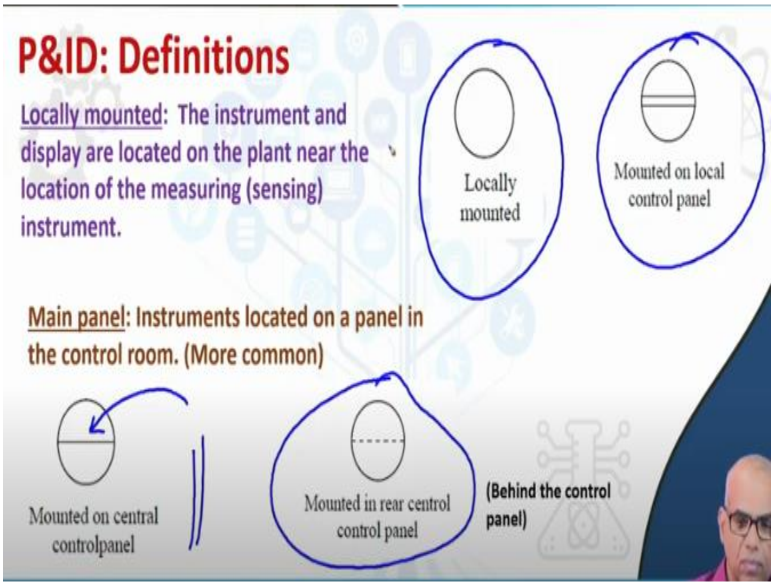

Now let us try to be familiar with certain definitions. The instrument and the display when located on the plant, near the location of the measuring or sensing instrument we call is locally mounted. And these are the symbols for the locally mounted instruments or control systems. Instruments located on a panel in the control room will be called instruments or main panel.

This symbol is for instruments mounted on central control panel. Whereas this one is for locally mounted. So what is the difference? The difference is in the horizontal straight line. Now if this line is broken it represents the instrument is mounted in rear control panel. It means the behind the control panel. This is not accessible by the operator. If there are two horizontal lines it means it is mounted on local control panel.

So this is an alternate position or place which is accessible by the operator. So locally mounted, mounted on central control panel, and mounted in rear control panel.

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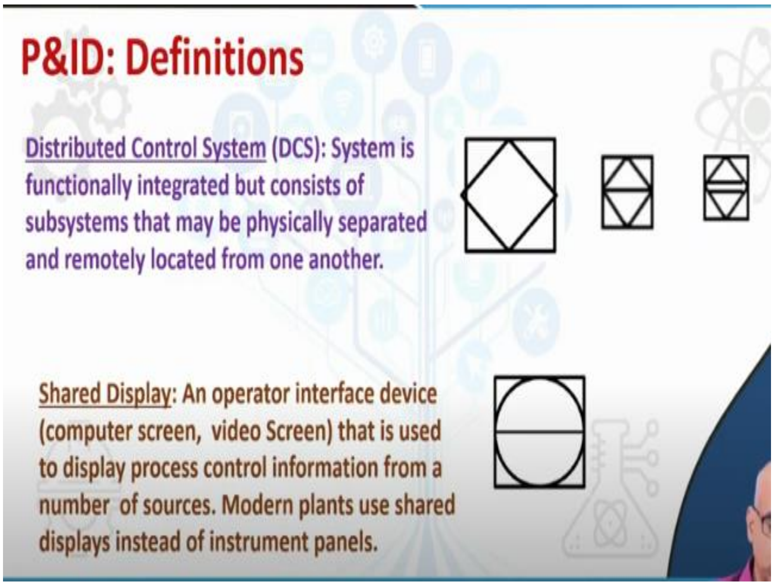

Distributed control system is functionally integrated, but consists of subsystems that may be physically separated and remotely located from one another. So in case of distributed control system, system is functional integrated but consists of subsystems that may be physically separated and remotely located from one another. And this is the symbol for distributed control system.

Shared display. An operator interface device such as computer screen, video screen that is used to display process control information from a number of sources. Modern plants use shared display instead of instrument panels. And this is the symbol for shared display.

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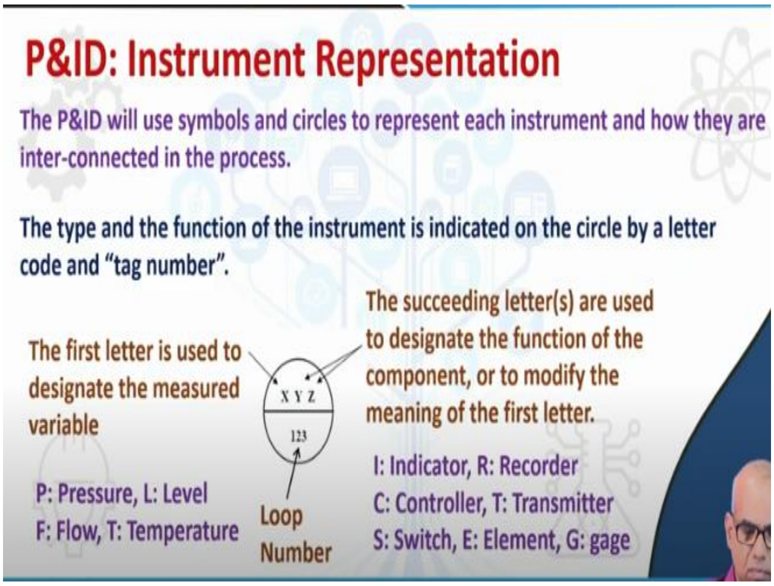

Now let us learn how to represent instruments on piping and instrumentation diagram. The piping and instrumentation diagram will use symbols and circles to represent each instrument and how they are interconnected in the process. The type and the function of the instrument is indicated on the circle by a letter code and tag number. The first letter is used to designate the measured variable.

Look at the circle. It has a horizontal line and then above that line we have written x y z; below the line, 123. So the first letter of x y z is used to designate the measured variable. The succeeding letters second and third letters are used to designate the function of the component or to modify the meaning of the first letter. For example, if x is P, this means that this instrument measures pressure.

If the first letter is L, it means this instrument measures level. Similarly, flow, temperature etc. For second and third letters, I will stand for indicator, R for recorder, C for controller, T for transmitter, S for switch, E for element, G for gage. The number 123 represents loop number.

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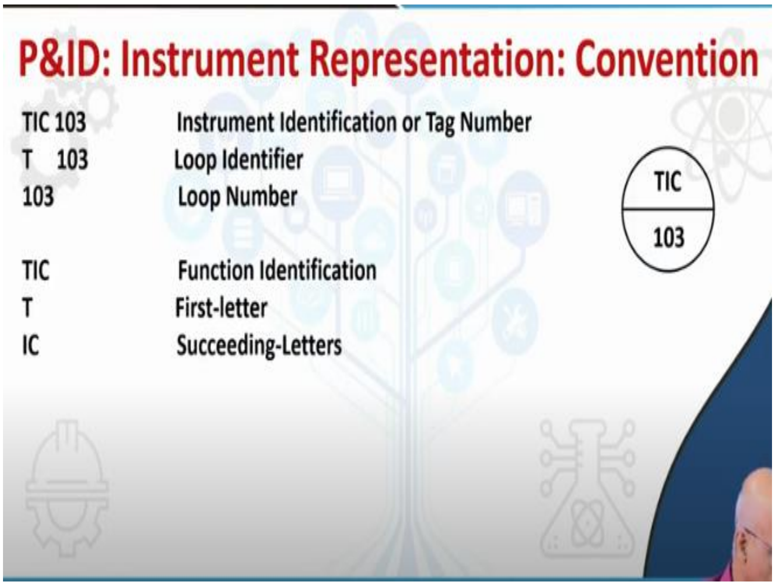

Now you see what is written is TIC and 103. So it is temperature, indicator, controller and the loop number is 103. So TIC 103 instrument identification or tag number, T 103. So 103 is loop number. T the first letter represents temperature. Succeeding letters I and C means indicator and controller.

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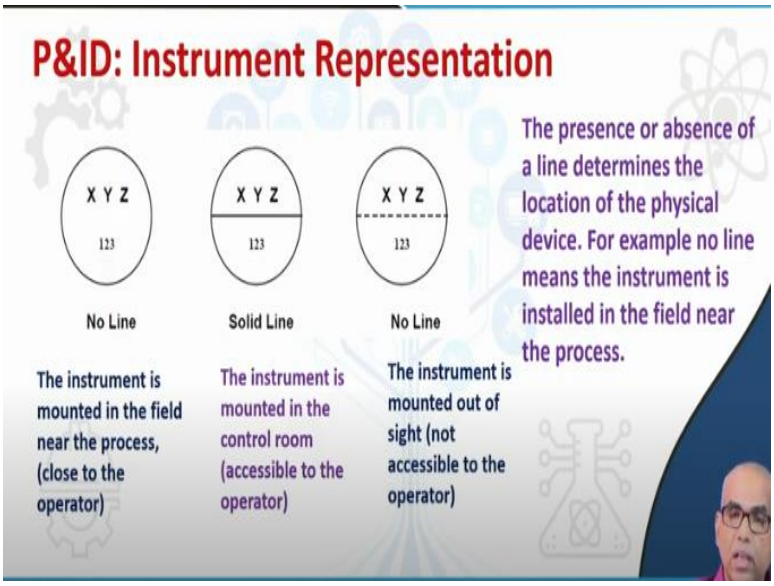

The presence or absence of a line determines the location of the physical device. This we have already seen. For example, no line means the instrument is installed in the field near the process or we call it locally mounted. When you have a solid horizontal line, it means the instrument is mounted in the control panel and it is accessible to the operator. When you have a broken horizontal line, it represents the instrument is mounted out of sight.

It is not accessible to the operator, it is behind the control panel. It is on the rear side of the control panel. So if we now go back here, it means the temperature indicator controller loop number 103 and it is mounted on the control panel.

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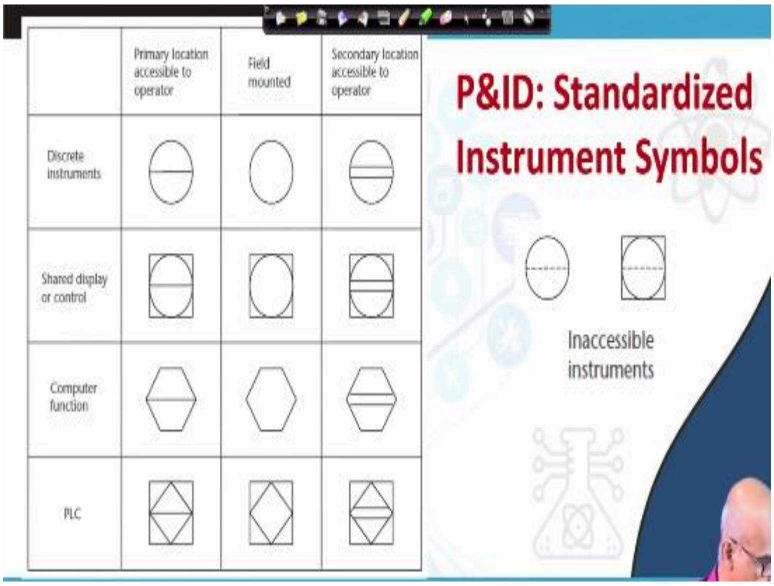

Now here is the summary of the standardized instrument symbols. You need to be familiar with this.

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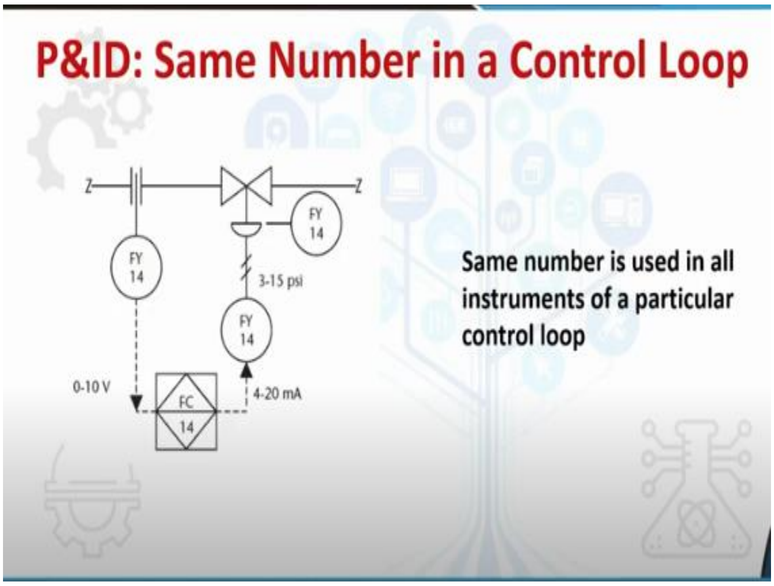

Now same number will be used in all instruments of a particular control loop. If you look at this control loop all instruments carries the number 14. So this is loop number 14 and all the instruments that belong to loop number 14 will have tag number 14. You should be able to identify that this control loop is for flow control. Look at the orifice.

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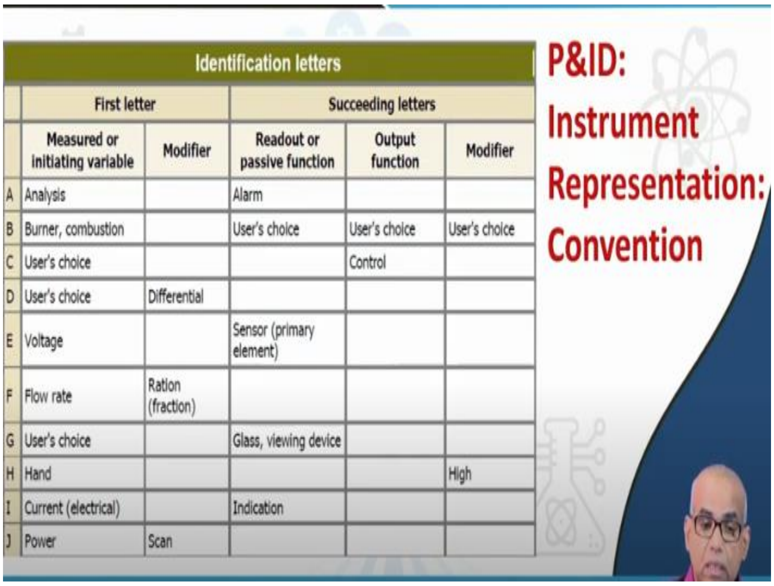

Identification letters					
	First letter		Succeeding letters		
	Measured or initiating variable	Modifier	Readout or passive function	Output function	Modifier
A	Analysis		Alarm		
B	Burner, combustion		User's choice	User's choice	User's choice
C	User's choice			Control	
D	User's choice	Differential			
E	Voltage		Sensor (primary element)		
F	Flow rate	Ration (fraction)			
G	User's choice		Glass, viewing device		
H	Hand				High
I	Current (electrical)		Indication		
J	Power	Scan			

Now this is a detailed table which will tell you more about the identification letters. So what does first letter represent and what does succeeding letters represent

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K	Time, time schedule	Time rate of change		Control station	
L	Level		Light		Low
M	User's choice	Momentary			Middle, intermediate
N	User's choice		User's choice	User's choice	User's choice
O	User's choice		Orifice, restriction		
P	Pressure, vacuum		Point (test connection)		
Q	Quantity	Integrate, totalizer			
R	Radiation		Record		
S	Speed, frequency	Safety		Switch	
T	Temperature			Transmit	
U	Multivariable		Multifunction	Multifunction	Multifunction
V	Vibration, mechanical analysis			Valve, damper, louver	
W	Weight, force		Well		
X	Unclassified	X axis	Unclassified	Unclassified	Unclassified
Y	Event, state, or presence	Y axis		Relay, compute, convert	
Z	Position, dimension	Z axis		Driver, actuator	

when you use letters A to Z are all here.

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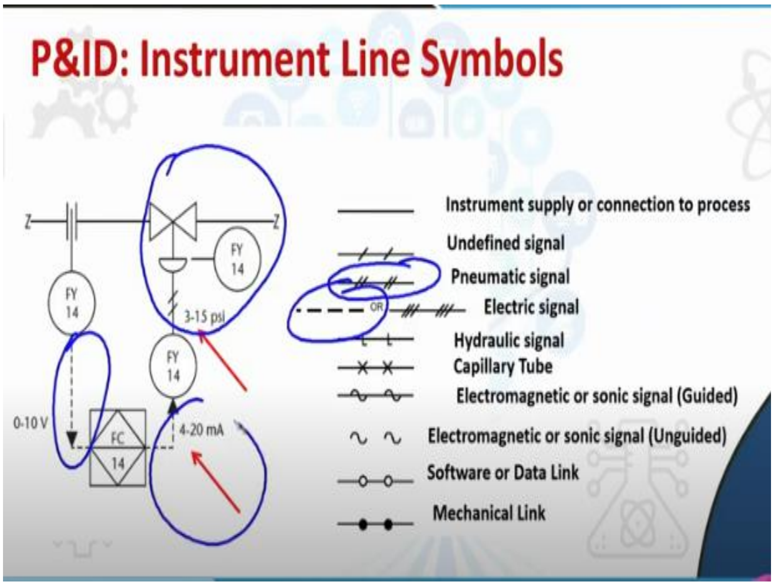

Now how to represent various lines such as pneumatic signal, electrical signals, hydraulic signals etc. So there will be various line symbols on piping and instrumentation diagram which represent lines corresponding to various signals such as pneumatic signal, electrical signal, electromagnetic signals, mechanical links, software or data link etc. So they all use different symbols.

So you need to be familiar with these instrument line symbols. This represents pneumatic signal. So you see the pneumatic control valve has this signal on the line. Again, this one is for electrical signal. So here you have a control loop, which is showing presence of both pneumatic signal as well as electric signal.

So if your control system uses pneumatic control valve as well as transmitters which transmits say 4 to 20 milliampere current your diagram will have both electrical lines as well as pneumatic lines. So you must be familiar with corresponding lines.

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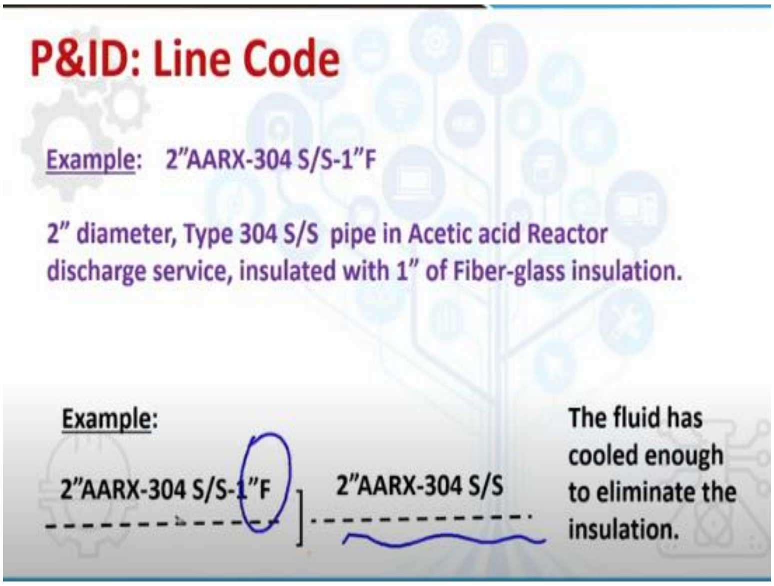

This is line code 2 inch AARX-304 S/S 1 inch F. What it represents is 2 inch diameter, type 304 stainless steel pipe in acetic acid reactor discharge service, insulated with 1 inch of fiberglass insulation. So the pipeline carries the entire information with it. If the fluid has cooled enough to eliminate the insulation as it flows so beyond the point when it is cooled enough to eliminate the installation it will be indicated as follows.

The difference is this that we now have dropped 1 inch F because insulation is no more required.

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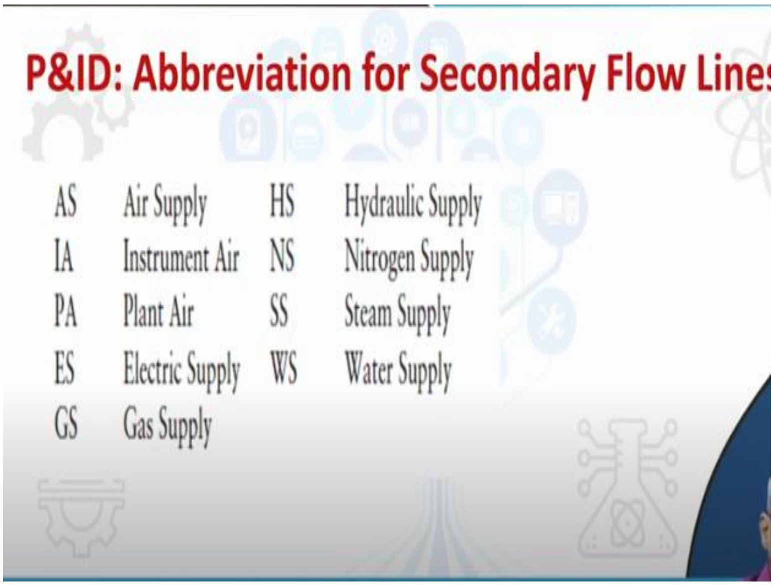

These are some abbreviations commonly used for secondary flow lines. Air supply AS, instrument air IA etc.

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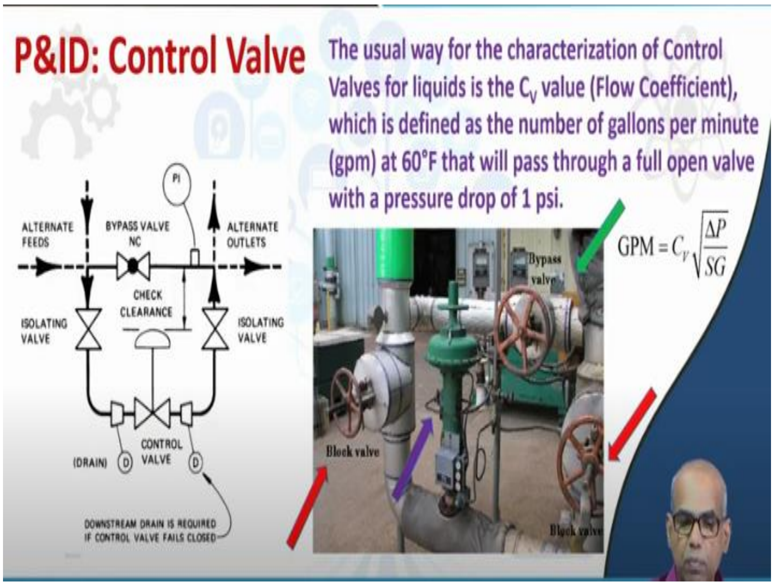

What you see is a loop for control valve. Note carefully that this is the control valve but then there are two isolating valves and there is a bypass valve. This is required because suppose control valve is not working or you have to take it for maintenance then you can separate the system using these two isolating valves and can let the flow occur through this bypass valve.

Perhaps you can manually control the bypass valve and can go on with your operation. The image also shows the same thing. You have this as pneumatic control valve. You have two block valves which are isolating valve and you have this bypass valve. So generally control valve is placed with two isolating valves and a bypass valve so that when the need arises, you can separate the control valve using these two isolating valves.

And the flow can take place through the bypass valve. The usual way for the characterization of control valves for liquids is the flow coefficient value C v value, which is defined as the number of gallons per minute at 60 degree Fahrenheit that will pass through a fully open valve with the pressure drop of 1 psi.

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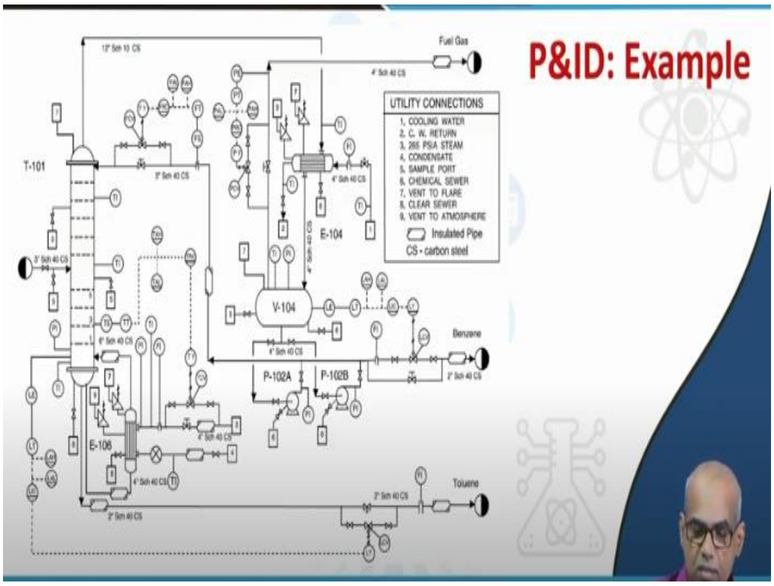

This is an example of piping and instrumentation diagram only for the distillation column part. You are already familiar with this. This was the production of benzene from toluene and hydrogen that we have discussed in our previous lecture. So this is the part where the affluent from the reactor comes and goes through the distillation column for separation of benzene and toluene.

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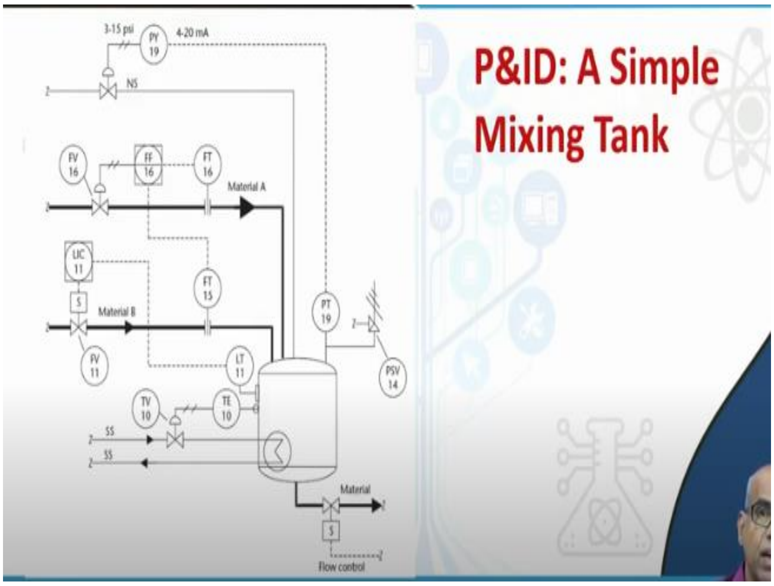

This is another piping and instrumentation diagram for a simple mixing tank. So try to identify the instruments, whether they are pneumatic type, or electric type. Identify all the lines and the instrument types.

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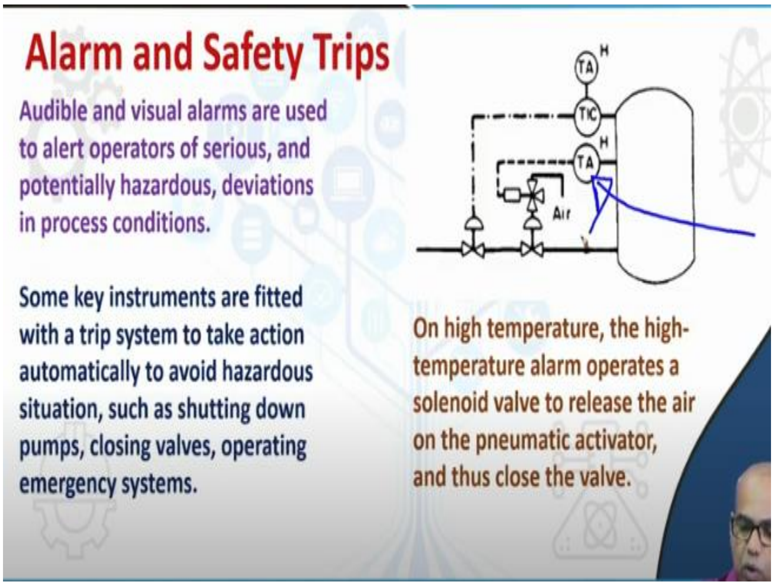

Now let us talk about alarm and safety trips. Audible and visual alarms are used to alert operators of serious and potentially hazardous deviations in process conditions. Some key instruments are fitted with a trip system to take action automatically to avoid hazardous situation such as shutting down pumps, closing valves, operating emergency systems, etc.

The figure shows that on a high temperature, the high temperature alarm will operate a solenoid valve to release the air on the pneumatic activator and thus close the valve.

So on high temperature, the high temperature alarm will operate a solenoid valve to release the air on the pneumatic activator and thus release, thus close the valve.

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Remember, there are false alarms sometimes. Alarms that actuate because of faulty sensors, or because the alarm limit is set too close to normal operating conditions frequently provide false alarms. It is difficult to tell when these unreliable alarms are warning of a real deviation that requires action. If a display is crowded with many such nuisance alarms operators may fail to notice a real alarm that requires action.

Remember, you should never ignore safety alarms. If your plant has alarms that do not require a response, evaluate the need for the alarms.

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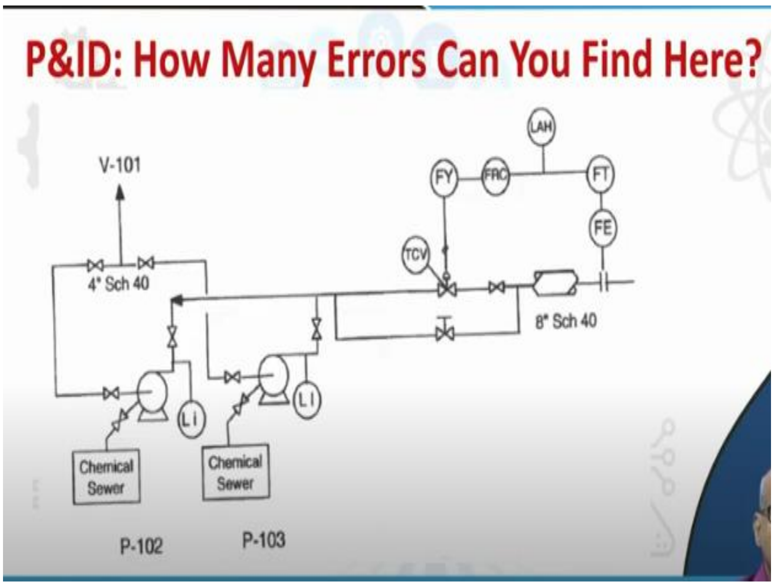

Now can you identify the errors in this figure? In this piping and instrumentation diagram, there are errors. How many errors can you find?

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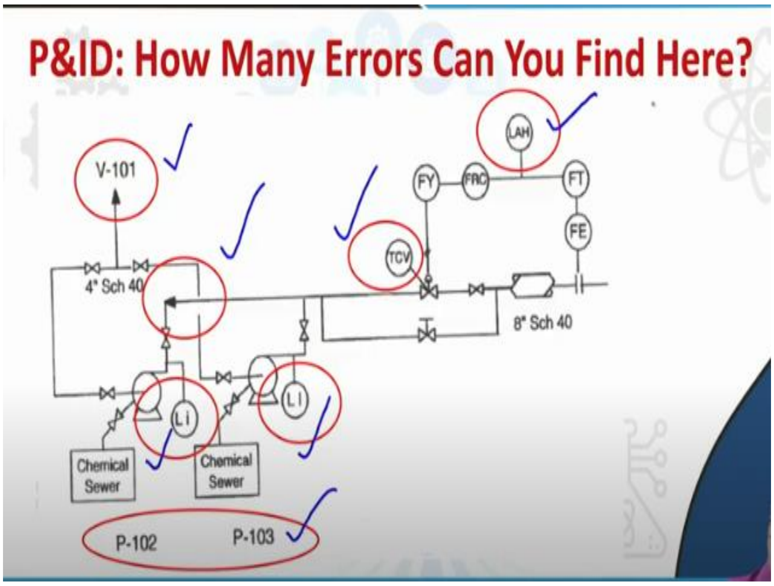

Now it will be easier for you. Look at this and this. The direction of the arrows should be reversed. Let the flow be from left to right. Look at this and this. These are pressure indicators connected to the outlet of the pump. So this should be P I. Also look at these numbers. P-102 and P-103. These two pumps are identical pumps connected in parallel. One is idle and the other is in service.

So it should be represented as P-102 A/B. This we have seen when we talked about process flow diagram. Look at here. Instead of TCV which represents temperature control valve, it should be flow control valve FCV. Similarly, it is not level alarm, high level alarm, it is flow. We are not measuring level here we are measuring flow. So these are the errors associated with these piping and instrumentation diagram.

With this, we stop our discussion on piping and instrumentation diagram here.