

## Chemical Engineering 4N04

### Workshop on Reading Process Drawings

Engineers use process drawings to efficiently and clearly describe process designs. Here, we will gain experience in reading these diagrams by answering questions on the drawing PID-2A in Woods PDEP. This drawing is more complicated than those we have seen in the past, but it is typical of drawings used in engineering practice.

The following are questions to help groups with their self study. Groups should also formulate and solve their own questions.

**This document provides solutions to the workshop questions. We caution that no one standard is used by all companies in all countries. Therefore, the engineer should seek a symbol key from the source of the drawings and ask questions when not sure of the meanings.**

**1. Terminology – We’ve got to understand one another!**

a. What is the meaning of PFD?

**PFD means process flow diagram. It contains symbols for units connected with lines representing pipes. The symbols represent the type of equipment, and each piece of equipment has a unique number and name. Usually, the drawing shows basic control systems that regulate the flows between units and important compositions. All utility flows to process units are shown. In some cases, the drawing is combined with the results of the flowsheet calculations that give the rate, composition, pressure and enthalpy of each stream.**

b. What is the meaning of P&I D? (Note that this is not the PID algorithm in process control.)

**P&ID means “piping and instrumentation”. This drawing includes details on each piece of equipment (including spares), all entering and exit connections, limited details on internals (e.g., trays), drains, instrument connections, all sensors (including location of display and calculation), valves, utility streams, safety equipment, isolation valves, and machinery (motors).**

c. Why do engineers give numbers to all equipment? (It’s not because we are jealous of accountants.)

**We must be able to connect pipes and instrumentation many times to provide the complex structures. This requires detailed, unequivocal identification of all equipment.**

2. **Overview of the process – What’s going in and coming out?**

- a. Identify all feeds to and products from units on the drawing.

**One feed from the left to a drum. The material then proceeds to the feed of the Depropanizer.**

**Products**

- (1) from the depropanizer overhead to fuel gas and liquid propane,**
- (2) from the debutanizer overhead to liquid butane product**
- (3) from the bottoms of the debutanizer**

- b. Why are the distillation towers called “depropanizer” and “debutanizer”?

**Each separates the feed into De-X (all components lighter than and including X) overhead. All heavier components exit at the bottoms. Naturally, the separation is not perfect.**

- c. Highlight the main process flow(s) in the process.

- d. What utility streams are used in the process (e.g., water, steam, hydrogen, nitrogen, etc.)?

- **Cooling water is used in the condensers.**
- **Steam is used as heating in the reboilers and to power a turbine that drives a pump F-25.**
- **Compressed air is used for all control valves.**
- **Electricity to power pump motors.**
- **No fuel gas is consumed; however, the vapor product for the depropanizer goes to fuel gas.**

3. **Piping and valves– Keeping the materials in the plant and away from us!**

- a. With what symbols are the pipes represented in the drawing?

**Lines.**

- b. What symbols are used for pumps? What general class of pumps is used in this process?

**See the symbol for F-25. These are centrifugal pumps.**

- c. Why does the pipe size change from the inlet and outlet of E-25?

**The inlet to the condenser is a gas. After the condenser, the fluid is liquid, which requires a smaller pipe.**

- d. Find valve FV-1.  
- Is this an automated control valve or a “hand” valve?

**This is an automated control valve. Variable air pressure is used to change the stem position as it acts against the force of a spring.**

- Why are all of the other valves located around FV-1?

**The hand valves can be used to isolate FV-1 and open a bypass. This procedure enables the maintenance or replacement of FV-1 without stopping plant operation. Note the drain valve used to clear material after isolation.**

- e. What is the size of the pipe between F-26 and FV-1?

**The drawing shows it to be 12 cm.**

- How is the “best” pipe size determined?

**The pipe diameter is determined by an economic evaluation that reduces the combined cost of pumping (favoring large diameters) and pipe cost (favoring small diameter).**

- What is a rule of thumb for the velocity in the liquid-filled pipe?

**A value of 1 m/s is reported in Woods, PDEP, Figure 2-30. This can be used as a rule of thumb; a detailed procedure for calculating the proper best diameter is shown in Figure 2-62.**

- f. - What is PSV-1? (Coming attractions – We will discuss this in the classes on safety!)

**This is a safety relief valve that will open when the pressure exceeds a specified maximum value.**

- g. - What type of valve body is used in FV-4? (Globe, ball, needle, etc.)

**This level of detail is not typically provided in a P & I D.**

#### **4. Pumps – Getting to the heart of the matter.**

- a. Find pump F-26.  
- What is the equipment in the feed pipe to the pump?

**There is a hand valve that can be used (with the exit valve) to isolate the pump so that it can be maintained or replaced when the plant is in operation. Also, there is a filter to prevent solid material from entering the pump.**

- What is the equipment at the outlet pipe from the pump?

**There is a valve that can be used (with the inlet valve) to isolate the pump so that it can be maintained or replaced when the plant is in operation. Also, there is a one-way (or “check”) valve to prevent flow reverse to the expected direction.**

- What provides the power to the pump?

**Power is provided by an electric motor.**

- b. Pump F-27 is located after V-30. Why does the drawing specify that V-30 must be 4.5 m above ground level?

**The liquid to the pump leaves the vessel at its bubble point. If it entered the pump at the bubble point, it would vaporize. This is called cavitation, which can cause severe damage to the pump. The head of 4.5m of liquid provides additional pressure to prevent vaporization in the pump for this specific pump. The net positive suction head (NPSH) is reported by the manufacturer.**

**5. Sensors – The eyes of the operators.**

- a. Where are the displays located?  
- To read PI-3, where would you look?

**This is a local instrument (it has no line in the “bubble”). Sorry, you have to walk out to the plant location to read the local display. Also, no record of historical data would be available.**

- To read TI-4, where would you look?

**This is available in the central control room. It is displayed on a control panel for analog instrumentation, or it is displayed on a computer screen for digital instrumentation. If analog, a short history on the paper would be available. If digital, a history of past data would be available.**

- To read PT-6, where would you look?

**This is a transmitter, which converts the measurement to a pneumatic signal for use in calculations. This is used to calculate a differential pressure between locations determined by the position of the switch (PS). No display is provided by a transmitter.**

- Could you find historical data for FC-4? For TI-6?

**For FC-4, yes. If analog control equipment, a chart recorder would have the last few hours of data. If digital control equipment, the data would be stored for a very long time. The most recent few hours would have frequent samples, and as the data proceeds back in history, it is compressed (e.g., by taking minute or hourly averages) to save storage space.**

- b. What is the meaning of the lines with cross-hatching?

**These are instrumentation signals being transmitter around the plant. Usually, the hatched lines indicate pneumatic signals. In most new plants, these would be electronic signals, which would be designated by dashed lines.**

c. What is the purpose of PS7?

**This is a switch that selects two of the many signals inputted to the switch.**

- Why are so many instruments linked to it?

**We have the ability to calculate the pressure differences between different locations in the distillation tower.**

- What process variable does dPI1 display?

**This is the pressure difference. It would be measured to monitor for changes to the resistance to flow. For example, corrosion of trays could cause a change in pressure drop. Also, excessive liquid flow could cause a buildup of liquid on the trays (flooding) which has the symptom of a high pressure drop.**

d. What type of flow sensor is used for FC-4?

**An orifice meter is used, as designated by the three same lines perpendicular to the pipe. Many other flow meters have symbols, so that we have to refer to detailed backup documentation.**

e. What type of temperature sensor is used in TC-12?

**This information is not available on the drawing.**

f. What type of analyzer is used for AI-1?

**This detail is not usually provided on the drawing. The variable being measured is usually indicated (e.g., C3 for propane).**

## **6. Process equipment – the reason for the plant.**

a. How many theoretical trays exist in the debutanizer?

**We do not know how many theoretical trays were used in designing the tower. The drawing shows that 23 actual trays are in the tower.**

b. Explain the principles of the condenser E-28, specifically how the pressure is controlled by changing the heat transfer duty.

**When the heat transfer duty is changed (increased), the rate of condensation is affected (increased, which reduces the vapor in the fixed volume of the distillation tower. As a result, the pressure is affected (decreased).**

**The heat duty depends on the area for heat transfer, specifically the area available for condensation. Remember that the heat transfer for condensation is very high per unit area. The condenser duty is changed by adjusting the valve in the liquid exit line from the exchanger to the accumulator drum. This changes the heat**

**transfer in the exchanger. For example, opening the valve slightly will lower the liquid in the heat exchanger, which will increase the area for condensation, which will increase the condensation rate, which will decrease the pressure.**

- c. Why is TC12 controlling the temperature of a tray in the debutanizer?

**The temperature is not of importance, because the steel vessel is strong enough to withstand any possible temperature. However, the temperature of a bubble point mixture at a constant pressure gives an indication of the composition. Therefore, we (approximately) control composition by controlling the temperature. We call this approach inferential control.**

- d. What type of reboiler is provided in the debutanizer? (kettle, thermosyphon, pumped circulation, etc.)

**This is a thermosyphon. All of the fluid entering the reboiler returns to the tower. The returning fluid is partially vaporized. The flow is not pumped; it occurs because of the density different – a thermosyphon effect.**

- e. Find heat exchanger E-24.  
- Why is steam entering and water leaving?

**Heat transfer results in the steam being condensed. A steam trap at the exit of the exchanger prevents any steam from exiting the exchanger. This prevents a waste of steam that had not been condensed.**

- What is the meaning of the box with “T” inside?

**This is a steam trap.**

- Describe the working of one device used in the question above.

**A float could rise in condensate and open the exit for water. If no condensate has accumulated in the trap, the exit from the trap will be closed by the position of the float.**

**O.K., now it's your turn to formulate questions – with answers!**

**Questions submitted by students**  
**The great class of 2002**

1. **Are there different symbols for different kinds of pumps, heat exchangers, etc.?**

**Yes, the symbols indicate the basic features of the heat exchangers, e.g., shell and tube, plate, kettle reboiler, thermosyphen, and so forth. Typical symbols can be found in the following references.**

Austin, D., Chemical Engineering Drawing Symbols, Halsted Press, London, 1979  
Weaver, R., Process Piping Drafting (3<sup>rd</sup> Ed.), Gulf Publishing, Houston, 1986.  
ISA, ISA-S5.3, Graphic Symbols for Distributed Control/Shared Display Instrumentation, Logic and Computer Systems, Instrument Society of America, Research Triangle Park, 1983  
ISA, ISA-S5.1, Instrumentation Symbols and Identification, Instrument Society of America, Research Triangle Park, 1984  
ISA, ISA-S5.5, Graphic Symbols for Process Displays, Instrument Society of America, Research Triangle Park, 1985

2. **Why would the depropanizer overhead go to flare?**

**The depropanized vapor product stream is predominantly ethane and methane. These components are often used as fuel gas; therefore, the overhead is normally sent to fuel gas. In case of excessive pressure, the pressure relief valves must open and cause a stream of hydrocarbon gas to leave the depropanizer. When this happens, the gas cannot be released to the atmosphere – it could combust or explode! Therefore, the high pressure safety valve is connected to the flare where the gas can be safely burned. Naturally, this involves a loss of valuable fuel and is to be avoided.**

3. **What is the purpose of the drains?**

**We must supply a drain for spills and for equipment maintenance, when we disconnect parts of the process.**

4. **What indicates an alarm?**

**See the course tab on safety.**

5. **Explain how the bottoms from the depropanizer enters the debutanizer as 67% vapor.**

**The bottoms from the depropanizer is 100% liquid. After flowing through the control valve (LV-2), the stream pressure decreases from about 1.1 to close to 0.48 Mpa. Because of the decrease in pressure, the stream partially vaporizes.**

6. **What is the purpose of the hand valve near the control valve FV-1 and inside the block valves.**

**This is a drain valve for removing fluid and reducing pressure after the block valves have been closed and before the control valve is removed from the line.**

9. **What does PS mean?**

**P = pressure ; S = switch; This device determines which connections are used tfor the dPI-1 (differential pressure indicator)**

10. **How do we determine the type of sensor (thermocouple, RTD, etc.) and the specific type of control valve body (ball, globe, etc.)?**

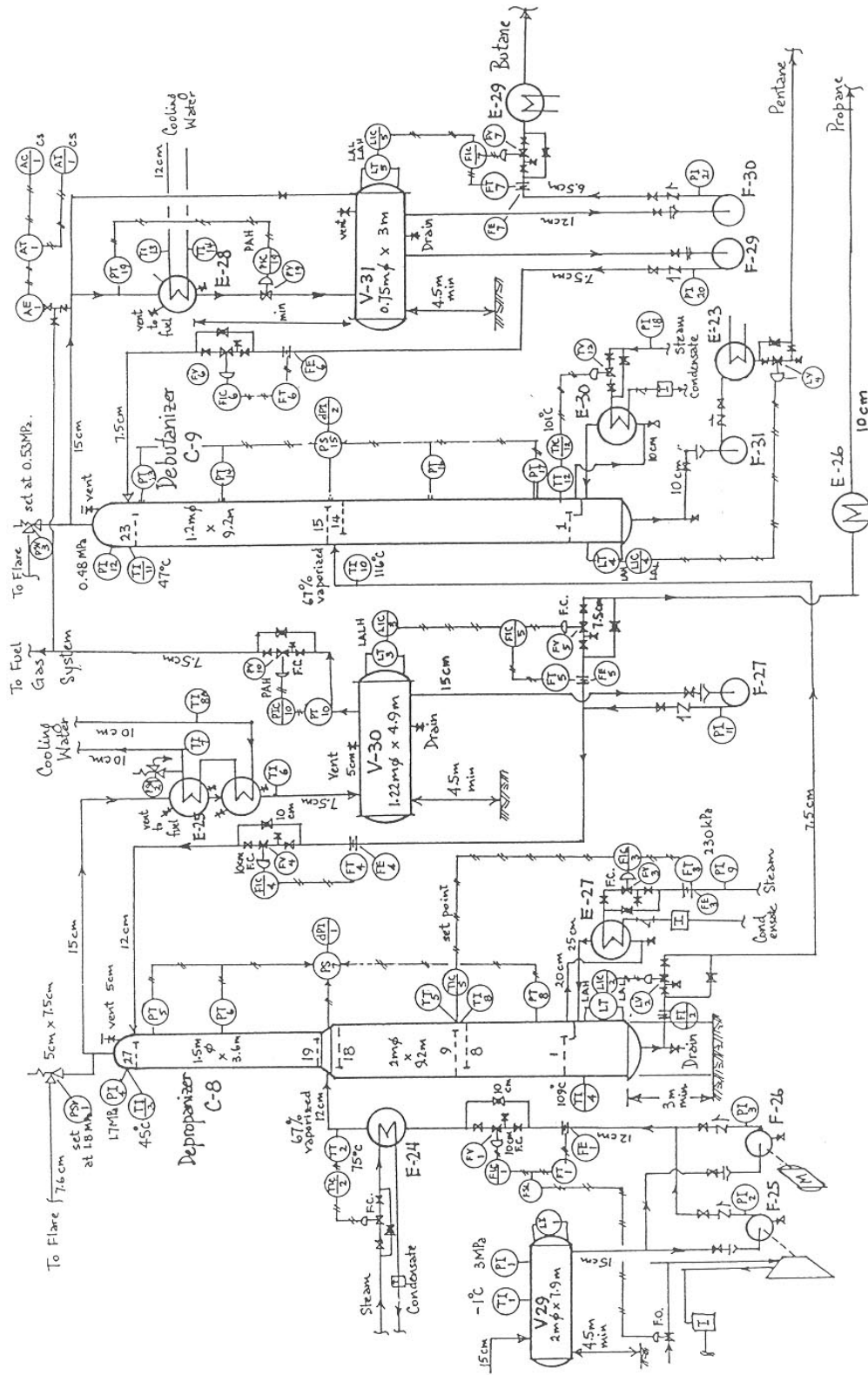
**This information is not provided on the P&I drawing. Further details are given on the instrumentation specification sheets and valve specification sheets.**

11. **Why is AE-1 connected to the fuel gas system?**

**A small sample of gas from the debutanizer overhead is required for the analyzer. This gas is combustible and must be processed; it cannot be vented to the atmosphere. Thus, the analyzer exhaust gas and the part of the flow not used in the analyzer flows to the fuel gas system.**

12. **What is the composition of the overhead stream exiting the depropanizer reflux drum, V-30?**

**The composition is not given on the drawing because it will change during plant operation. Since the purpose of the tower is to remove propane and lighter overhead and to recover most of the propane as liquid product for sale, we expect the vapor product to be predominantly ethane and lighter.**



PID-2A Depropanizer/Debutanizer

Figure used in this exercise. The figure is from Dr. Wood's textbook, PDEP.