Solutions for Analysis Synthesis and Design of Chemical Processes 5th Edition by Turton

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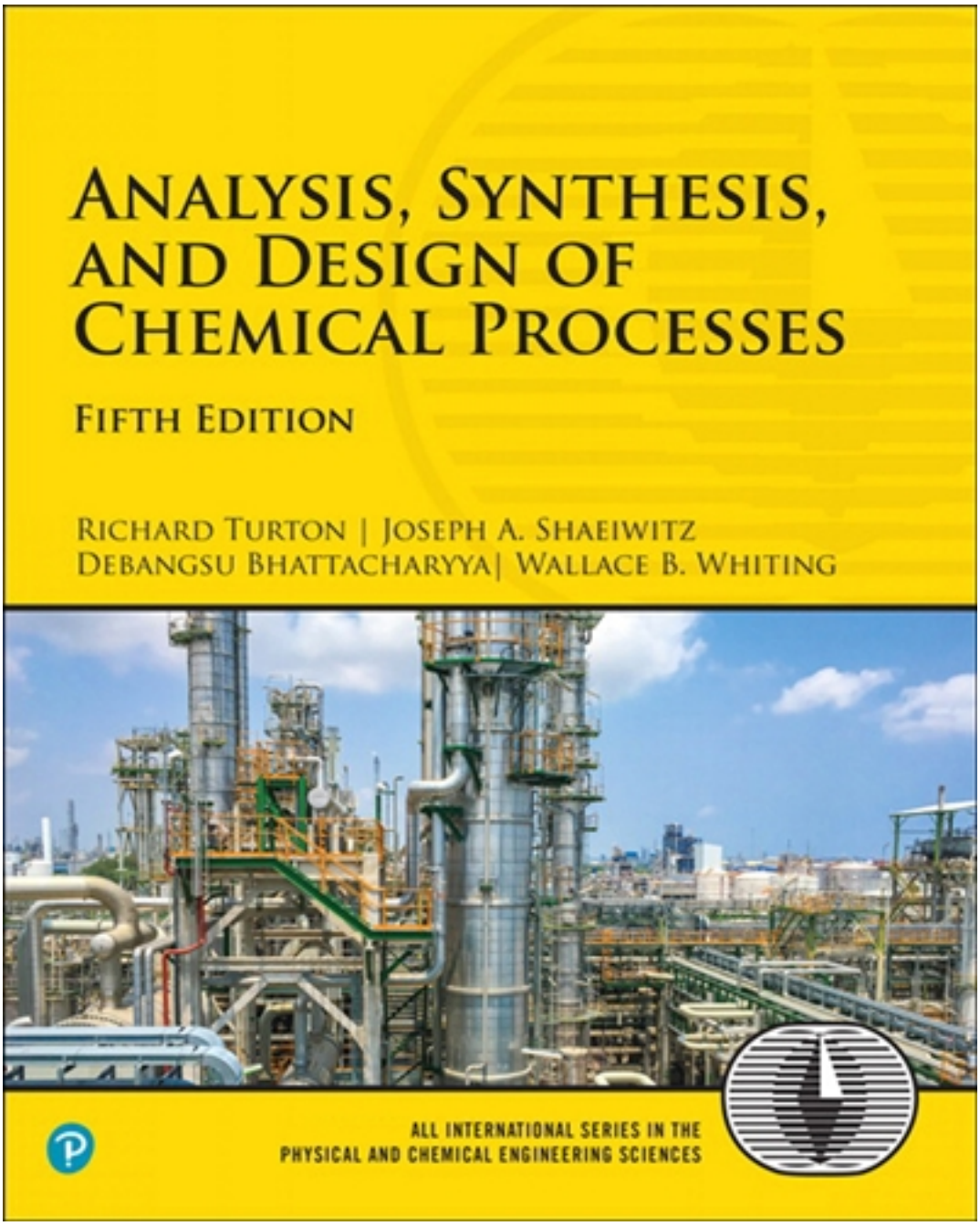

Solutions

Instructor's Manual for

Analysis, Synthesis, and Design of Chemical Processes

Fifth Edition

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CHAPTER 1

SHORT ANSWER QUESTIONS

1.1 Block Flow Diagram (BFD)
Process Flow Diagram (PFD)
Piping and Instrument Diagrams (P&ID)
(a) PFD
(b) BFD
(c) PFD or P&ID
(d) P&ID
(e) P&ID

1.2 P&ID

1.3 It is important for a process engineer to be able to review a 3-dimensional model prior to the construction phase to check for clearance, accessibility, and layout of equipment, piping, and instrumentation.

1.4 Things that would affect the locations of different pieces of equipment when determining the layout of equipment in a process unit

(1) Clearance for tube bundle removal on a heat exchanger.

(2) NPSH on a pump affects the vertical separation of feed vessel and pump inlet.

(3) Accessibility of an instrument for an operator must be able to read a PI or change/move a valve.

(4) Separation between equipment for safety reasons reactors and compressors.

(5) Crane access for removing equipment.

(6) Vertical positioning of equipment to allow for gravity flow of liquid.

(7) Hydrostatic head for thermosiphon reboiler affects height of column skirt.

1.5 Why are accurate plant models (made of plastic parts) no longer made as part of the design process? What function did these models play and how is this function now achieved?
Plastic models are no longer made because they are too expensive and difficult to change/revise. These models have been replaced with virtual/e-models using 3-D CAD. Both types of model allow revision of critical equipment and instrument placement to ensure access, operability, and safety.

1.6 OTS = Operator Training Simulator ITS = Immersive Training Simulator

1.7 Augmented reality refers to a feature of an immersive training system (ITS) where by an operator can obtain additional information about equipment by "peeling back" the wall of a vessel, etc., and looking inside the equipment.

1.8 What are the two principle methods for the layout of process equipment in a chemical plant?
(a) Grade-Mounted, Horizontal, In-line Arrangement and (b) Structure-Mounted Vertical Arrangement

1.9 When is it appropriate to add a flag to a stream in a PFD rather than including the stream in the stream flow table?

When only temperature or pressure changes in the equipment. So for example at the outlet of a pump or the outlet of a heat exchanger. Flags should also be considered around critical equipment for example reactors.

1.10 What problems would you foresee in naming equipment in a process that had a unit number of 10 (for example, pumps starting with P-11, P-12, etc.)?
By having a unit number with only 2 digits (10, 20, 30, etc.), the maximum number of equipment items within an equipment class is 9. For example, pump 11 in unit 20 would become P-31, which could be in conflict with the first pump of unit 30. By numbering units in the hundreds (200, 300, etc.), the maximum number of items in an equipment class is 99 so there will never be a conflict of this type.

1.11 What diagram would you refer to in order to estimate the frictional loss through a certain piping run within a process?
This would require a piping isometric(s) for the whole piping run.

1.12 In the vast majority of cases what is the final control element in a process control loop?

Nearly always, this control element will be a control valve.

1.13 What is the most effective way of communicating information about a process?
Through the use of diagrams (or computer generated models) – but always a visual representation.

1.14 Vessel V-307 is to be replaced in a plant with a vessel that is designed to withstand a higher pressure and which has a larger volume. Should this vessel be numbered V-307 to correspond with the vessel it is replacing? Explain your answer.

Generally, the answer is No. Unless the replacement equipment is essentially identical in function and characteristics to the original equipment a new number should be chosen to avoid confusion when locating information about the equipment. For the case considered in this question, calling the vessel V-307A would probably be ok.

PROBLEMS

1.15 There are two common reasons for elevating the bottom of a tower by means of a "skirt." One reason is to provide enough $NPSH_A$ for bottoms product pumps to avoid cavitation. What is the other reason?

Another reason to elevate the bottom of a tower is to provide enough hydrostatic head driving force to operate a thermosiphon reboiler

1.16 (a) PFD or P&ID
(b) PFD
(c) PFD
(d) P&ID
(e) BFD (or all PFDs)

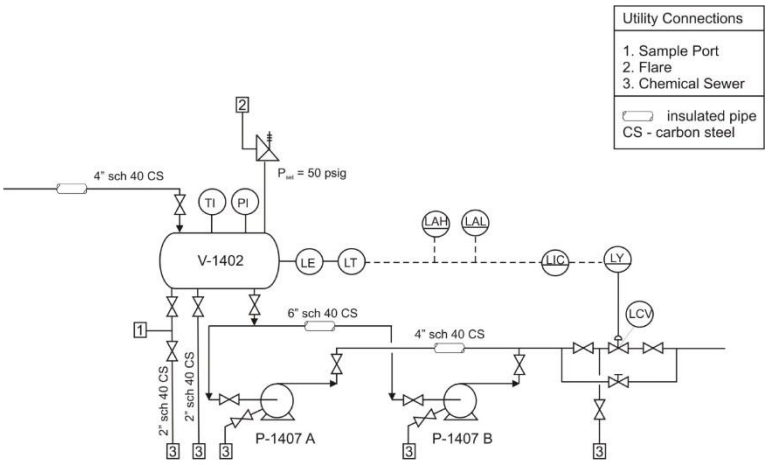
1.17 A pipe rack provides a clear path for piping within and between processes. It keeps piping off the ground to eliminate tripping hazards and elevates it above roads to allow vehicle access.

1.18 A structure mounted vertical plant layout is preferred when land is at a premium and the process must have a small foot print. The disadvantage is that it is more costly because of the additional structural steel.

1.19 (a) BFD - No change
PFD - Efficiency changed on fired heater, resize any heat exchanger used to extract heat from the flue gas (economizer)
P&ID - Resize fuel and combustion air lines and instrumentation for utilities to fired heater. Changes for design changed of economizer (if present)
(b) BFD - Change flow of waste stream in overall material balance
PFD - Change stream table
P&ID Change pipe size and any instrumentation for this process line
(c) BFD - No change
PFD - Add a spare drive, e.g. D-301 → D-301 A/B
P&ID - Add parallel drive
(d) BFD - No change
PFD - No change
P&ID - Note changes of valves on diagram

1.20 (a) A new vessel number need not be used, but it would be good practice to add a letter to donate a new vessel, e.g. V-203 → V-203N. This will enable an engineer to locate the new process vessel sheet and vendor information.
(b) P&ID definitely
PFD change/add the identifying letter.

1.21



Solution to Problem 1.21

1.22 (a) (i) Open globe valve d

(ii) Shut off gate valves a and c

(iii) Open gate valve e and drain contents of isolated line to sewer

(iv) Perform necessary maintenance on control valve b

(v) Reconnect control valve b and close gate valve e

(vi) Open gate valves a and c

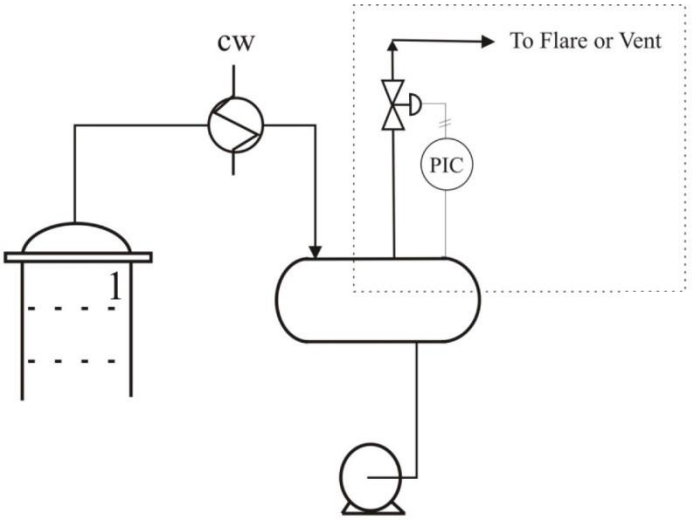
(vii) Close globe valve d

(b) Drain from valve e can go to regular or oily water sewer.

(c) Replacing valve d with a gate valve would not be a good idea because we loose the ability to control the flow of process fluid during the maintenance operation.

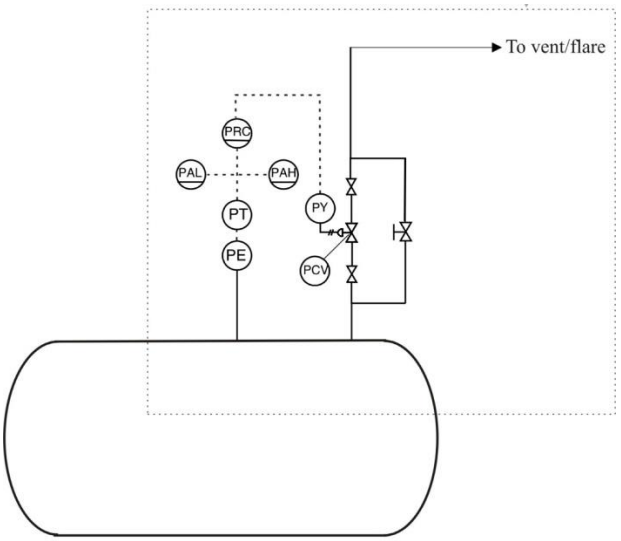
(d) If valve d is eliminated then the process must be shut down every time maintenance is required on the control valve.

1.23



Solution to Problem 1.23

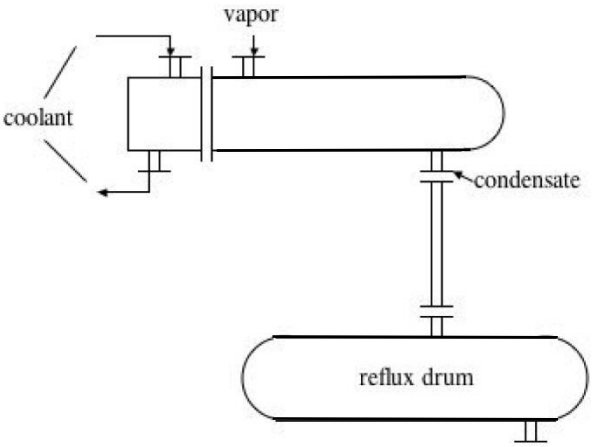
1.24



Solution to Problem 1.24

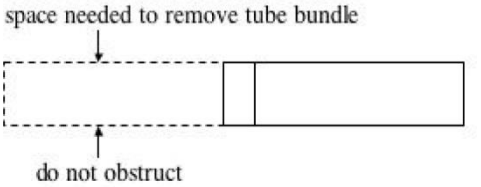
1.25 (a) For a pump with a large NPSH, the vertical distance between the feed vessel and the pump inlet must be large in order to provide the static head required to avoid cavitating the pump.

(b) Place the overhead condenser vertically above the reflux drum, the bottom shell outlet on the condenser should feed directly into the vertical drum.



(c) Pumps and control valves should always be placed either at ground level (always for pumps) or near a platform (sometimes for control valves) to allow access for maintenance.

(d) Arrange shell and tube exchangers so that no other equipment or structural steel impedes the removal of the bundle.



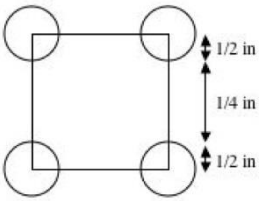
(e) This is why we have pipe racks never have pipe runs on the ground. Always elevate pipes and place on rack.

(f) Locate plant to the east of major communities.

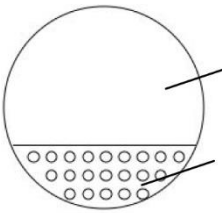
1.26 HT area of 1 tube $= \pi DL = \pi\left(\frac{1}{12}\right)(12\text{ft}) = 3.142\,\text{ft}^2$

Number of tubes $= (145\text{m}^2)\left(\frac{3.2808\text{ft}}{\text{m}}\right)^2\left(\frac{1}{3.142\text{ft}^2}\right) = 497$ tubes

Use a 1¼-inch square pitch ⇒



Fractional area of the tubes $= \frac{\pi}{4}\left(\frac{1}{1.25}\right)^2 = 0.5027$



$$A_{VAP} = 3\,A_{LIQ} \therefore CSA_{SHELL} = 4\,A_{LIQ}$$

$$A_{LIQ} = \left(\frac{497}{0.5027}\right)\left(\frac{\text{in}}{\text{m}}\right)^2\left(\frac{\pi}{4}\right)(1\text{ m})^2 = 777\text{ in}^2$$

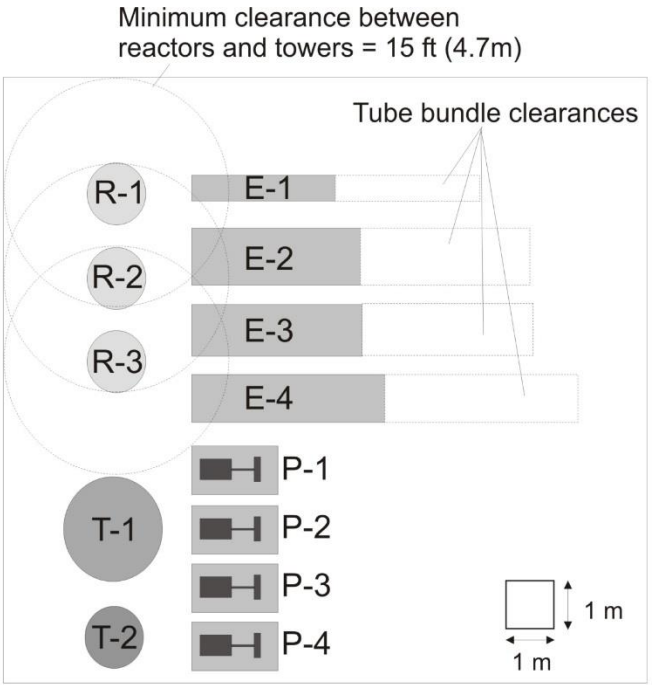
$$CSA_{SHELL} = (4)(777) = 3108\text{in}^2 \Rightarrow \frac{\pi}{4}D_{SHELL}^2 = 3108\text{in}^2$$

$$D_{SHELL} = \sqrt{\frac{(4)(3108\text{in}^2)}{\pi}} = 62.9\text{in} = 1.598\text{m}$$

Length of Heat Exchanger = (2 + 12 + 2) ft = 16 ft = 4.877 m

Foot Print = 1.598 × 4.877 m

1.27 From Table 1.11 towers and reactors should have a minimum separation of 15 feet or 4.6 m and no other restrictions apply. See sketch for details.

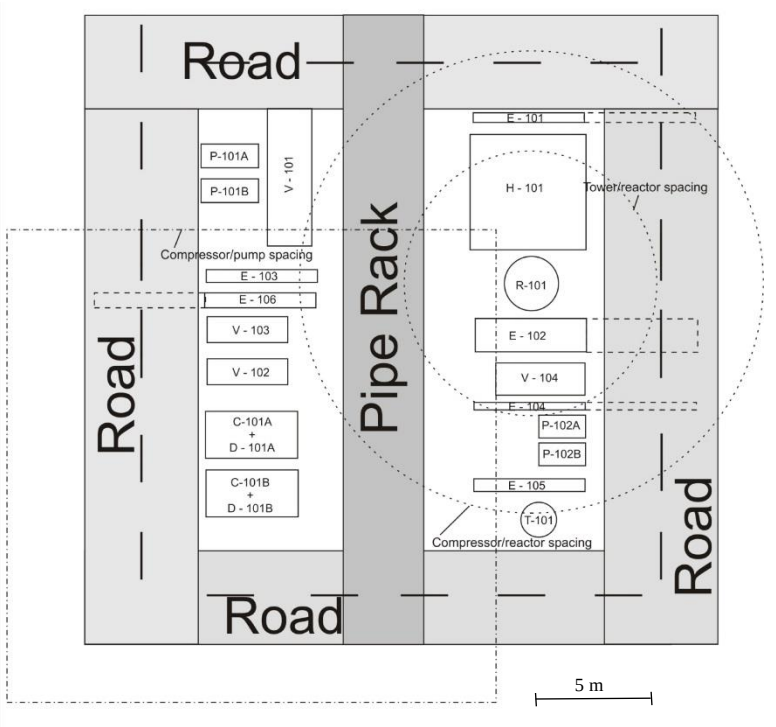


Solution to Problem 1.27

1.28

For shell and tube exchangers							
Assume 12 ft 1.25" tubes on a 1.5" square pitch							
Area per tube	3.9270	ft2	0.3648	m^2			
fractional area of tubes			0.5454				
assume length of shell = tube length + 2 + 2 = 16 ft							
For double pipe exchangers (E-103 and E-105)							
Outer pipe diameter = 8" Sch 20 = 8.125"							
inner pipe diameter = 6" sch 40	6.065	inch		0.1541	m		
length of pipe	12	ft					
HT Area per single run of pipe			1.7702	m^2			
HT per 4 pass unit			7.0806	m^2			
length of 1 unit - 4 stacked Double pipes with U-bends				16	ft		
width of multiple units - assume that units are spaced 1 foot apart							
	E-101	**E-102**	**E-103**	**E-104**	**E-105**	**E-106**	
Area	36	763	11	35	12	80	
number of tubes	99	2092		96		220	
Number of units			1.5535		1.69477		
Shell pass	1	1		1		1	
Tube pass	1	2		2		1	
CSA of tubes	0.0784	0.8282		0.0380		0.1742	m^2
CSA of Shell	0.1437	1.5184		0.0697		0.3194	m^2
Shell Diameter	0.4278	1.3904		0.2979		0.6377	m
length	16	16	16	16	16	16	ft
length	4.9	4.9	4.9	4.9	4.9	4.9	m
Foot print							
L	**4.9**	**4.9**	**4.9**	**4.9**	**4.9**	**4.9**	**m**
W	**0.43**	**1.39**	**0.51**	**0.30**	**0.51**	**0.64**	**m**
Vessels, Towers and Reactor							
	V-101	**V-102**	**V-103**	**V-104**	**T-101**	**R-101**	
Foot print							
L	**5.9**	**3.5**	**3.5**	**3.9**			**m**
W	**1.9**	**1.1**	**1.1**	**1.3**			**m**
D					**1.5**	**2.3**	**m**
Pumps and Compressors							
	P-101	**P-102**	**C-101+D-101**				
Foot print							
L	**2.5**	**2**	**4**	**m**			
W	**1**	**1**	**2**	**m**			
Fired Heater							
Foot print	**H-101**						
L	**5**	**m**					
W	**5**	**m**					

1.29



1.30 (a) A temperature (sensing) element (TE) in the plant is connected via a capillary line to a temperature transmitter (TT) also located in the plant. The TT sends an electrical signal to temperature high (TAH) and temperature low (TAL) alarms located on the front of a panel in the control room.

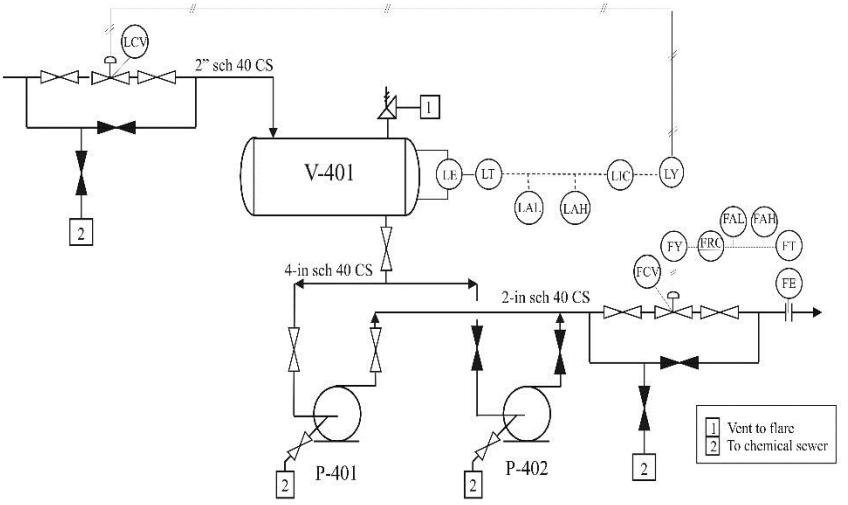
(b) A level switch (LS) located in the plant sends an electrical signal to …

(c) A pressure control valve (LCV) located in the plant is connected by a pneumatic (air) line to the stem of a control valve.

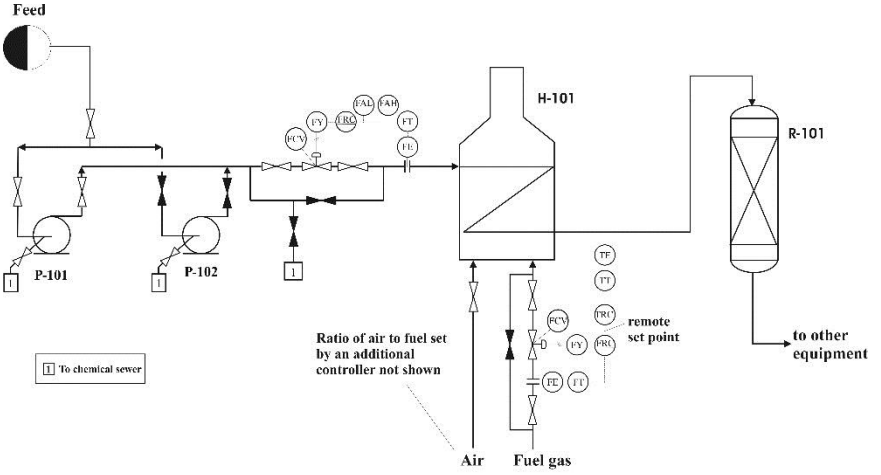
(d) A local flow indicator (FI) is attached to a flow orifice both instruments are located in the plant.

(e) A safety (pressure) relief valve is shown attached to two process lines. The top process line appears to vent to atmosphere but could be attached to a flare system – there is not enough information to determine this based on the sketch provided.

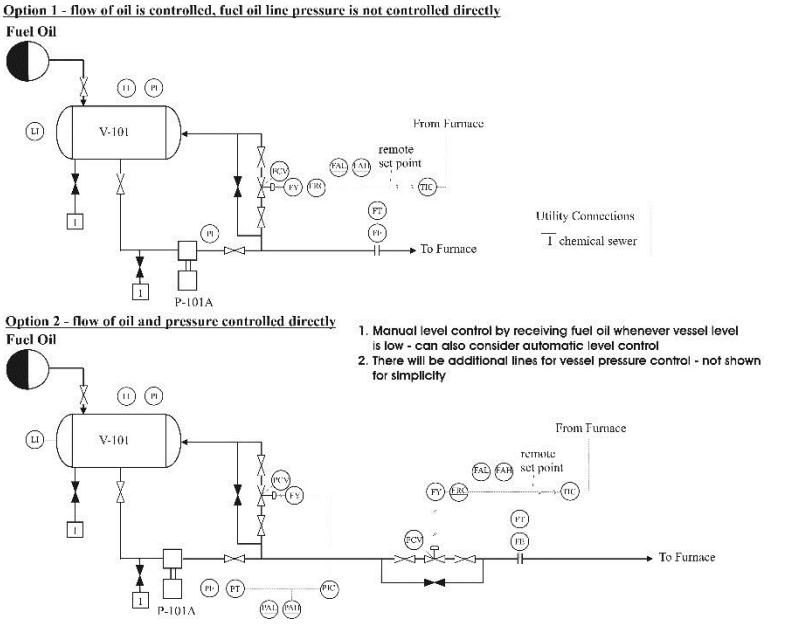
1.31



1.32



1.33



1.34