458.401 Process & Product Design

01

Diagrams for Understanding Chemical Processes

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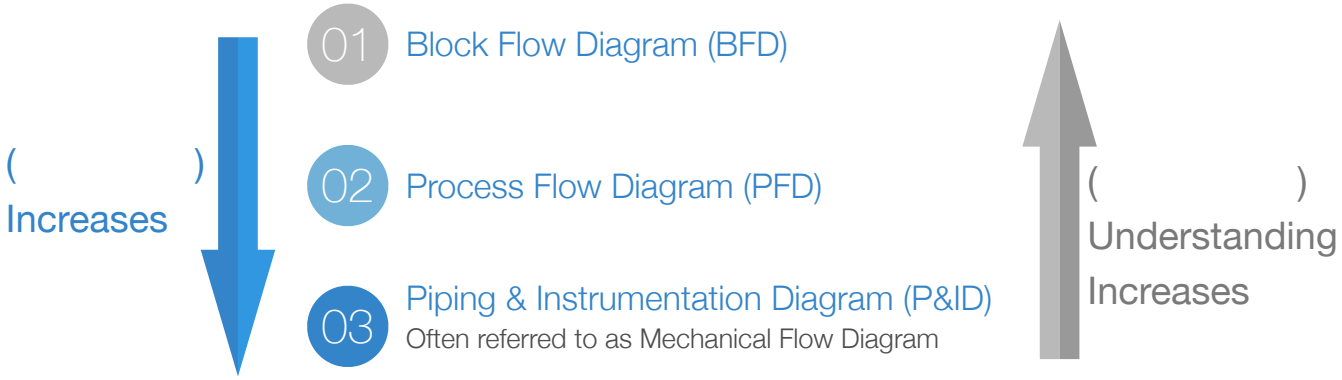
3 Levels of Diagram

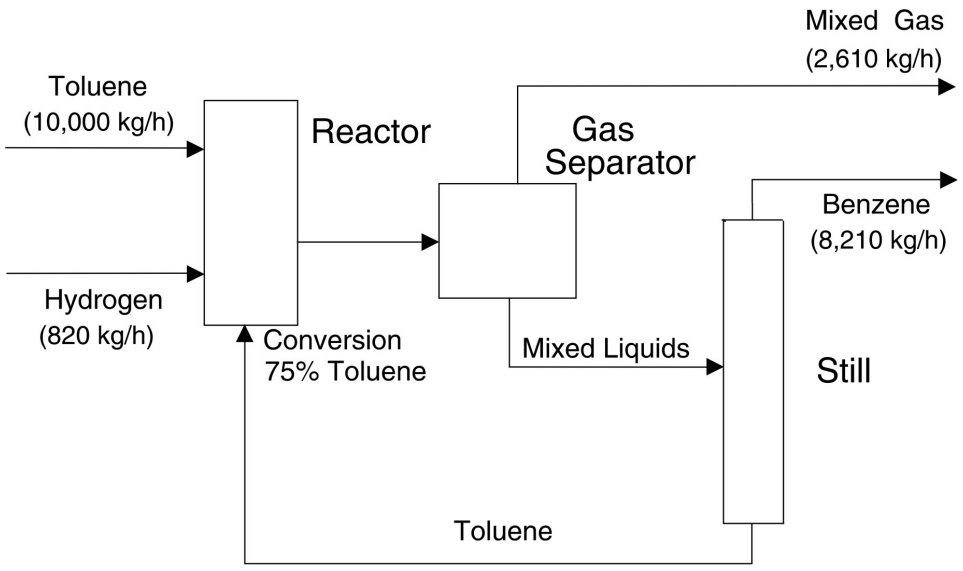


As chemical engineers, we are most familiar with BFD and PFD

The Block Flow Diagram (BFD)

- BFD shows overall processing picture of a chemical complex
  - Flow of raw materials and products may be included on a BFD
  - BFD is a superficial view of facility - ChE information is missing
- Block Flow Process Diagram (Fig. 1.1)
  - Similar to sketches in material and energy balances
- Block Flow Plant Diagram (Fig. 1.2)
  - Gives a general view of a large complex plant

Block Flow Process Diagram for the Production of Benzene



Reaction : $C_7H_8 + H_2 = C_6H_6 + CH_4$

The Process Flow Diagram

- PFD shows all process engineering information
  - Often PFD is drawn on larger paper; textbook breaks down information into 1 diagram and 2 tables
  - The topology of the process: showing the connectivity of all the streams and the equipment
    - Example for toluene HDA - Figures 1.3 and 1.5
    - Tables 1.2 and 1.4 - list information that should be on the PFD but cannot fit
    - Use appropriate conventions - consistency is important in communication of process information
      ex. Table 1.2

Equipment Numbering

- XX-YZZ A/B/…
  - XX represents a 1- or 2-letter designation for the equipment (P = pump)
  - Y is the 1 or 2 digit unit number (1 - 99)
  - ZZ designates the equipment number for the unit (1 - 99)
  - A/B/… represents the presence of spare equipment
- Use unambiguous letters for new equipment
  - Ex. Turbine: use Tb or J not T (for tower)
  - Replace old vessel V-302 with a new one of different design; use V-319 (say) not V-302 since it may be confused with original V-302

Example-01

What would be an equipment numbering for

i) the 5th tower in unit nine hundred, and

ii) the 1st pump in unit three hundred plus a spare?

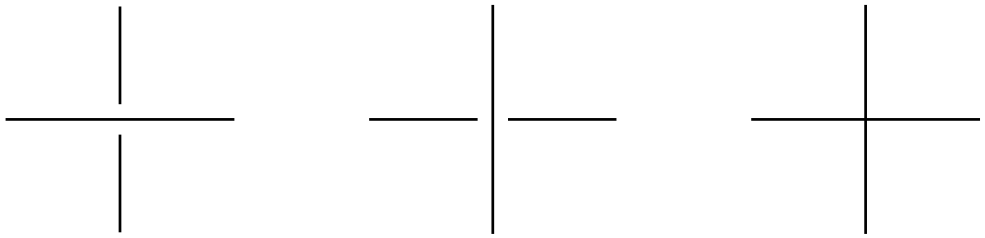
Example-02

You found serious fluctuations in pressure drop of E-102, which are attributable to two-phase mixture from partial condensing. Hence, you decided to replace E-102 with two separate heat exchangers. What numbering is appropriate for these two new heat exchangers?

a) E-102A and E-102B
b) E-102 A/B
c) E-106 and E-107
d) E-107 and E-108

Stream Numbering and Drawing

- Number streams from left to right as much as possible
- Horizontal lines are dominant



YES NO NO

- Add arrows for change in direction and inlet of equipment
- Utility streams should use convention given in Table 1.3, lps, cw, fg, etc.

Stream Information

- Since diagrams are small, not much stream information can be included
- Include important data - around reactors and towers, etc.
  - Flags are used - see toluene HDA diagram
  - Full stream data, as indicated in Table 1.4, are included in a separate flow summary table (See Table 1.5)

A Portion of Table 1.5

Stream Number	1	2	3	4	5	6	7	8	9	10
Temperature (°C)	25	59	25	225	41	600	41	38	654	90
Pressure (bar)	1.90	25.8	25.5	25.2	25.5	25.0	25.5	23.9	24.0	2.6
Vapor Fraction	0.0	0.0	1.00	1.0	1.0	1.0	1.0	1.0	1.0	0.0
Mass Flow (tonne/h)	10.0	13.3	0.82	20.5	6.41	20.5	0.36	9.2	20.9	11.6
Mole Flow (kmol/h)	108.7	144.2	301.0	1204.4	758.8	1204.4	42.6	1100.8	1247.0	142.2
Component Mole Flow (kmol/h)										
Hydrogen	0.0	0.0	286.0	735.4	449.4	735.4	25.2	651.9	652.6	0.02
Methane	0.0	0.0	15.0	317.3	302.2	317.3	16.95	438.3	442.3	0.88
Benzene	0.0	1.0	0.0	7.6	6.6	7.6	0.37	9.55	116.0	106.3
Toluene	108.7	143.2	0.0	144.0	0.7	144.0	0.04	1.05	36.0	35.0

Equipment Information

- Equipment are identified by number and a label (name) positioned above the equipment on the PFD
- Basic data such as size and key data are included in a separate table (Equipment Summary Table) Table 1.7 (and Table 1.6) in textbook

Vessel	V-101	V-102
Temperature (°C)	55	38
Pressure (bar)	2.0	24
Orientation	Horizontal	Vertical
MOC	CS	CS
Size		
Height/Length (m)	5.9	3.5
Diameter (m)	1.9	1.1
Internals		s.p. (splash plate)

PFD Summary

- PFD, Equipment Summary Table, and Flow Summary Table represent a true PFD
- This information is sufficient for a preliminary estimation of capital investment (Chapter 7) and cost of manufacture (Chapter 8) to be made

The Piping and Instrument Diagram (P&ID)

- P&ID - Construction Bible
- Contains: plant construction information: piping, process, instrumentation, and other diagrams
- P&ID information is explained in Tables 1.8 and 1.9
- Conventions for instrumentation are shown in Figure 1.10

Look at V-102 on P&ID

- V-102 contains an LE (Level Element)
- LE senses liquid level in separator (reflux drum) and adjusts flow rate leaving
- LE opens and closes a valve depending on liquid level (control logic)
- LE and valve represent a feedback control loop

Example-04

Heuristics for Equipment Sizing

What should be the pipe diameter of the suction line to P-202 A/B?

Figure B.1.1 of Turton's

Solution-04

From Table 11.8, 1(b) for liquid pump suction, the recommended velocity is

$$u = (1.3 + D\ (\text{in})/6)\ [\text{ft/s}] \qquad (1)$$

The mass flow rate of the stream entering P-202 = Stream ( ) + Stream ( ) = ( ) kg/h

The density is found to be 800 kg/m^3

The volumetric flow rate is 8140/800 = 10.2 m^3/h = 0.0998 ft^3/s

Nominal Pipe Diameter (inch)	Velocity (ft/s)	Velocity from (1)
1.0	18.30	1.47
1.5	8.13	1.55
2.0	4.58	1.63
3.0	2.03	1.80
4.0		

Other Common Diagrams

- Plot Plans - plan or map drawn looking down on plant (drawn to scale with all major equipment identified)
- Elevation Diagrams - show view from side and give information about equipments distance from ground

Figure 1.11

Section of Plot Plan

Figure 1.12

Section of Elevation Diagram

Other Common Diagrams

- Piping Isometrics - show piping in 3-dimensions
- Vessel Sketches - show key dimensions of equipment and locations of inlet and outlet nozzles, etc.

Figure 1.13

Scale Models and Virtual Plants

- 25 years ago physical models were used for review
- Now virtual or electronic models are generated using software (3D plant diagrams)
- Purpose of Models - catch errors such as
  - Piping clashes
  - Misaligned piping
  - Equipment not easily accessed
  - Sample points not easily reached by operators