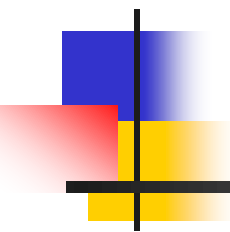
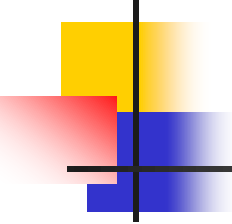


Chapter 1 - Chemical Process Diagrams

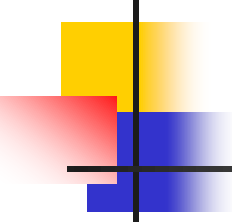


Department of Chemical Engineering
West Virginia University



Outline

- Flow Diagrams
 - Block Flow Diagrams (BFD)
 - Process Flow Diagrams (PFD)
 - Piping and Instrument Diagrams (P&ID)
- Other common diagrams
- 3-D plant layout diagrams



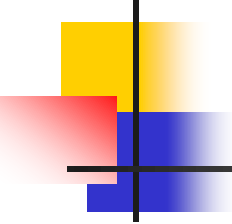
3 Levels of Diagram

- Block Flow Diagram (BFD)
- Process Flow Diagram (PFD)
- Piping and Instrumentation Diagram (P&ID) – often referred to as Mechanical Flow Diagram

↑ Complexity
increases

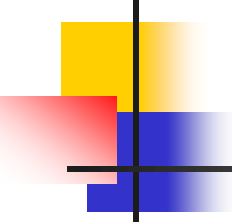
↑ Conceptual
understanding
increases

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



Definitions of BFD

- Block Flow Process Diagram
 - Figure 1.1
 - Similar to sketches in material and energy balances
- Block Flow Plant Diagram
 - Figure 1.2
 - Gives a general view of a large complex plant

The Block Flow Process Diagram

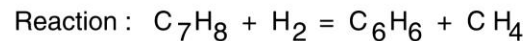
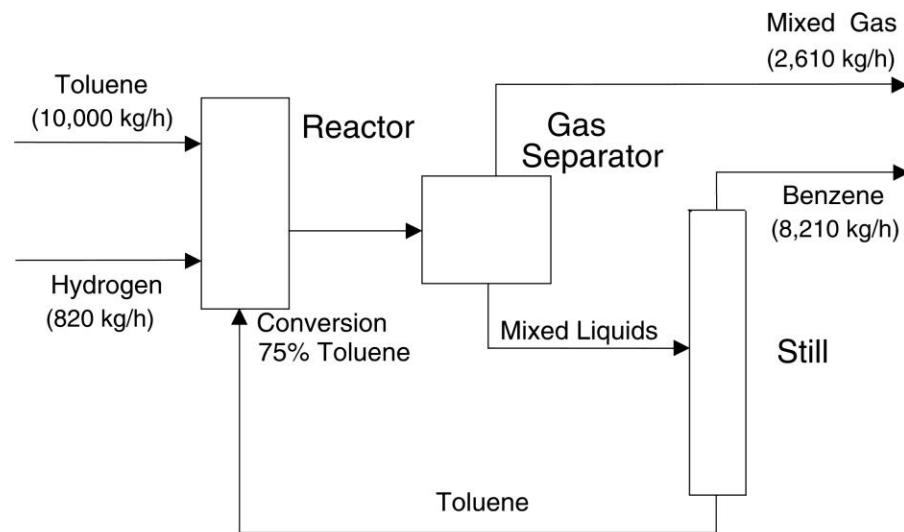
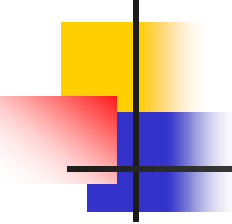
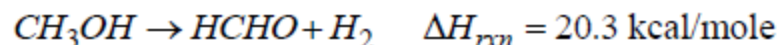
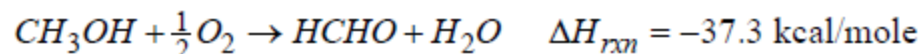


Figure 1.1: Block Flow Process Diagram for the Production of Benzene



Developing a Process



- Target product is 37% formaldehyde in water. Known as formalin
- Occurs of a silver catalyst at 200 °C and 2 – 3 atm pressure
- Reaction 1 is the predominant reaction
- Develop a block flow diagram that describes the process
- B.P. Pure formaldehyde = -19.3 °C
B.P. Formalin = 96 °C

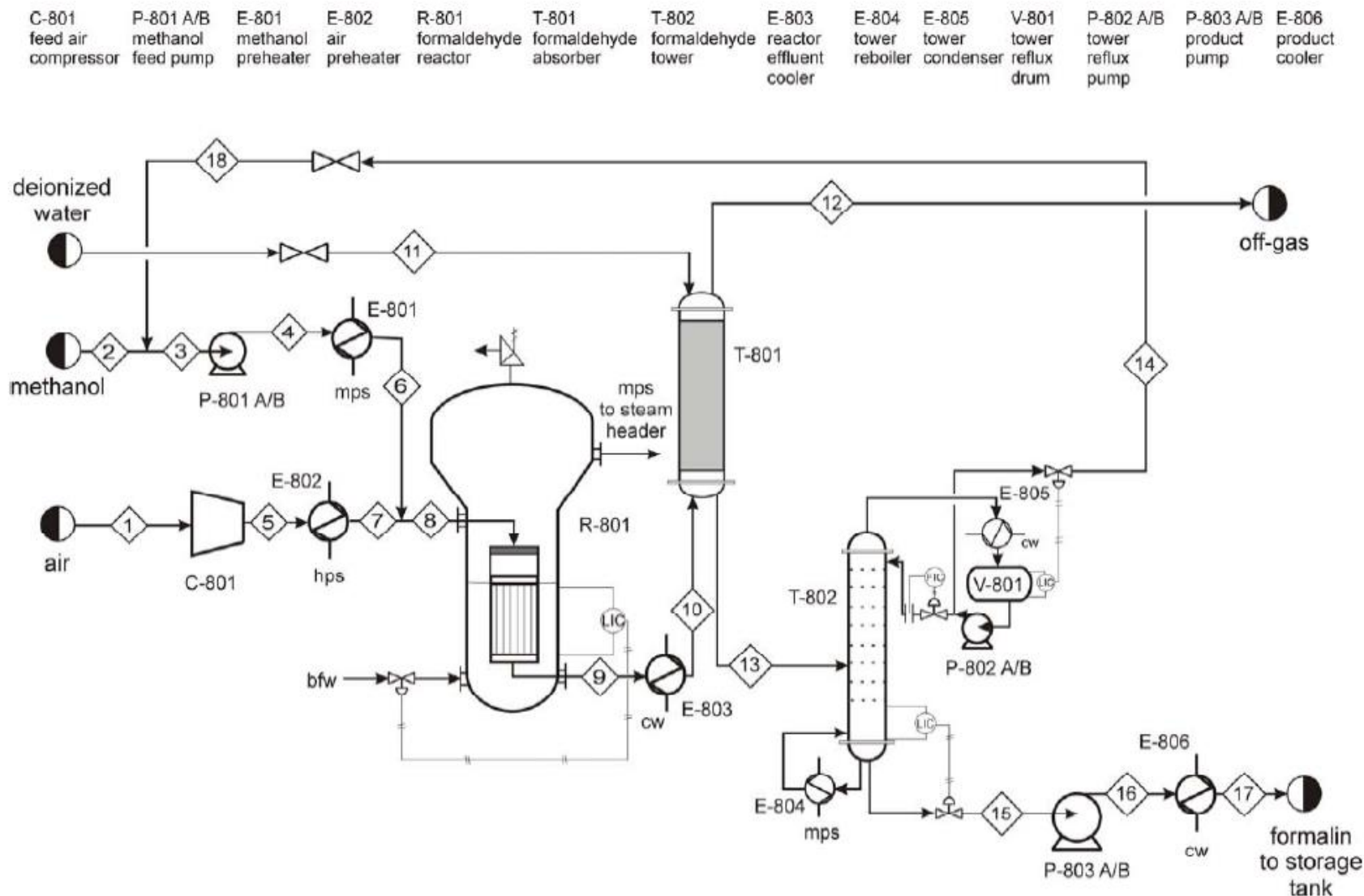


Figure 1: Unit 800 Formalin Production from Methanol

The Block Flow Plant Diagram

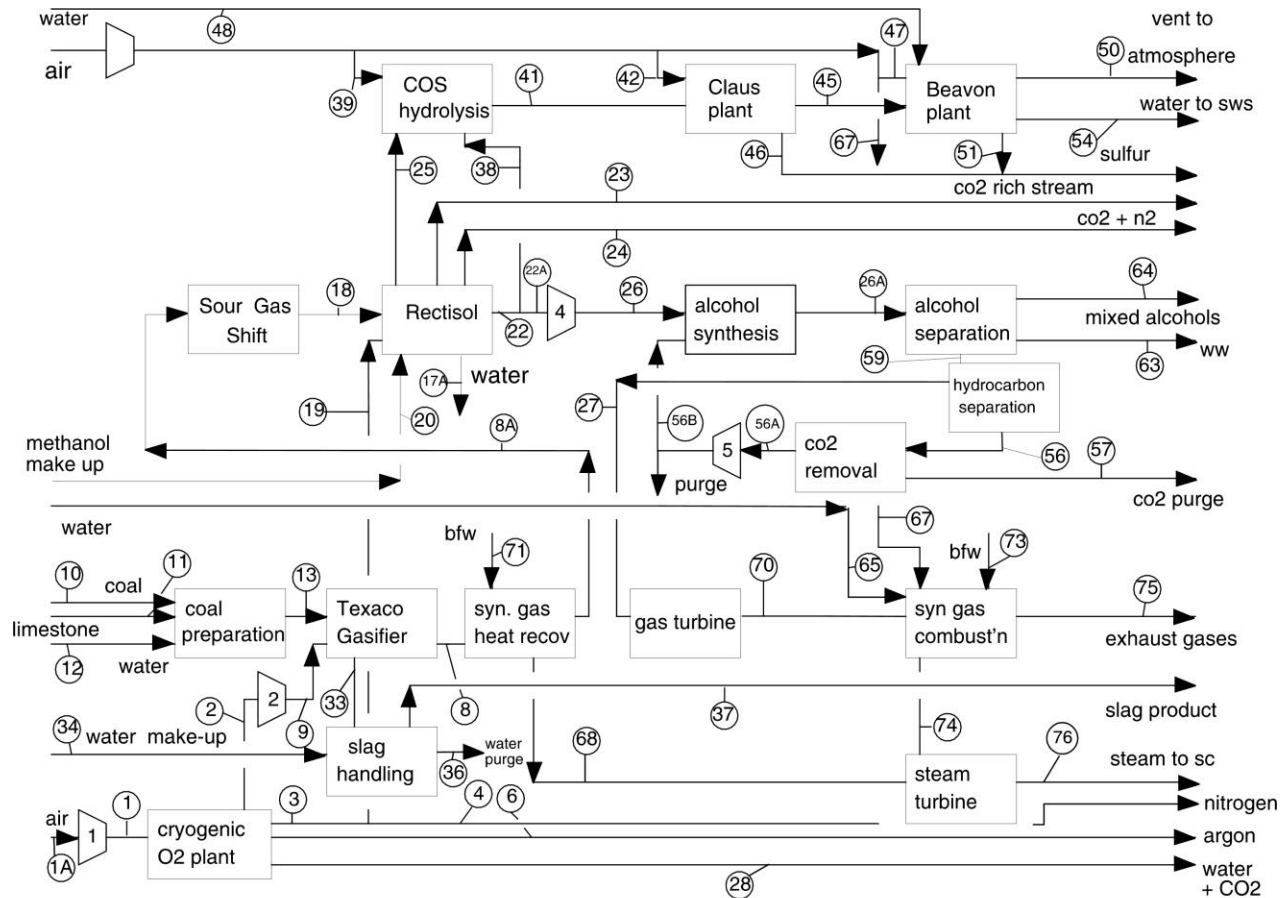
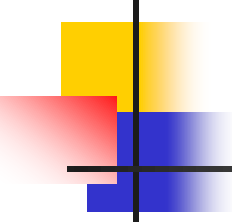
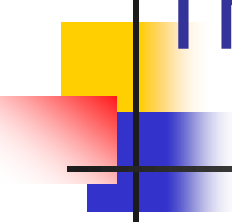


Figure 1.2: Block Flow Plant Diagram of a Coal to Higher Alcohol Fuels Process



The Process Flow Diagram

- PFD shows all process engineering information
 - Diagram developed in junior year design projects (especially the 2nd semester)
 - Often PFD is drawn on large paper – textbook breaks down information into 1 diagram and 2 tables



The Process Flow Diagram (cont'd)

- 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

The Process Flow Diagram (cont'd)

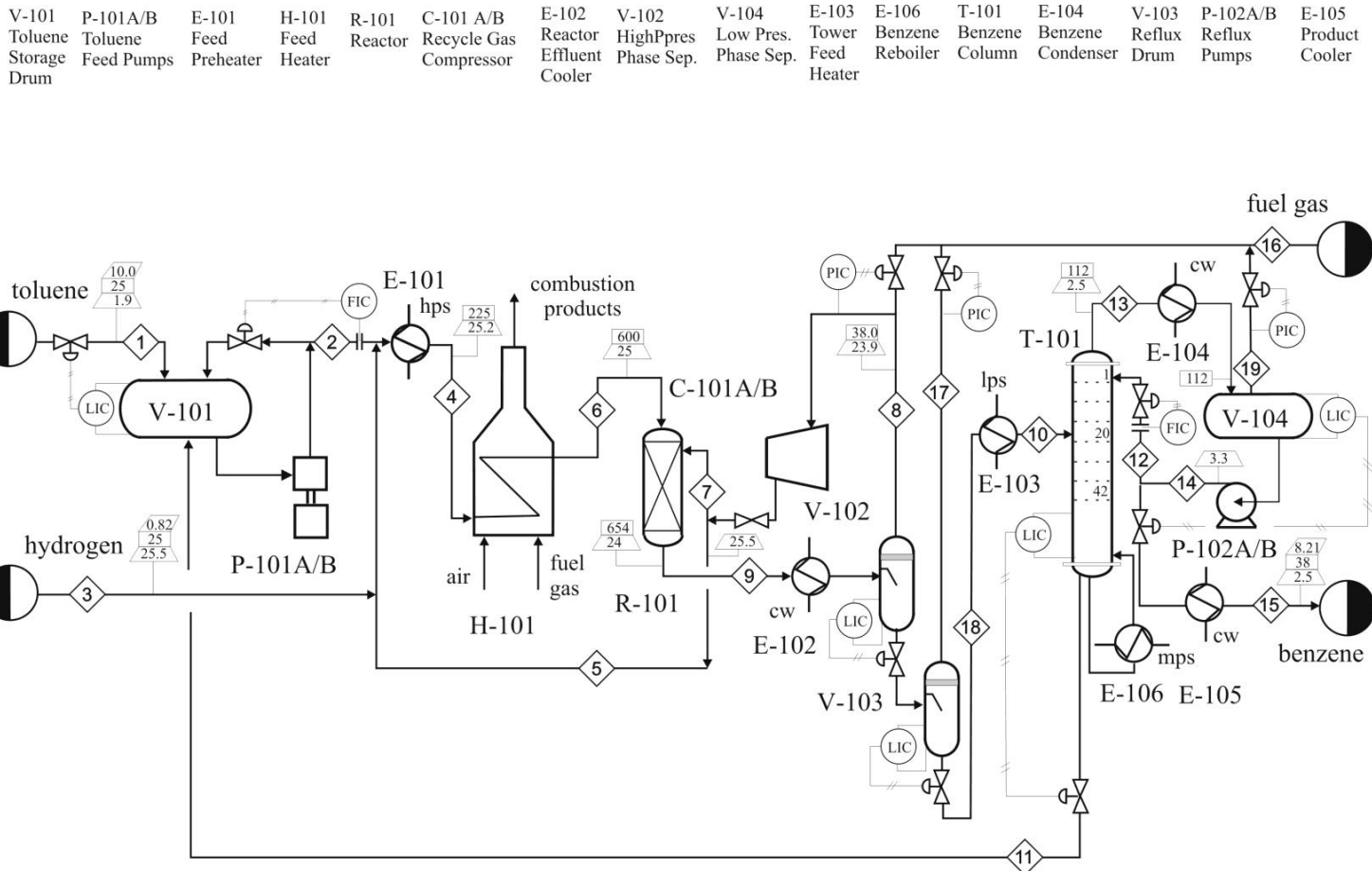


Figure 1.5: Process flow diagram (PFD) for the production of benzene via the hydrodealkylation of toluene

The Process Flow Diagram (cont'd)

Table 1.2 : Conventions Used for Identifying Process Equipment

Process Equipment

General Format **XX-YYY A/B**

XX are the identification letters for the equipment classification

C - Compressor or Turbine

E - Heat Exchanger

H - Fired Heater

P - Pump

R - Reactor

T - Tower

TK - Storage Tank

V - Vessel

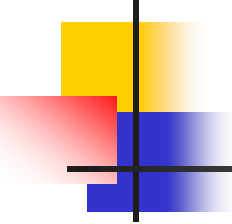
Y designates an area within the plant

ZZ are the number designation for each item in an equipment class

A/B identifies parallel units or backup units not shown on a PFD

Supplemental
Information

Additional description of equipment given on top of PFD



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

V-101	P-101A/B	E-101	H-101	R-101	C-101 A/B	E-102	V-102	V-104	E-103	E-106	T-101	E-104	V-103	P-102A/B	E-105
Toluene	Toluene	Feed	Feed	Reactor	Recycle Gas	Reactor	HighPres	Low Pres.	Tower	Benzene	Benzene	Benzene	Reflux	Reflux	Product
Storage	Feed Pumps	Preheater	Heater		Compressor	Effluent	Phase Sep.	Phase Sep.	Feed	Reboiler	Column	Condenser	Drum	Pumps	Cooler
Drum						Cooler			Heater						

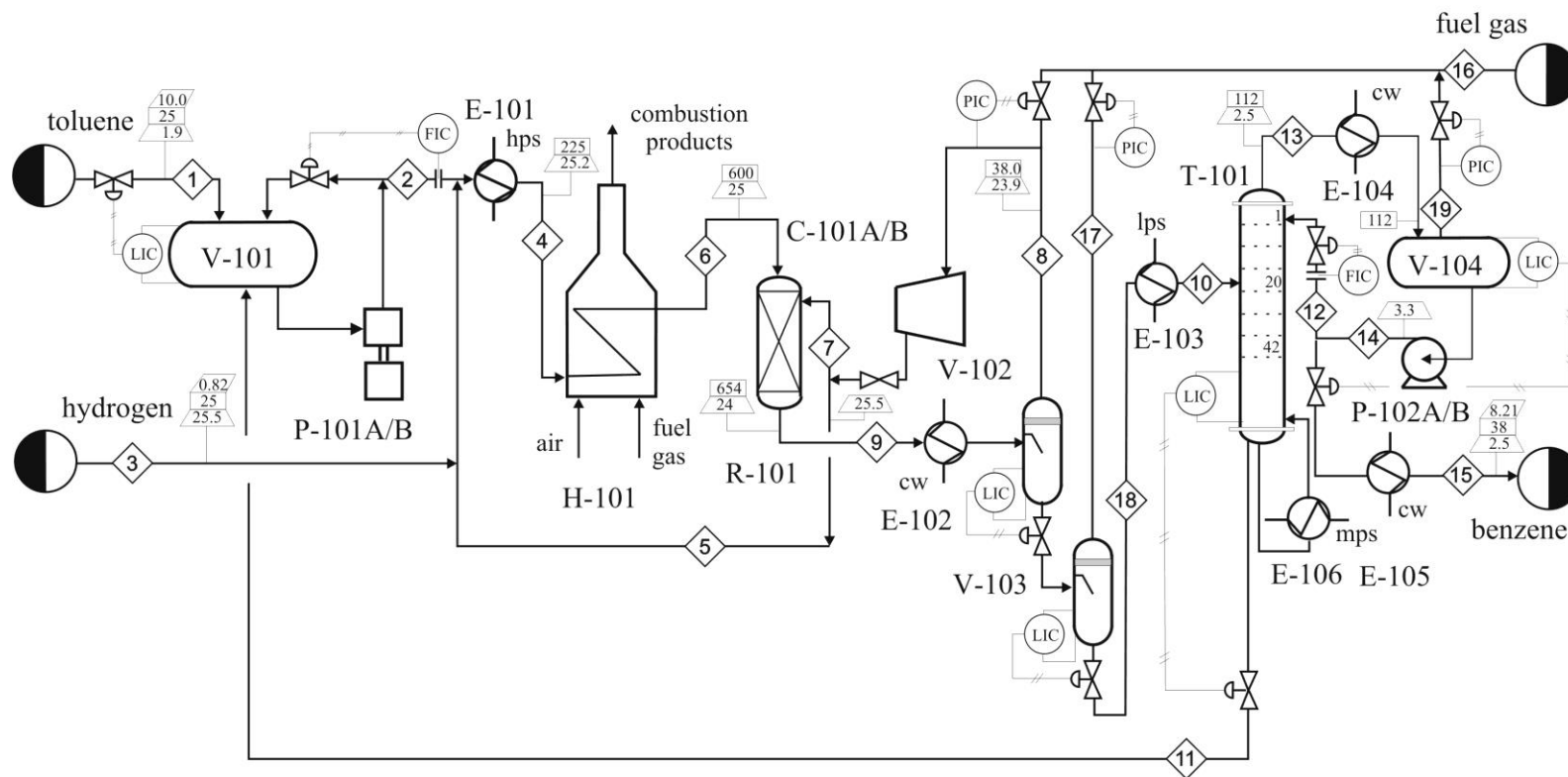
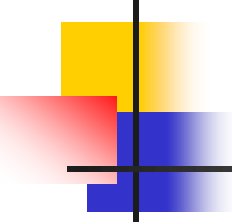


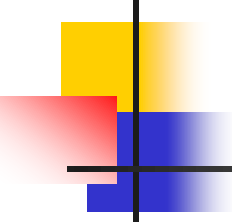
Figure 1.5: Process flow diagram (PFD) for the production of benzene via the hydrodealkylation of toluene



Equipment Numbering (cont'd)

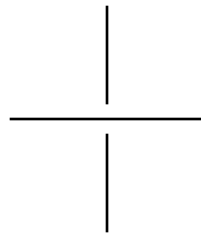
Thus, T-905 is the 5th tower in unit nine hundred P-301 A/B is the 1st Pump in unit three hundred plus a spare

- Use unambiguous letters for new equipment
 - Ex. Turbine use Tb or J not T (used for tower)
 - Replace old vessel V-302 with a new one of different design - use V-319 (e.g.) not V-302 – since it may be confused with original V-302

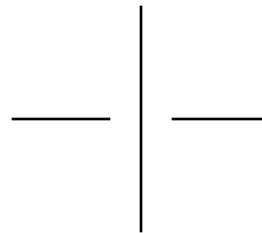


Stream Numbering and Drawing

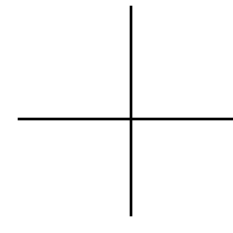
- Number streams from left to right as much as possible
- Horizontal lines are dominant



yes



no



no

V-101	P-101A/B	E-101	H-101	R-101	C-101 A/B	E-102	V-102	V-104	E-103	E-106	T-101	E-104	V-103	P-102A/B	E-105
Toluene	Toluene	Feed	Feed	Reactor	Recycle Gas	Reactor	HighPres	Low Pres.	Tower	Benzene	Benzene	Benzene	Reflux	Reflux	Product
Storage	Feed Pumps	Preheater	Heater		Compressor	Effluent	Phase Sep.	Phase Sep.	Feed	Reboiler	Column	Condenser	Drum	Pumps	Cooler
Drum						Cooler			Heater						

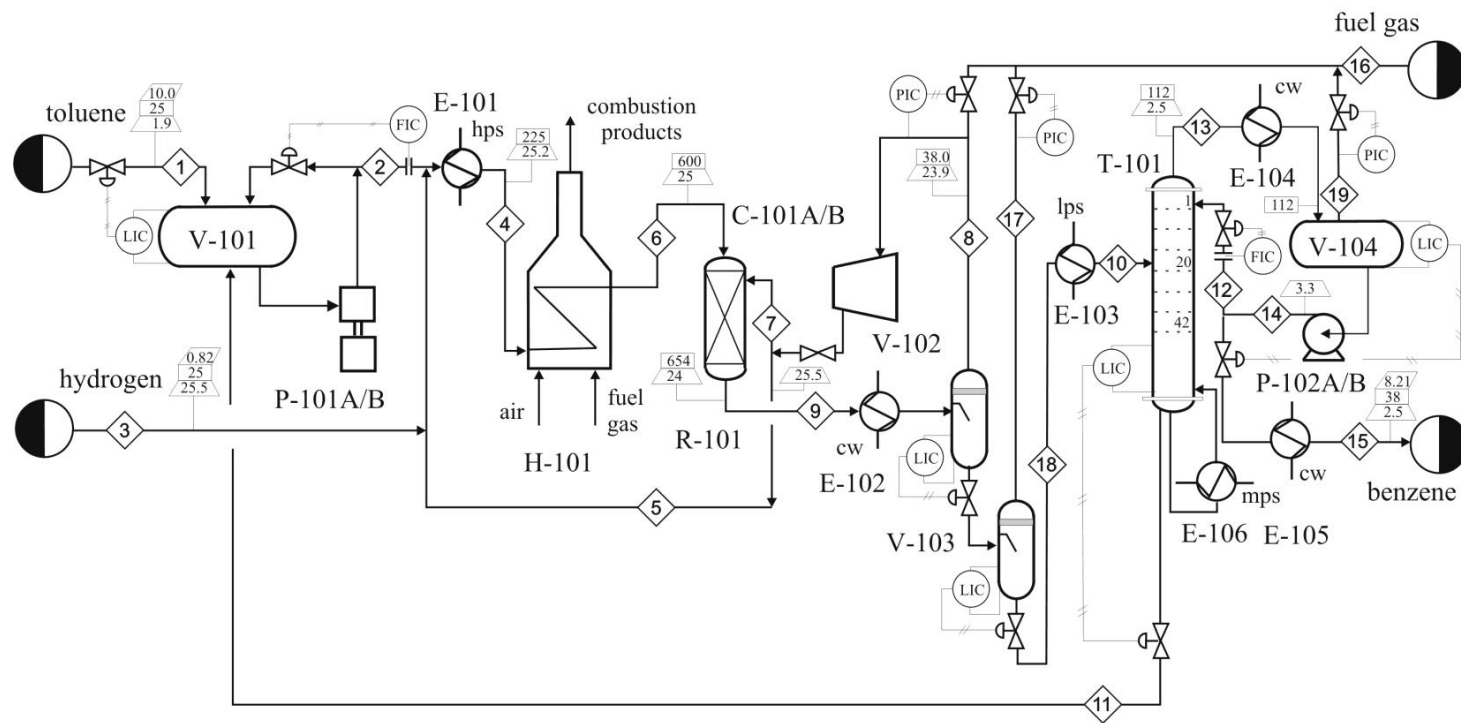
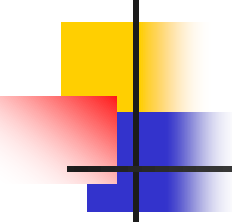
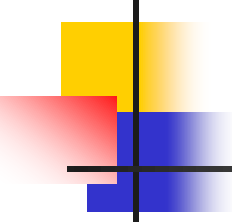


Figure 1.5: Process flow diagram (PFD) for the production of benzene via the hydrodealkylation of toluene



Stream Numbering and Drawing (cont'd)

- Add arrows for
 - Change in direction
 - 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

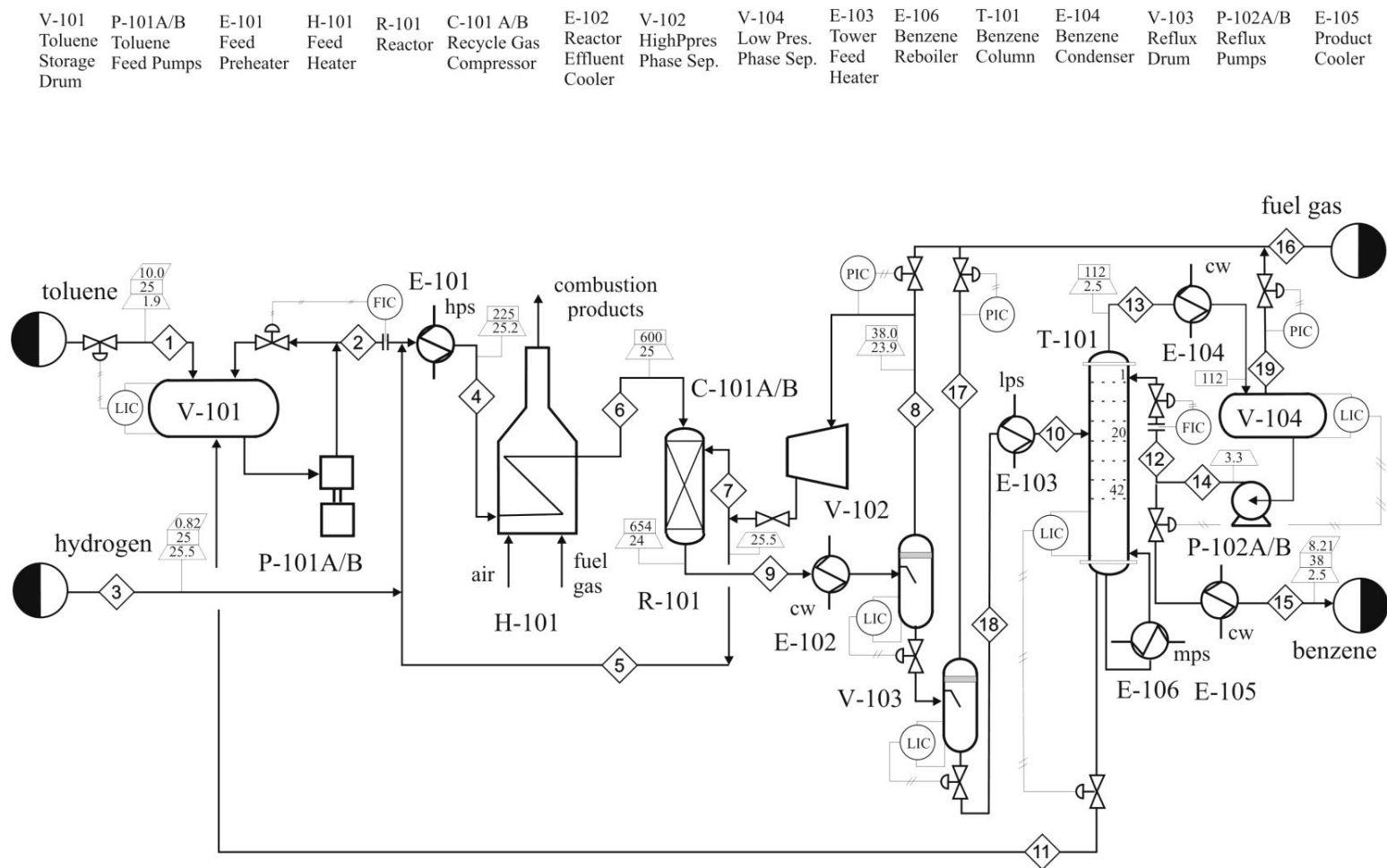
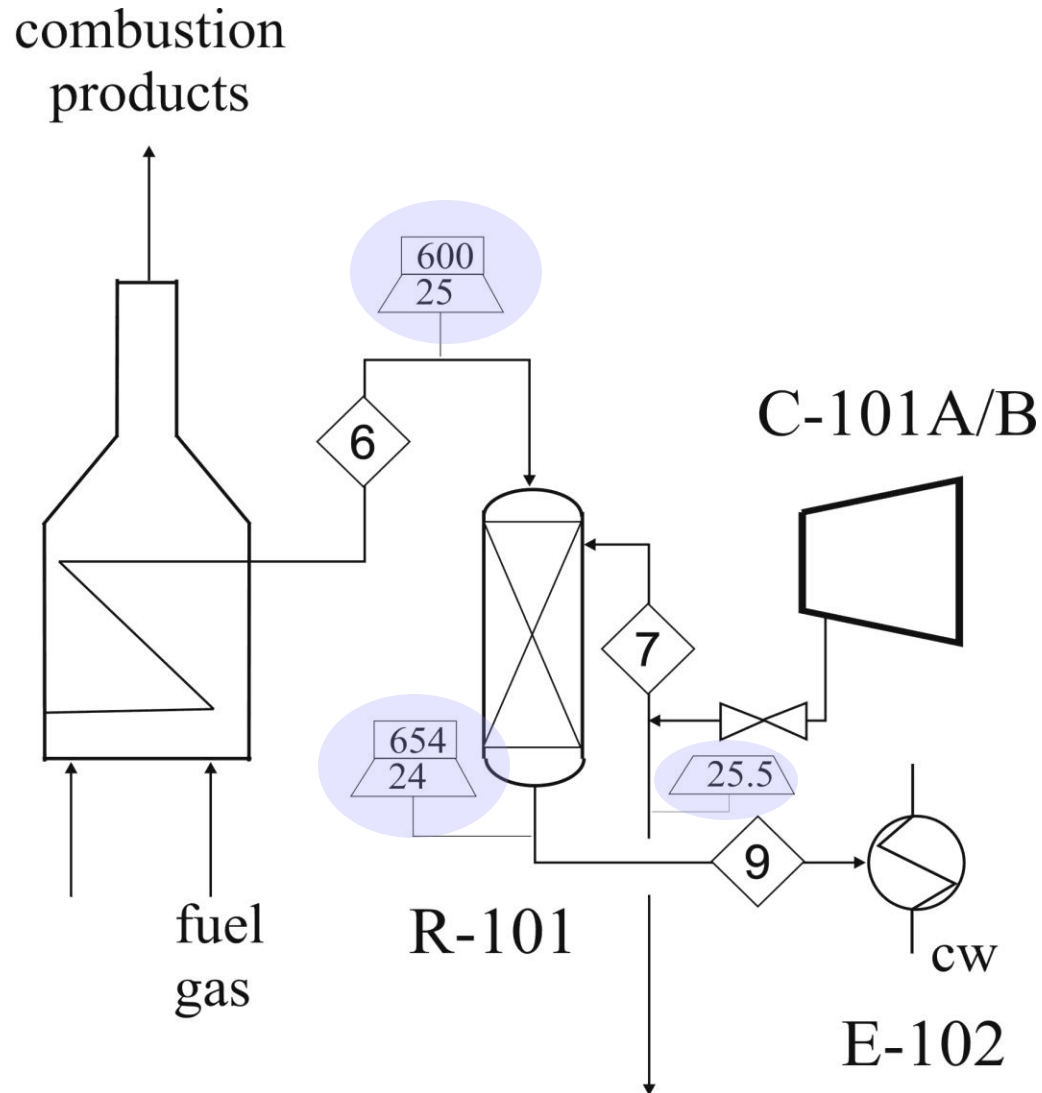


Figure 1.5: Process flow diagram (PFD) for the production of benzene via the hydrodealkylation of toluene

Stream Information - Flags



The Process Flow Diagram (cont'd)

Table 1.4: Information in a Flow Summary

Essential Information

Stream Number
Temperature ($^{\circ}$ C)
Pressure (bar)
Vapor Fraction
Total Mass Flow Rate (kg/h)
Total Mole Flow Rate (kmol/h)
Individual Component Flow Rates (kmol/h)

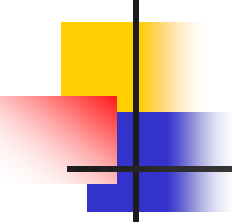
Optional Information

Component Mole Fractions
Component Mass Fractions
Individual Component Flow Rates (kg/h)
Volumetric Flow Rates (m^3/h)
Significant Physical Properties
 Density
 Viscosity
 Other
Thermodynamic Data
Heat Capacity
Stream Enthalpy
K-values
Stream Name

The Process Flow Diagram (cont'd)

A Portion of Table 1.5

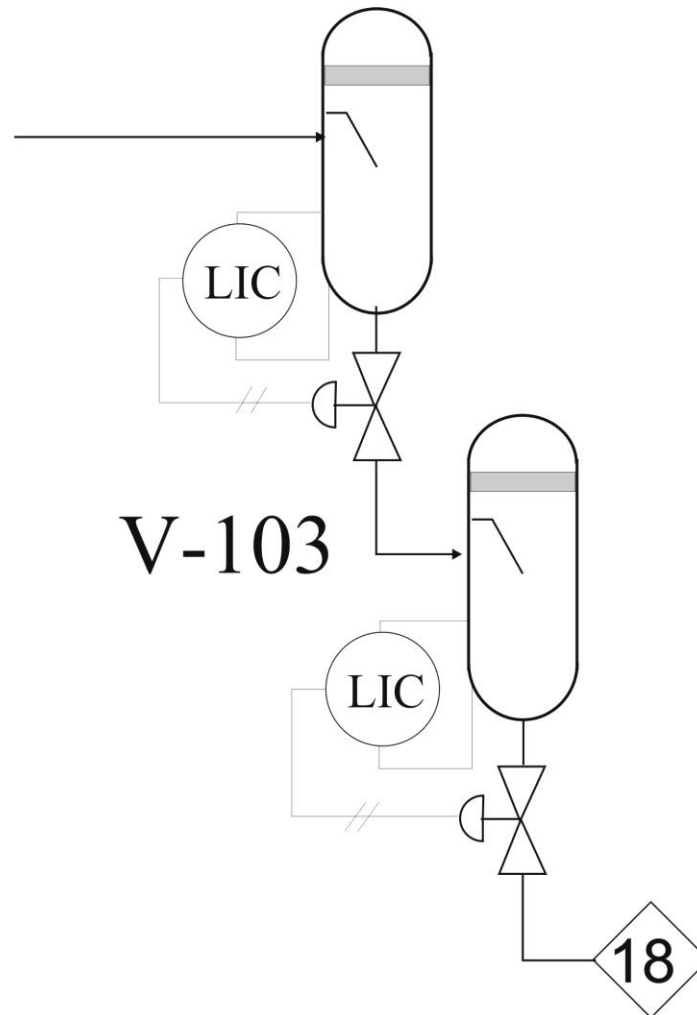
Stream Number	1	2	3	4	5	6	7	8	9	10
Temperature (° C)	25	59	25	225	41	600	41	38	654	90
Pressure (bar)	1.90	25.8	25.5	25.2	25.5	25.0	25.5	23.9	24.0	2.6
Vapor Fraction	0.0	0.0	1.00	1.0	1.0	1.0	1.0	1.0	1.0	0.0
Mass Flow (tonne/h)	10.0	13.3	0.82	20.5	6.41	20.5	0.36	9.2	20.9	11.6
Mole Flow (kmol/h)	108.7	144.2	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

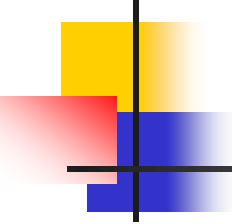


Basic Control Loops

- Often the basic control loops (those involving maintaining material balance and reactor controls) are included on the PFD; instrumentation and other control loops are not shown

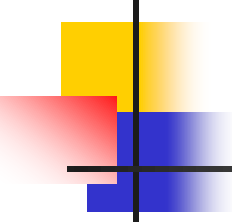
Basic Control Loops





Equipment Information

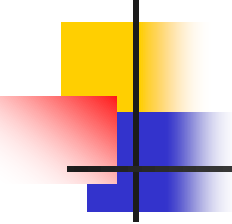
- Equipment are identified by number and a label (name) positioned above the equipment on the PFD
- Basic data such as size and key data are included in a separate table (Equipment Summary Table) Table 1.7 (and Table 1.6) in TBWS



Equipment Information

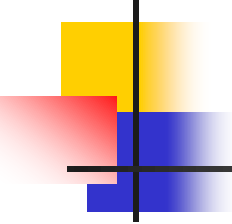
A Section of Table 1.7: Equipment Summary

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 5) and cost of manufacture (Chapter 6) 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

P&ID

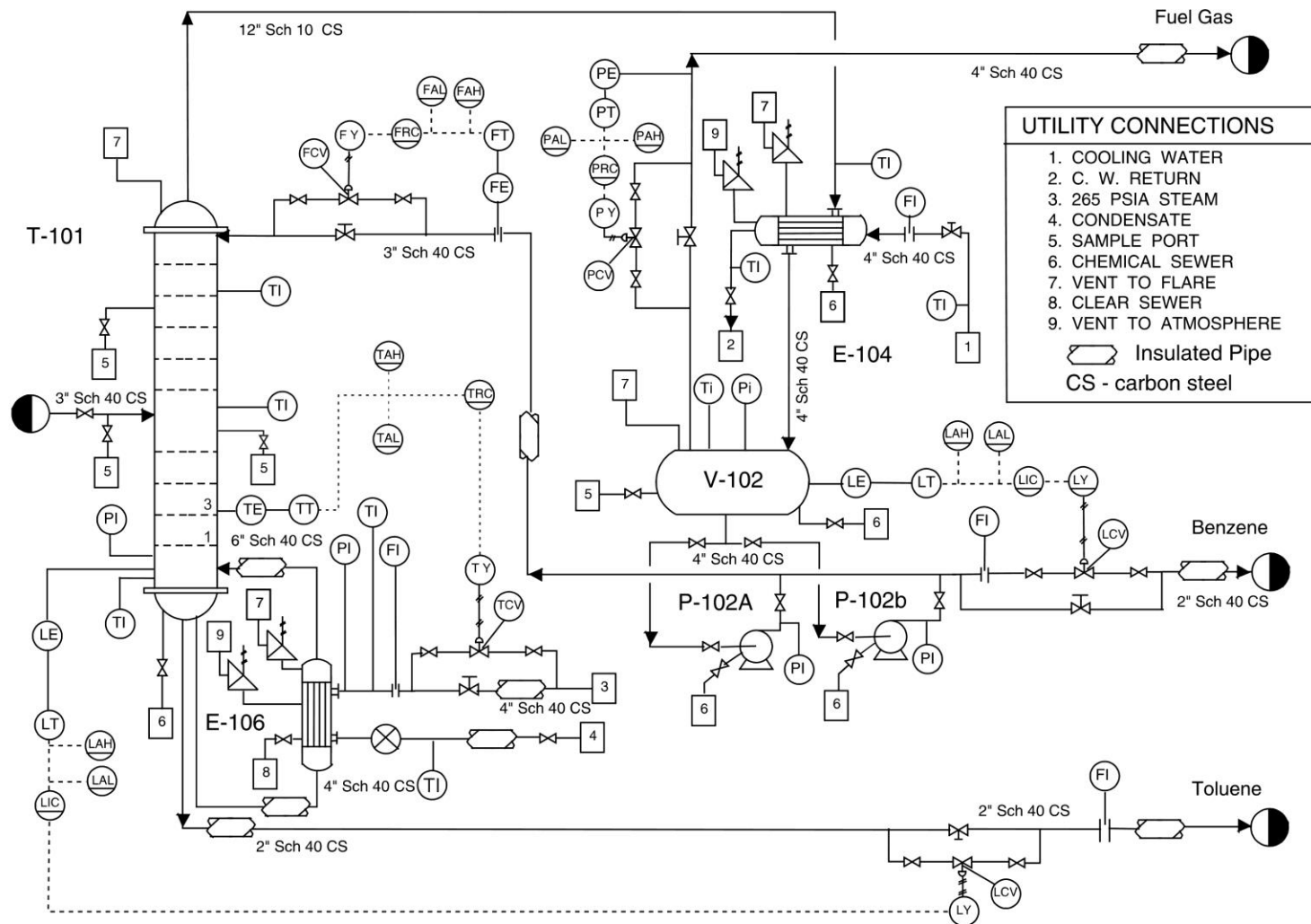
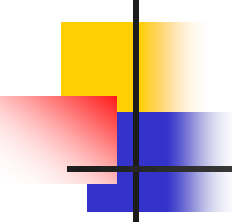
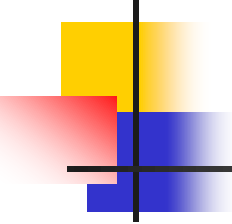


Figure 1.7 : Piping and Instrumentation Diagram for Benzene Distillation (adapted from Kauffman, D, Flow Sheets and Diagrams," AIChE Modular Instruction, Series G: Design of Equipment, series editor J. Beckman, AIChE, New York, 1986, vol 1, Chapter G.1.5, AIChE copyright © 1986 AIChE, all rights reserved)



Look at V-102 on P&ID

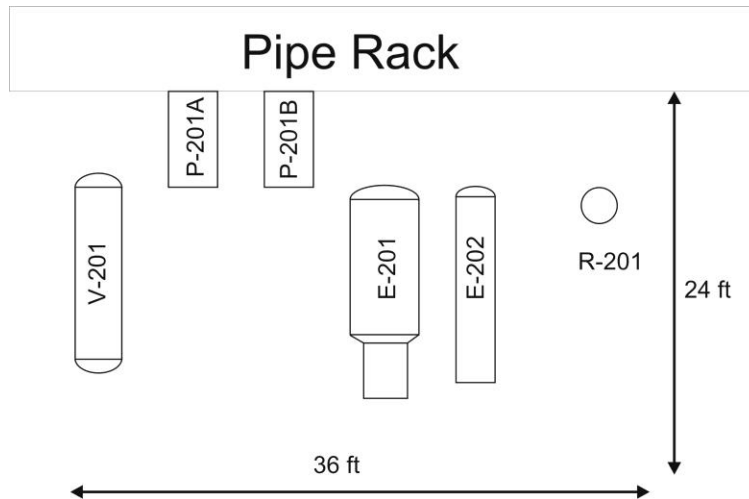
- V-102 contains an LE (Level Element)
- LE senses liquid level in separator and adjusts flow rate leaving
 - LE opens and closes a valve depending on liquid level
 - LE and valve represent a feedback control loop



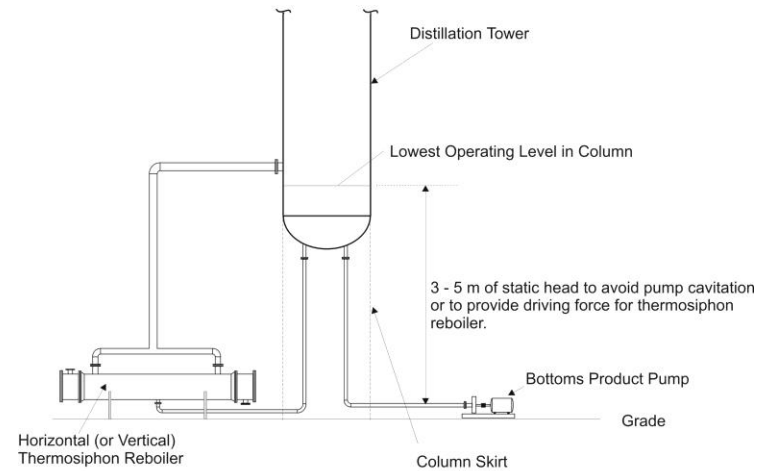
Other Common Diagrams

- 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

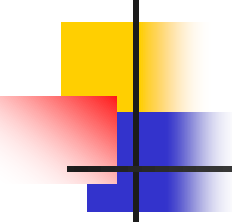
Other Common Diagrams



Section of Plot Plan

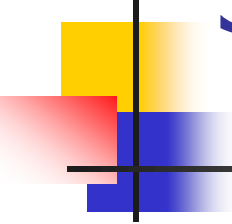


Section of Elevation Diagram



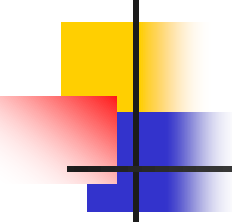
Other Common Diagrams (cont'd)

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



Scale Models and Virtual Plants

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



3-D Plant Diagrams

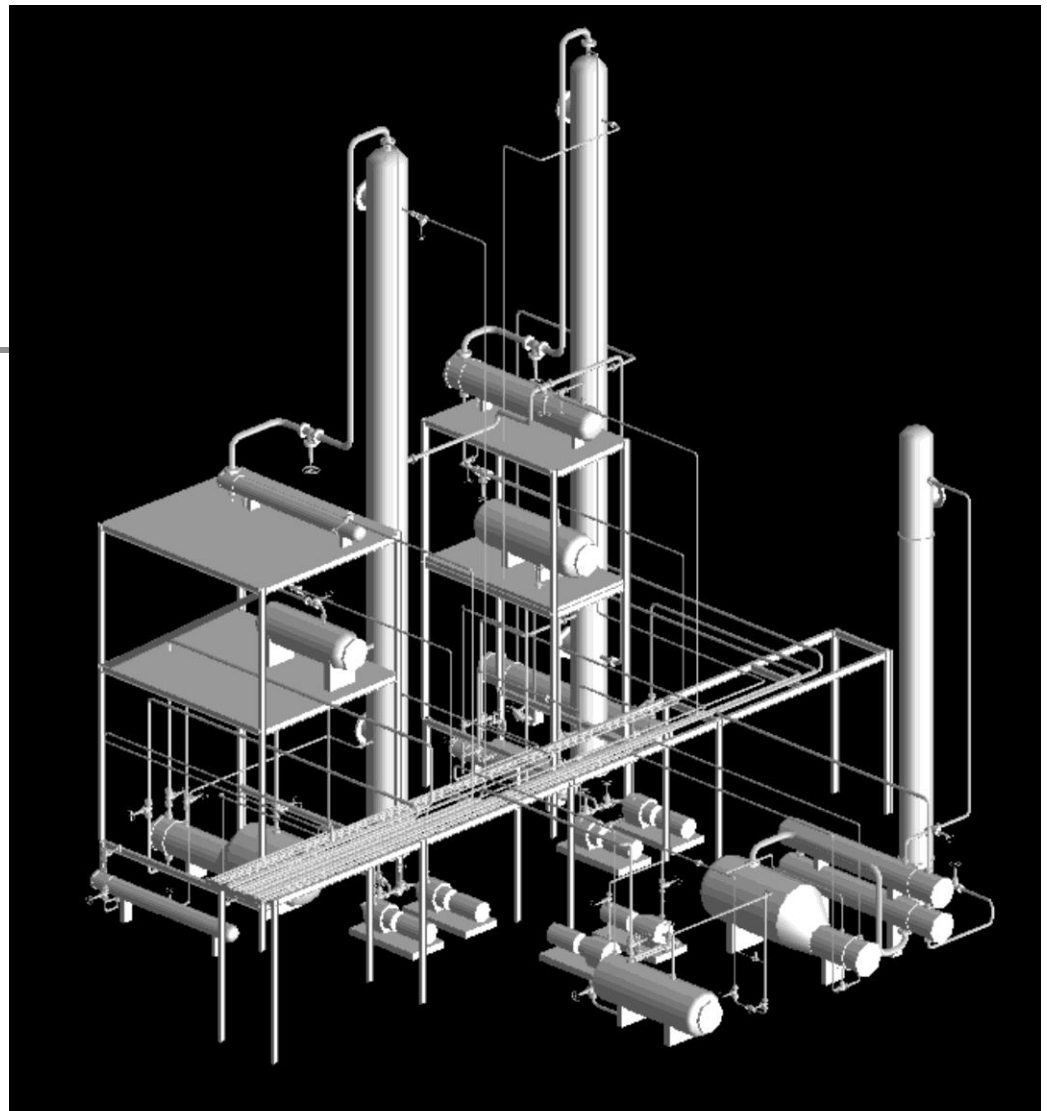
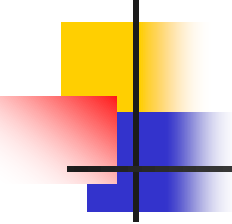


Figure 1.13: Isometric View of Preliminary 3-D Plant Layout Model for DME Process
(courtesy of Cadcentre, Inc.)

R. Turton and J. A. Shaeiwitz -
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Summary

- The three principal diagrams (BFD, PFD, and P&ID) are used to convey increasingly specific technical information about a process.
- Important to adhere to common standards for these diagrams in order to avoid confusion
- Information on equipment layout is most clearly conveyed through a 3-D plant layout diagram.