Chemical Process Diagrams

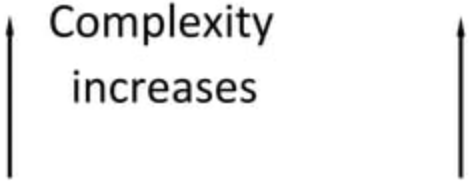
The most effective way of communicating information about a process is through the use of flow diagrams.

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



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 – Ch E information is missing

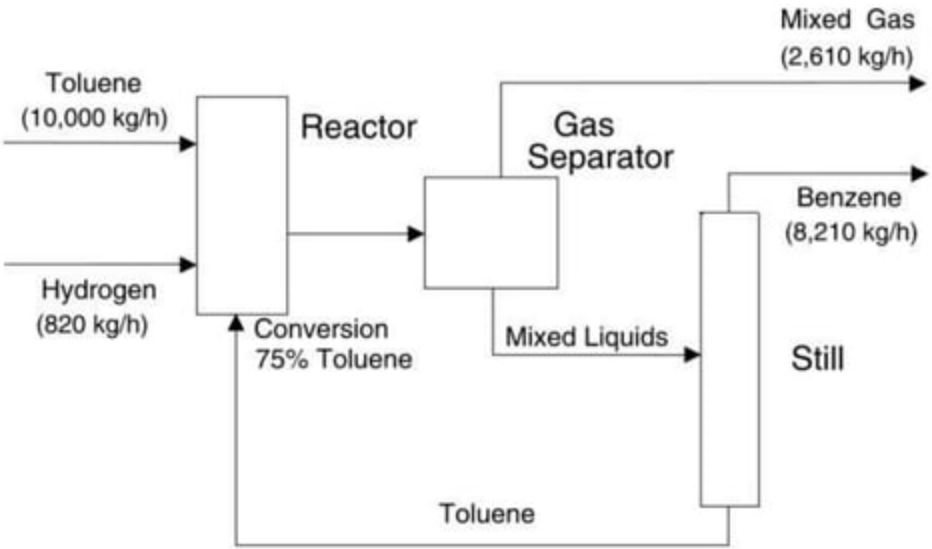
Block Flow Diagrams (BFD)

- Emphasis not on details regarding blocks; focus on flow of streams through process.
- Conventions:
  1. Operations shown by blocks
  2. Major flow lines shown with arrows giving flow direction
  3. Flow goes from left to right whenever possible
  4. Light streams toward top, heavy streams toward bottom
  5. Critical information unique to the process supplied (i.e., reaction stoichiometry, conversion)
  6. Avoid crossing lines; horizontal continuous, vertical broken.
  7. Simplified material balance (overall)

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



Reaction : $C_7H_8 + H_2 = C_6H_6 + CH_4$

The Block Flow Plant Diagram

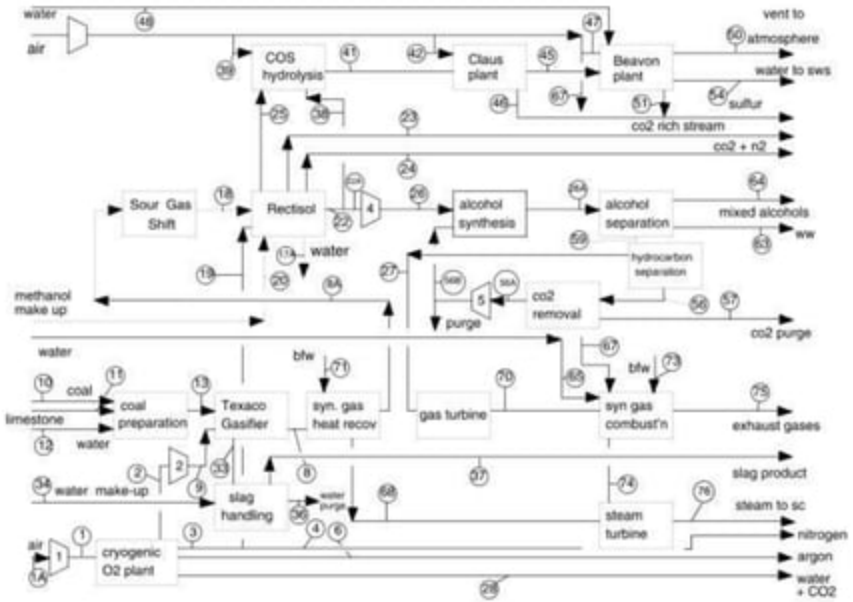


Figure 1.2: Block Flow Plant Diagram of a Coal to Higher Alcohol Fuels Process

The Process Flow Diagram (PFD)

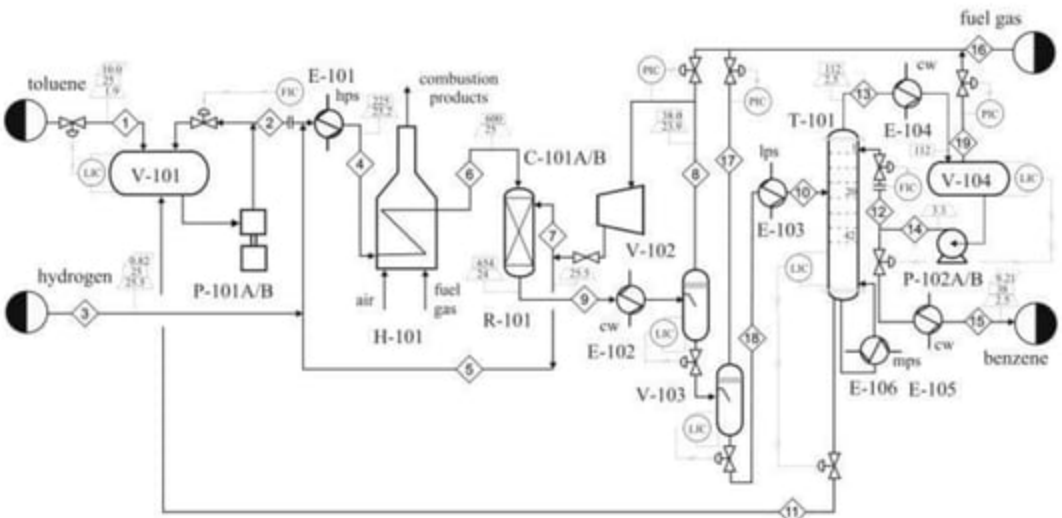
- PFD shows all process engineering information
- Typical conventions (vary by company):
  - All major equipment represented, uniquely numbered
  - All process flow streams shown and uniquely numbered, with description of thermodynamic conditions and composition (often in an accompanying table)
  - All utility streams supplied to major process equipment shown
  - Basic control loops, illustrating control strategy during normal operation

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

Process Flow Diagram (cont'd)

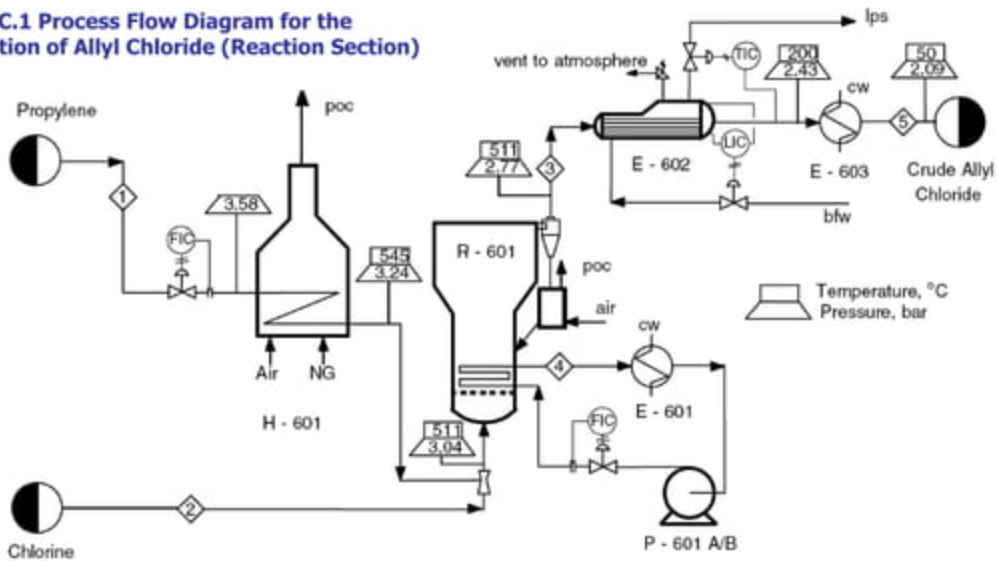
V-101 Toluene Storage Drum	P-101A/B Toluene Feed Pumps	E-101 Feed Preheater	H-101 Feed Heater	R-101 Reactor	C-101 A/B Recycle Gas Compressor	E-102 Reactor Effluent Cooler	V-102 HighPpres Phase Sep.	V-104 Low Pres. Phase Sep.	E-103 Tower Feed Heater	E-106 Benzene Reboiler	T-101 Benzene Column	E-104 Benzene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



Process Flow Diagram (cont'd)

H-601	R-601	J-601	E-601	P-601 A/B	E-602	E-603
Reactor Feed Heater	Fluidized Bed Reactor	Jet Mixer	Dowtherm Cooler	Dowtherm Pumps	Waste Heat Boiler	CrudeAllyl Chloride Cooler

Figure C.1 Process Flow Diagram for the Production of Allyl Chloride (Reaction Section)

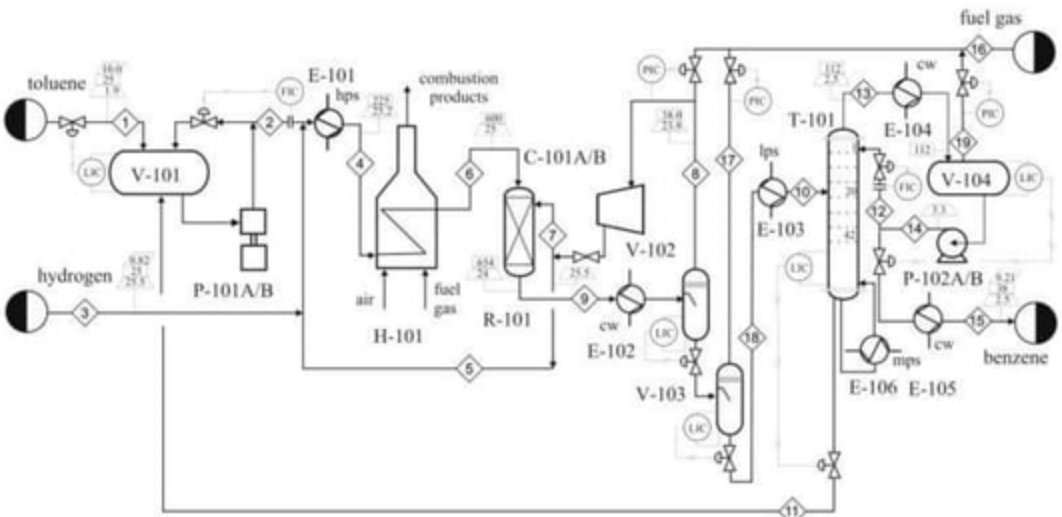


Equipment Numbering

- 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 equipment number of unit (1-99)
  - A/B/… represents presence of spare equipment

Equipment Numbering (cont'd)

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 Storage Drum	Toluene Feed Pumps	Feed Preheater	Feed Heater	Reactor	Recycle Gas Compressor	Reactor Effluent Cooler	HighPpres Phase Sep.	Low Pres. Phase Sep.	Tower Feed Heater	Benzene Reboiler	Benzene Column	Benzene Condenser	Reflux Drum	Reflux Pumps	Product Cooler



Equipment Numbering (cont'd)

- 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 univocal 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

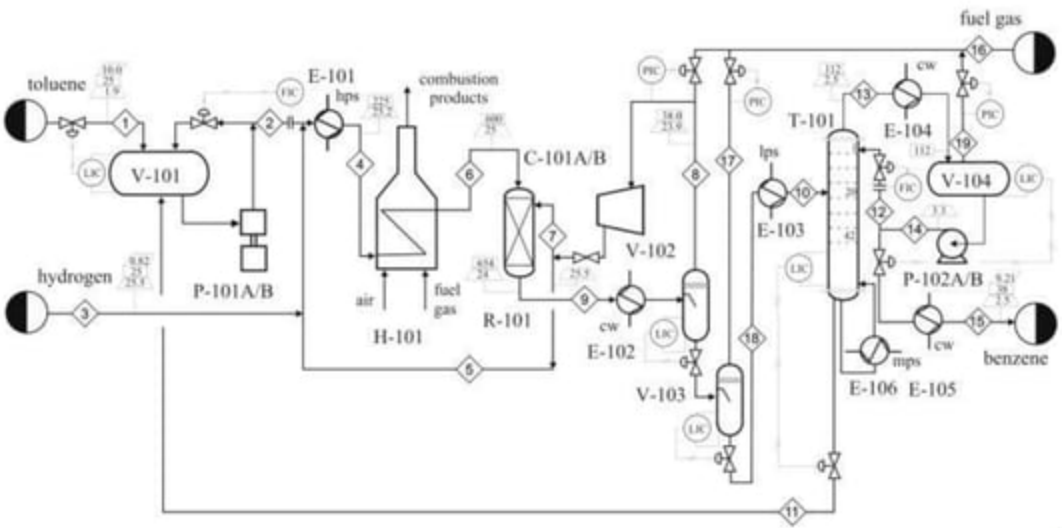
Stream Numbering & Drawing

- Number streams left to right when possible
- Horizontal lines are dominant

yes no no

Stream Numbering & Drawing (cont'd)

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



Stream Numbering & Drawing (cont'd)

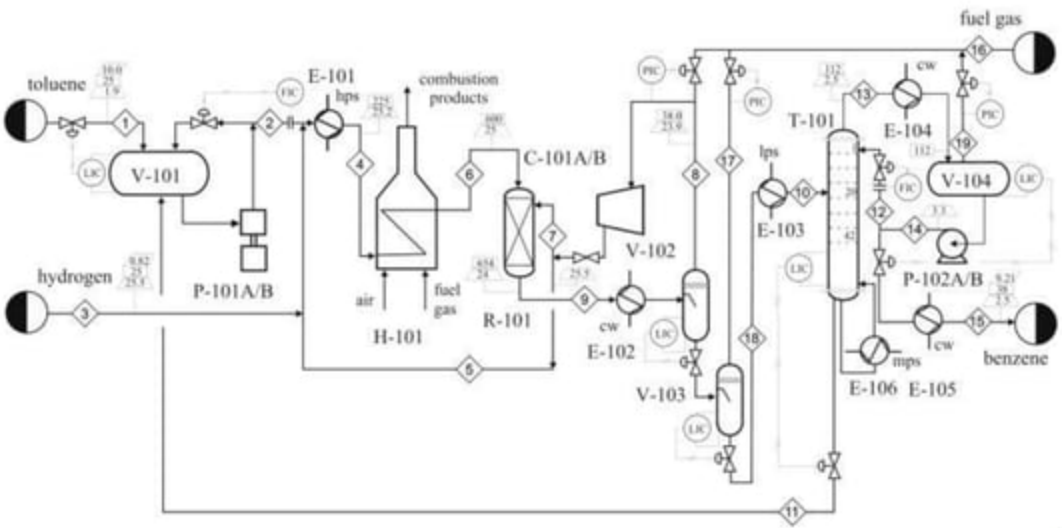
- Add arrows for
  - change in direction
  - inlet of equipment
- Utility streams
  - use convention in Table 1.3
  - lps, cw, fg, etc.

Stream Information

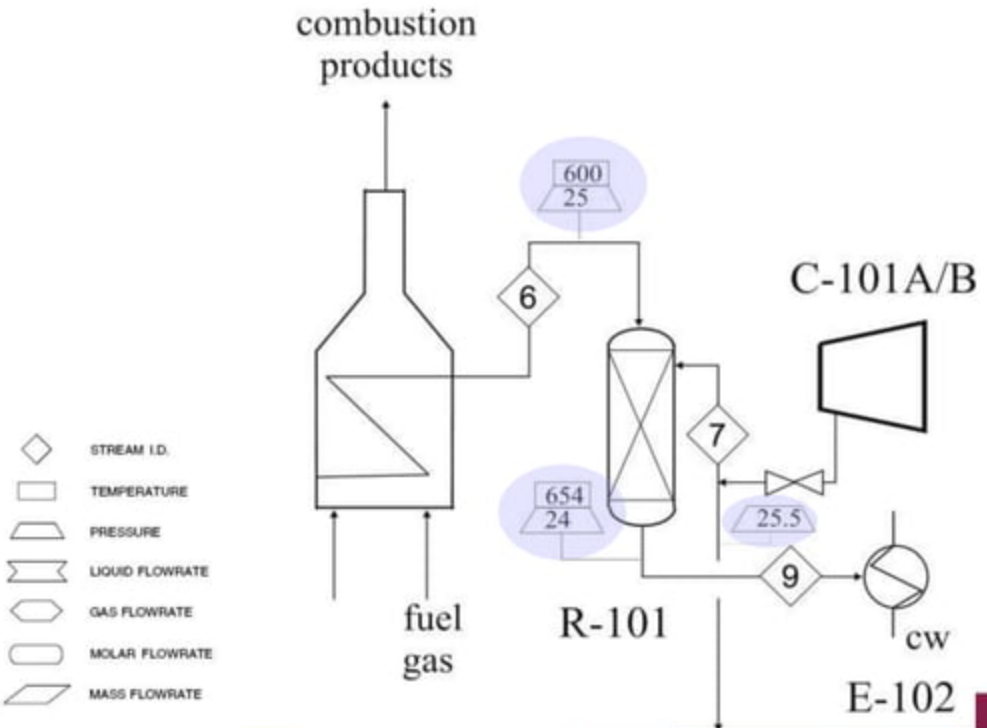
- Since diagrams are small, not much stream information can be included
- Include important data – around reactors and towers, etc.
  - Flags are used – see toluene HDA diagram
  - Full stream data, as indicated in Table 1.4, are included in a separate flow summary table – see Table 1.5

Stream Numbering & Drawing (cont'd)

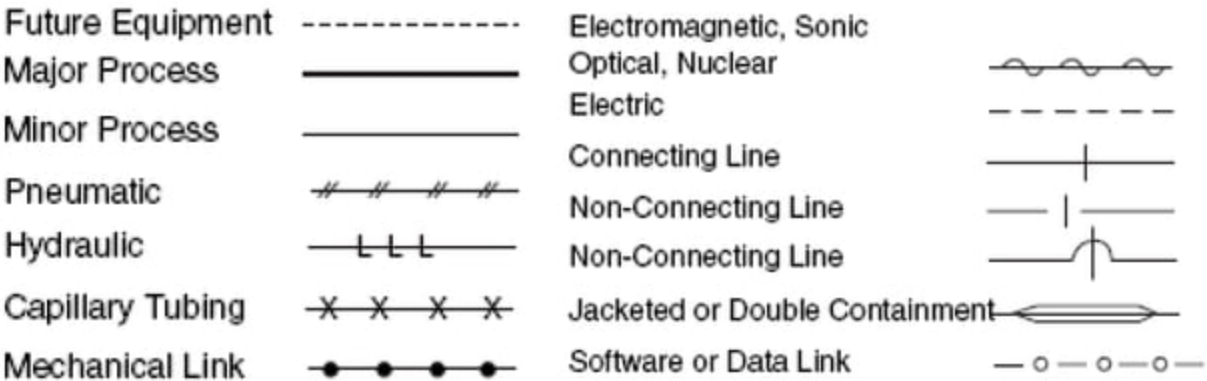
V-101 Toluene Storage Drum	P-101A/B Toluene Feed Pumps	E-101 Feed Preheater	H-101 Feed Heater	R-101 Reactor	C-101 A/B Recycle Gas Compressor	E-102 Reactor Effluent Cooler	V-102 HighPpres Phase Sep.	V-104 Low Pres. Phase Sep.	E-103 Tower Feed Heater	E-106 Benzene Reboiler	T-101 Benzene Column	E-104 Benzene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



Stream Information - Flags



Stream Drawing



The Process Flow Diagram (cont'd)

Essential Information

Stream Number
Temperature (°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

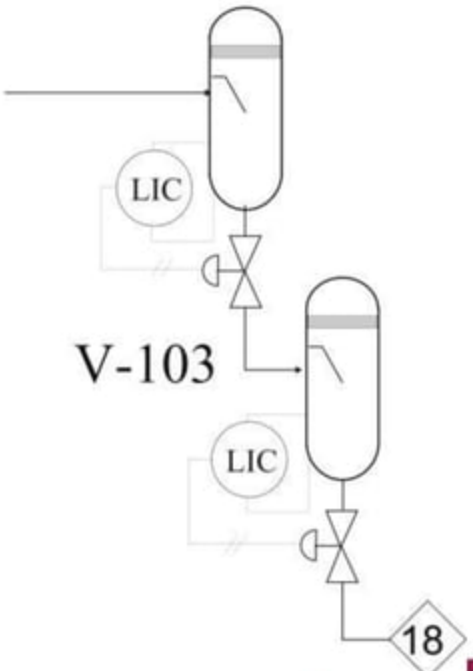
Thermodynamic Data
Heat Capacity
Stream Enthalpy
K-values
Stream Name

Table 1.4: Information in a Flow Summary

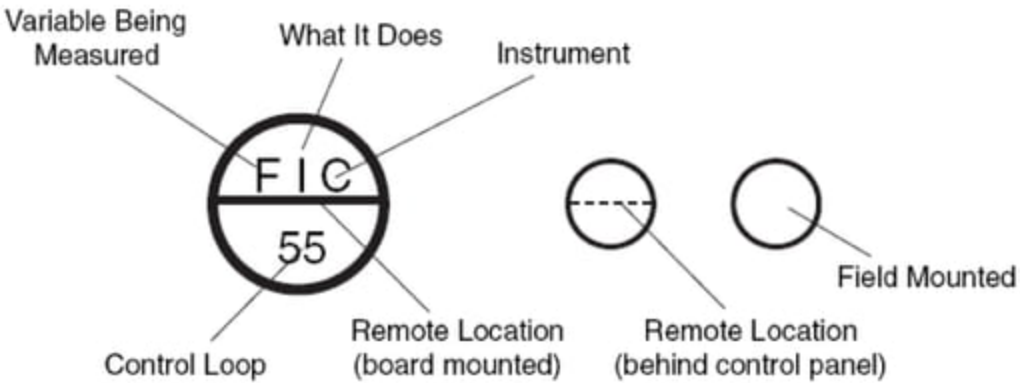
Basic Control Loops

- 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
- The final control element in nearly all chemical process control loops is a valve.

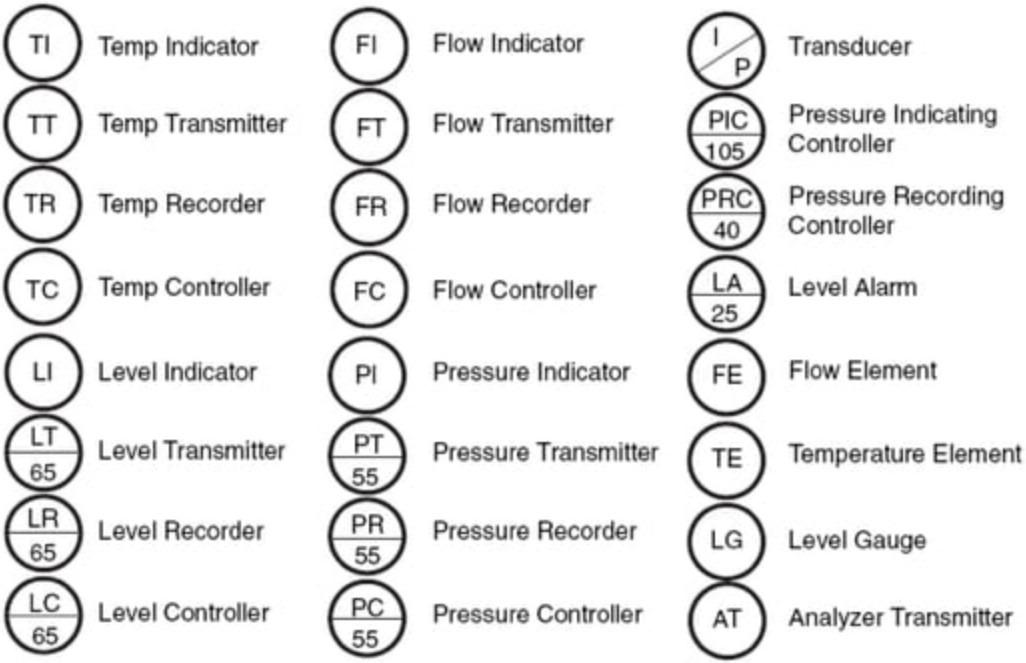
Basic Control Loops



Basic Instrumentation Symbols



Basic Instrumentation Symbols



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 (ºC)	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 complete PFD
- This information is sufficient to permit a one to complete a preliminary estimation of capital investment and cost of manufacture.

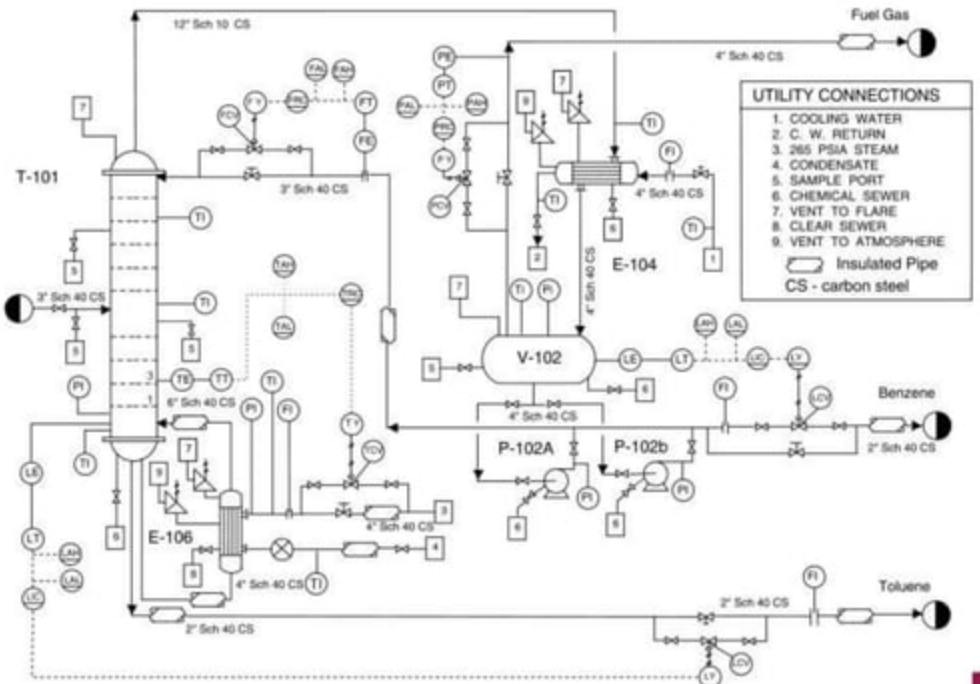
Piping & Instrument Diagram

- Piping & Instrument Diagram (P&ID) – Construction Bible
- Contains: plant construction information (piping, process, instrumentation)
- P&ID info explained in Tables 1.8 and 1.9
- Instrumentation conventions shown in Fig. 1.10

Piping & Instrumentation Diagram (P&ID)

- support documents of the PFD used for planning for plant construction and maintaining the plant thereafter
- Each PFD requires many P&IDs to provide the necessary data
- Used as a checklist at the final walk-through prior to start up to assure each detail has been attended to
- Use by/to
  - MEs and CEs to build/install equipment
  - Instrument engineers to specify/install/check control systems
  - Piping engineers to develop plant layout and elevation drawings
  - Project engineers to develop plant and construction schedules

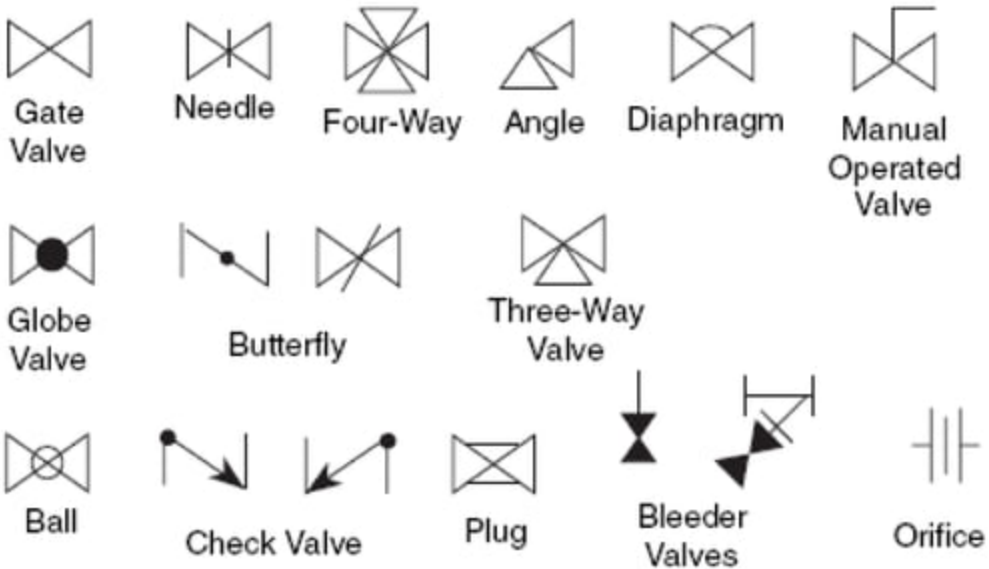
The P&ID (cont'd)



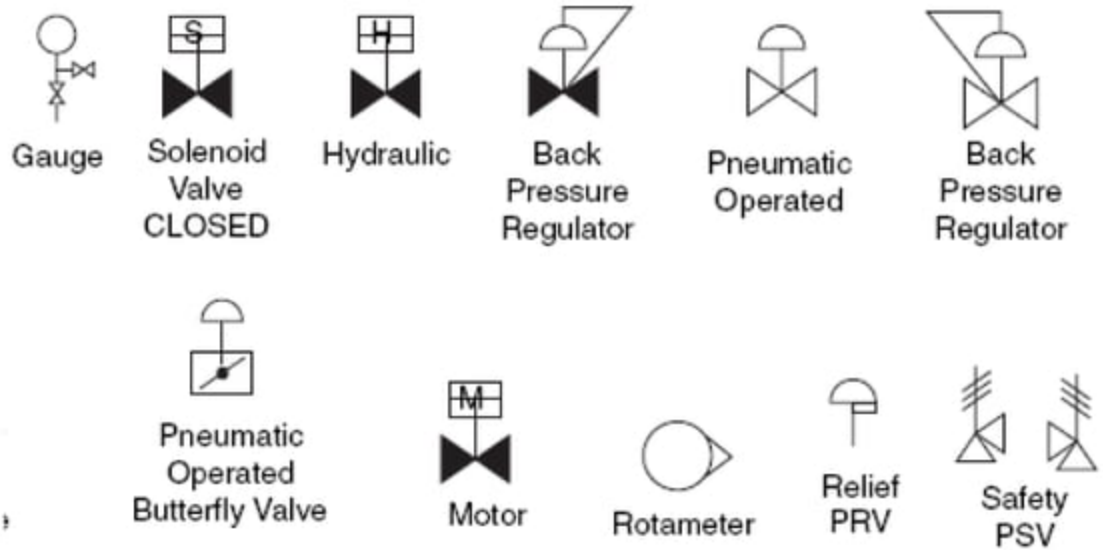
Look at V-102 on P&ID

- V-102 contains an LE (Level Element)
- LE senses liquid level in separator and adjusts flow rate leaving, by opening or closing a valve, depending on liquid level
- Together, the LE and valve represent a *feedback control loop*

Valve Symbols



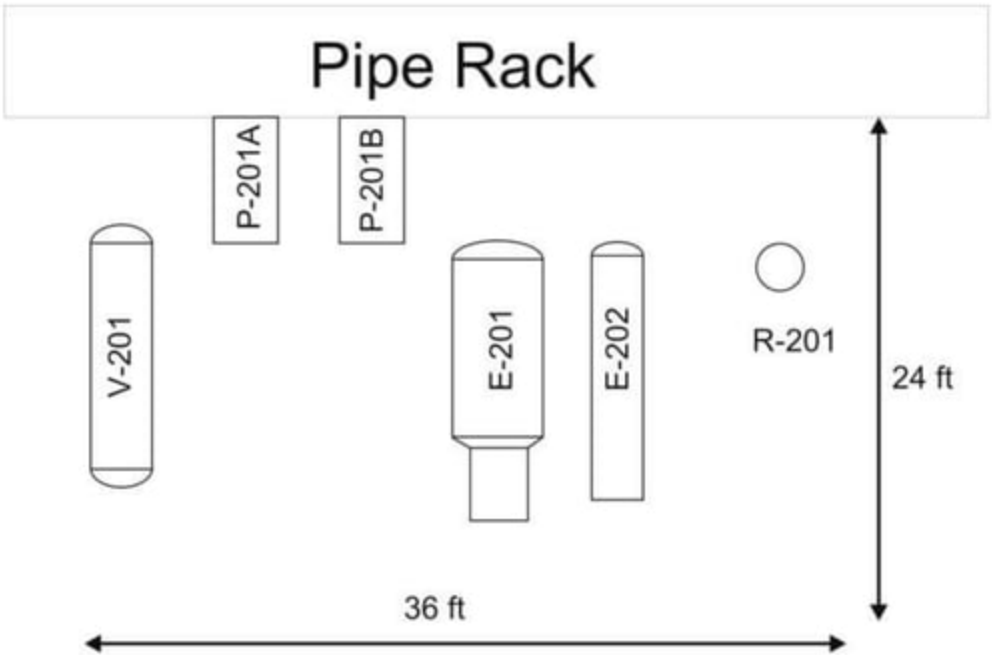
More Valve Symbols



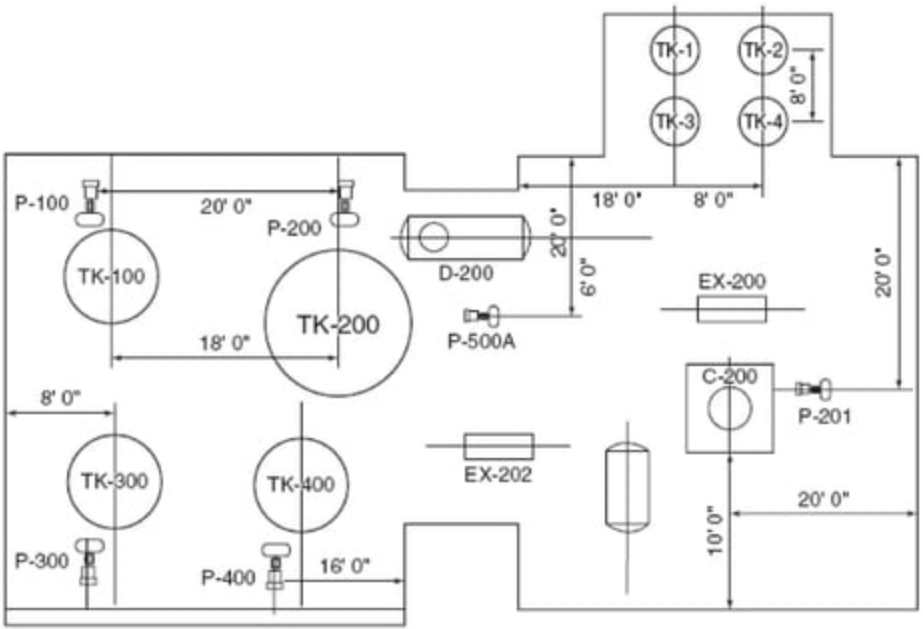
Other Common Diagrams

- 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
- Foundation drawings
- Electrical drawings

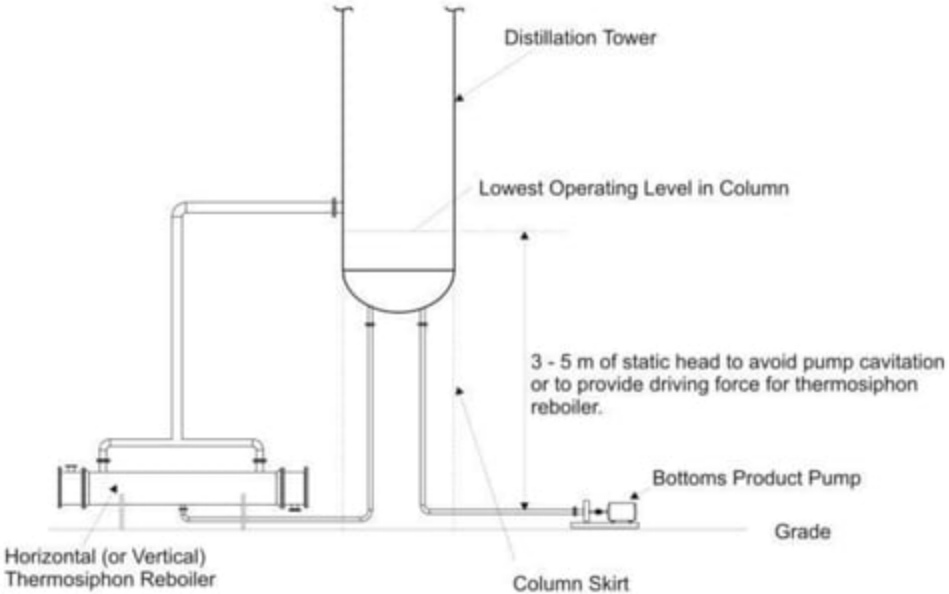
Plot Plan



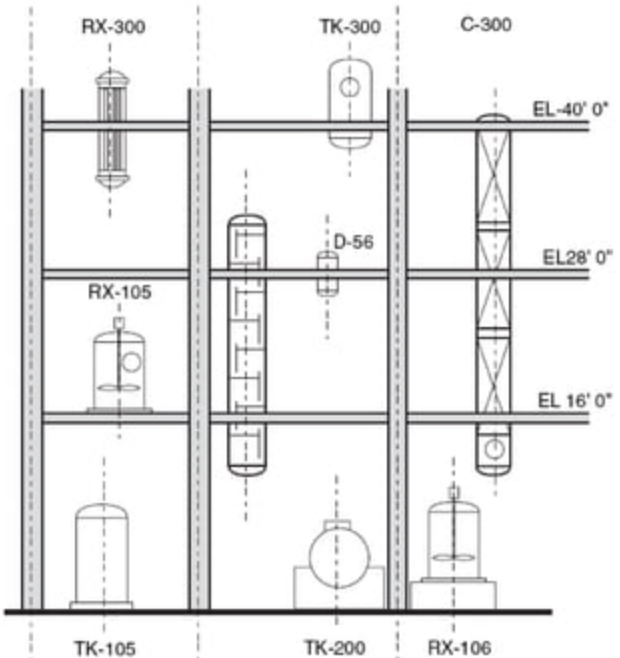
Plot Plan


TK-1
TK-2
TK-3
TK-4
8' 0"
18' 0"
8' 0"
20' 0"
P-100
20' 0"
P-200
TK-100
TK-200
D-200
6' 0"
EX-200
20' 0"
P-500A
18' 0"
C-200
P-201
8' 0"
TK-300
TK-400
EX-202
20' 0"
10' 0"
P-300
P-400
16' 0"

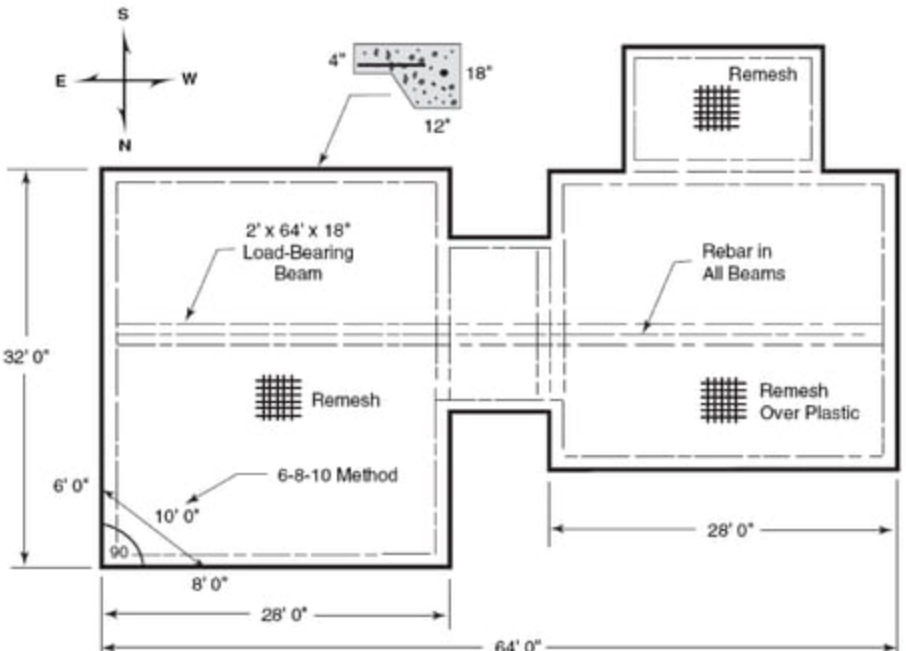
Elevation Diagram



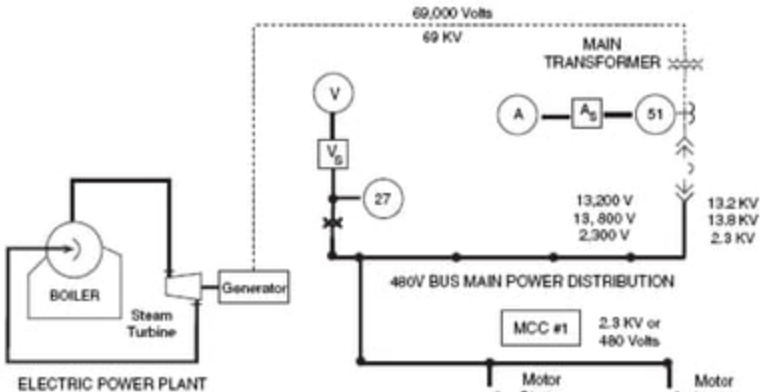
Elevation Drawing



Foundation Drawing



Electrical Drawing



M Motor	Fuse	MCC	Motor Control Center
V Voltmeter: measures voltage	V_S Voltmeter Switch		
27 Under Voltage Relay	Current Transformer: reduces high voltage to instrumentation.		
A Ammeter: measures electric current	A_S Ammeter switch		
50 Transformer Overcurrent Relay (Instantaneous)	Potential Transforming Symbol		
51 Transformer Overcurrent Relay (Time delay)	Power Transformer: reduces high voltage		
Circuit Breaker: a protective device that interrupts current flow through an electric circuit	Switch		Motor Circuit Contacts

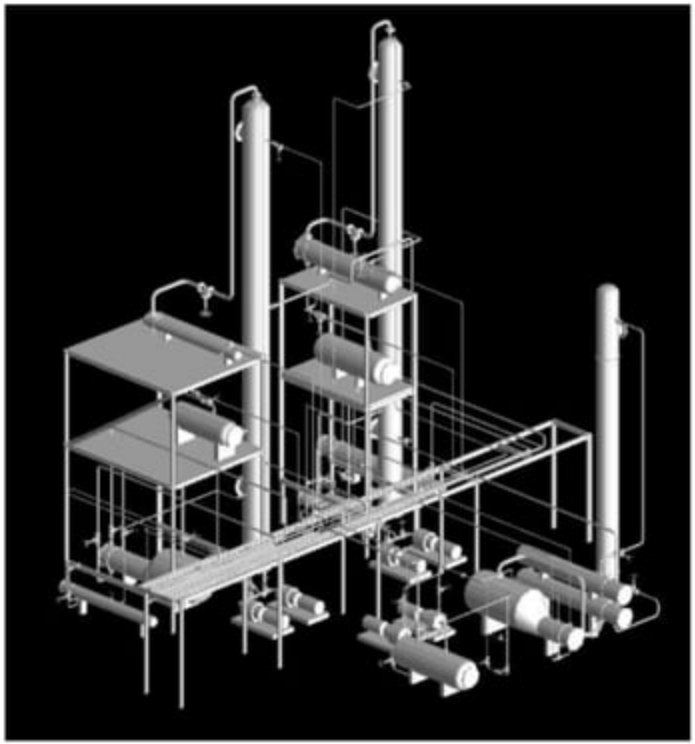
Other Common Diagrams (cont'd)

- 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 yr ago physical models 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

3-D Plant Diagrams



Summary

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