BFD, PFD, P&ID

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Diagrams in process engineering

- There are three main diagrams used by chemical engineers to design and describe the processes
  - **Block Flow Diagram BFD**
    - Starting from an input-output diagram of the process we divide it into its main functional blocks such as: the reaction section, the separation section, etc… Then we add the recycle streams and the preliminary material balances.
  - **Process Flow Diagram PFD**
    - The next step is to evaluate and quantify efficiently the material and energy balances for all the process streams. Then we add the preliminary design specifications of the equipment.
  - **Piping and Instrumentation Diagram P&ID**
    - We introduce the specific details describing the mechanics and the process instrumentation.

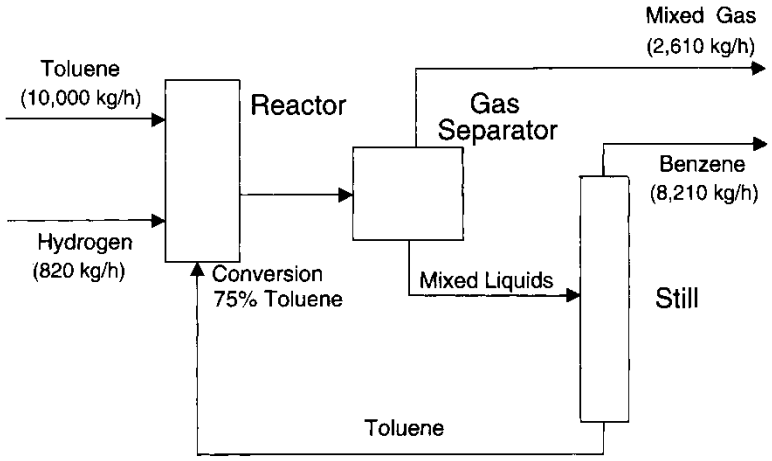
Diagrams in process engineering

- The most efficient way to communicate information related to a chemical process is to use flow charts. *Visual* information is the best way to present design data and it avoids misunderstandings and ambiguities.
- When possible it shall be adopted the English terminology and symbology since in most cases the documentation produced by an engineering company is for foreign orders.
- We refer to symbols and diagrams from the text:
  - R. Turton, R. Bailie, W. Whiting, J. Shaeiwitz

    Analysis, Synthesis and Design of Chemical Processes

    Prentice Hall, New Jersey, 1998

BDF: Block Flow Diagram



Reaction: C7H8 + H2 = C6H6 + CH4

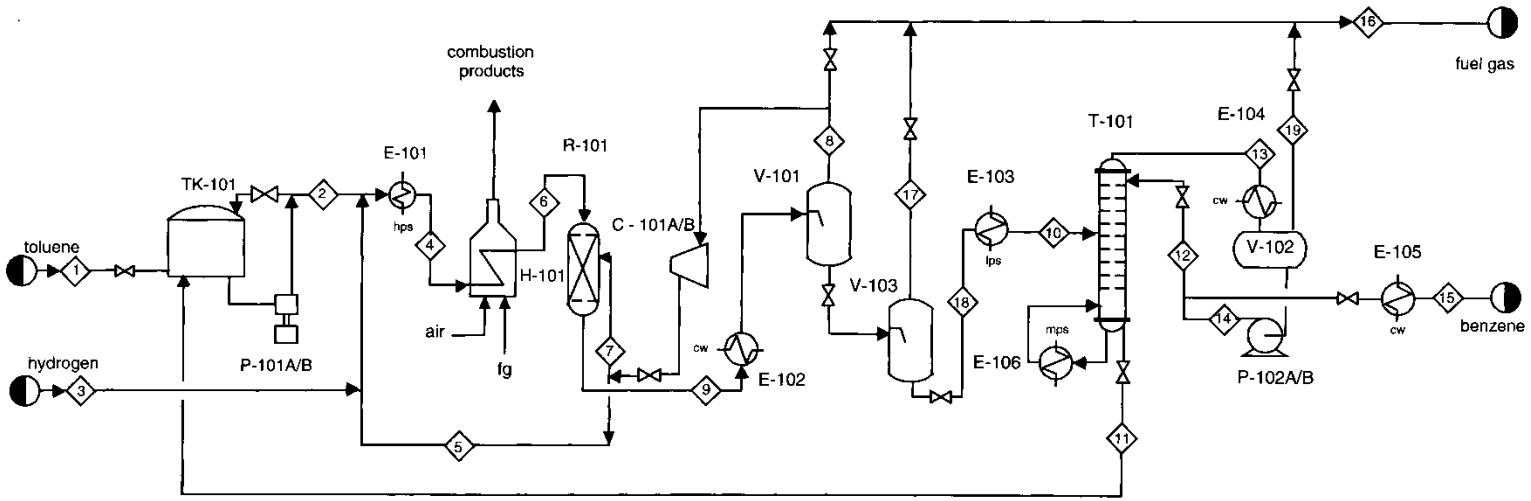
- **International conventions and recommended formats for the realization of BFDs**
  - The unit operations are indicated by blocks
  - The main streams are identified by lines with arrows indicating the flow direction
  - When possible, the direction of the streams is from left to right
  - Light currents (gas) upwards, heavy currents (liquids and solids) downwards of the blocks representing the single portions of the plant
  - Provide basic and most important information of the process
  - If the process lines intersect, the horizontal ones are held whilst the vertical one are broken
  - Provide simplified material balances and main reactions

PFD: Process Flow Diagram

- The PFD is greatly enhanced compared to the BFD. It is the most important and used diagram to describe with an adequate level of detail the structure of the process.
- There is not a universally accepted nomenclature. In general, a PFD contains the following information:
    1. The important equipment is shown together with a short description. Each device is identified by a code.
    2. The streams are shown and identified with a number. Every stream shows the process conditions and composition. These data can be entered directly on the PFD or in a summary attached table.
    3. The *utilities* of the equipment are shown and described
    4. The main control loops are shown
- The information provided by a PFD can be summarized as follows:
    - Topology of the process
    - Information on streams
    - Information on equipment

PFD: Process Flow Diagram

TK-101	P - 101 A/B	E - 101	H - 101	R - 101	C - 101 A/B	E - 102	V - 101	V - 103	E - 103	E - 106	T - 101	E - 104	V - 102	P - 102 A/B	E - 105
Toluene Storage Tank	Toluene Pump	Feed Preheat.	Feed Heater	Reactor	Recycle Gas Compssor	Reactor Effluent Cooler	H.P Phase Separtor	L.P Phase Separtor	Tower Feed Heater	Benz. Reboiler	Benz. Tower	Benz. Conden.	Reflux Drum	Reflux Pumps	Product Cooler



PFD for the production of benzene by the hydrodealkylation of toluene (HDA)

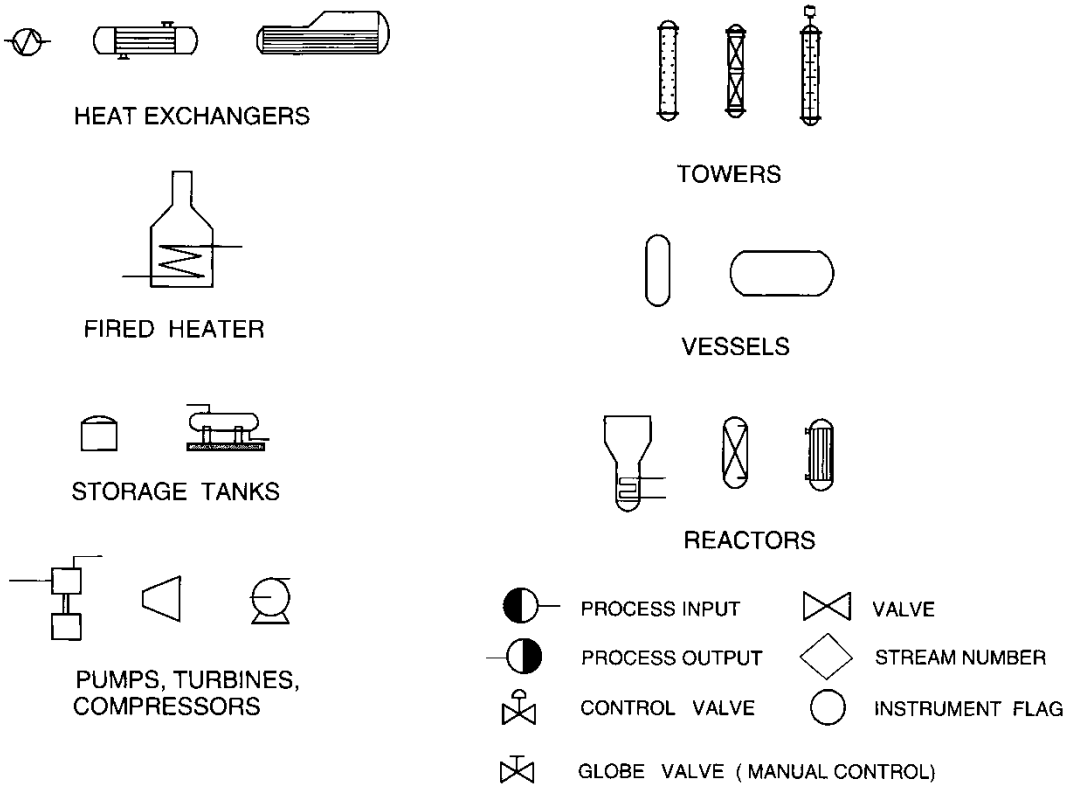
PFD: Process Flow Diagram

- We define as “topology of the process” the position and the interaction among the units and the streams of the process.
- The equipment is represented by icons. The ASME (American Society of Mechanical Engineers) periodically publishes a list of symbols to be used in the production of the PFD. Nevertheless, engineering companies are used at adopting *custom* symbols in order to make their own PFD recognizable and distinguishable from those of their competitors.
- Each piece of equipment is identified by a number on the PFD.

  For example, the toluene pump **P-101A/B** provides the following information:

  - **P**-101A/B means that the equipment as a pump
  - P-**1**01A/B means that the pump is located in the area **100** of the plant
  - P-1**01**A/B means that the specific pump is number **01** of the area 100
  - P-101**A/B** means that there are two pumps: **P-101A** and **P-101B**. The second one is a spare part that works as a back-up (*i.e.* normally is not working but it starts running when the former breaks or needs to be serviced).
  - The word “Toluene pump” is the colloquial name that identifies P101 and is used in discussions about the process.

PFD: Process Flow Diagram



Library of equipment symbols for a PFD

PFD: Process Flow Diagram

Conventions used to identify the equipment of the process

- General format: **XX-YZZ A/B**
- **XX** are the identification letters for the classification of the equipment
  - C – Compressor, turbine
  - E – Heat Exchanger
  - H – Fired Heater
  - P – Pump
  - R – Reactor
  - T – Tower
  - TK – Storage Tank
  - V – Vessel
- **Y** shows the area of the plant where the equipment is placed
- **ZZ** reports the sequential number of the specific process unit
- **A/B** means a parallel/spare/back-up equipment

PFD: Process Flow Diagram

Conventions used to identify the streams of the process

- Each process stream is identified by a number in a diamond above it. The direction is defined by one or more arrows.
- The utilities include: electricity, compressed air, cooling water, chilled water, steam, condensate, inert gas, chemical sewer, water treatment and flares. We use the following symbols:
  - **lps** low pressure steam 3-5 barg (sat)
  - **mps** medium pressure steam 10-15 barg (sat)
  - **hps** high pressure steam 40-50 barg (sat)
  - **htm** heat transfer medium (organic): to 400°C
  - **cw** cooling water: from cooling tower 30°C returned at less than 45°C
  - **wr** river water: from river 25°C returned at less than 35°C
  - **rw** refrigerated water: in at 5°C returned at less than 15°C
  - **rb** refrigerated brine: in at -45°C returned at less than 0°C
  - **cs** chemical waste water with high COD
  - **ss** sanitary waste water with high BOD
  - **el** electric energy (specify 220, 380, 440, 660V service)
  - **ng** natural gas
  - **fg** fuel gas
  - **fo** fuel oil
  - **fw** fire water

PFD: Process Flow Diagram

As already stated, each stream is identified by a number. A summary table which accompanies the PFD provides the data on the process streams.

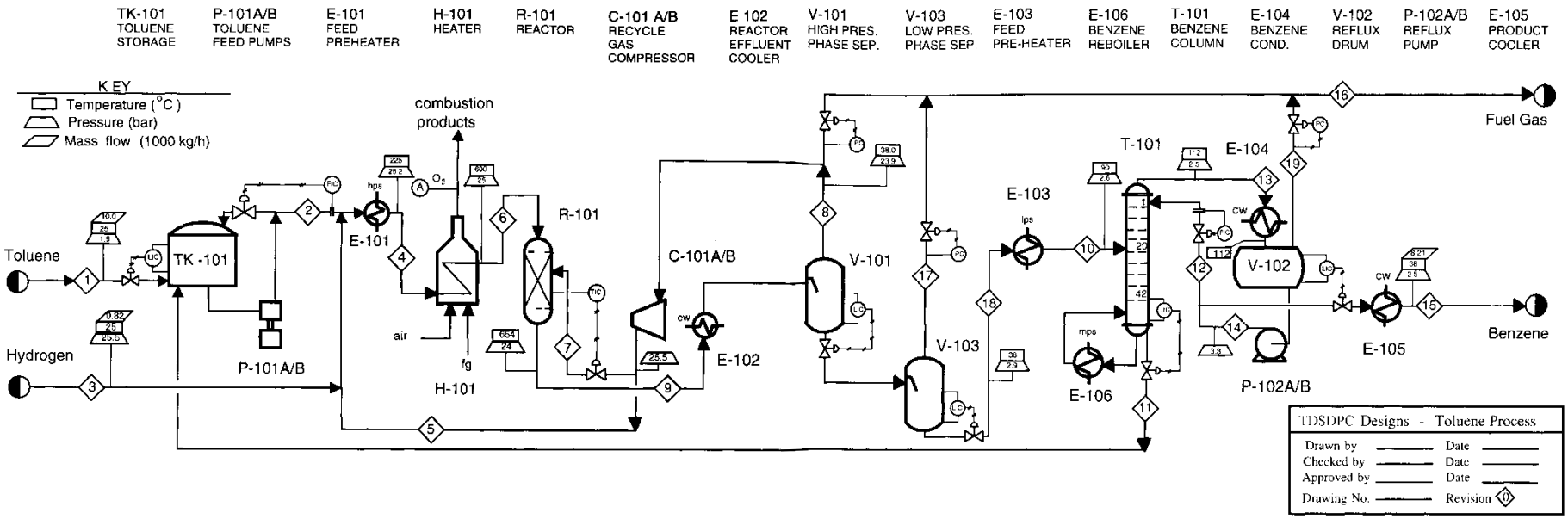
- **Essential information**
  - Stream number
  - Temperature [°C]
  - Pressure [bar]
  - Vapor Fraction
  - Total Mass Flow Rate [kg/h]
  - Total Mole Flow Rate [kmol/h]
  - Individual Component Flow Rates [kmol/h]
- **Optional information**
  - Component Mole Fractions
  - Component Mass Fractions
  - Individual Component Flow Rates [kg/h]
  - Volumetric Flow Rates [m^3/h]
  - Significant Physical Properties: Density, Viscosity, …
  - Thermodynamic Data: Heat Capacity, Enthalpy, K-values,…
  - Stream name

PFD: Process Flow Diagram

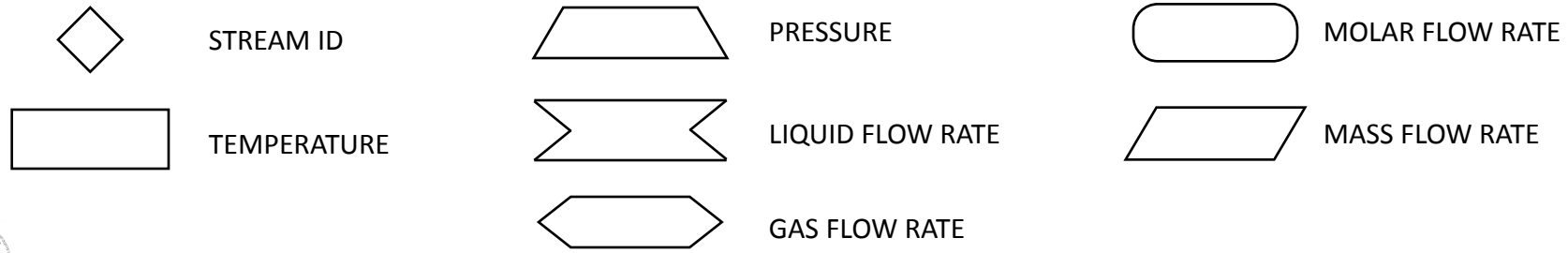
The last element of the PFD is a summary of the equipment which allows estimating the costs and provides the starting point to carry out a detailed design.

Equipment type	Description of the equipment
Towers	Size (height and diameter), Pressure, Temperature, Number and type of trays, Height and type of packing, Materials of construction
Heat Exchangers	Type: gas-gas, gas-liquid, liquid-liquid, Condenser, Vaporizer Process: Duty, Area, Temperature and Pressure for both streams Number of shell and tube passes Materials of construction: shell and tubes
Tanks, Vessels	Height, Diameter, Orientation, Pressure, Temperature, Materials of construction
Pumps	Flow, Discharge, Pressure, Temperature, ΔP, Driver type, Shaft power, Materials of construction
Compressors	Actual inlet flow rate, Pressure, Temperature, Driver type, Shaft power, Materials of construction
Heaters (fired)	Type, Tube pressure, Tube temperature, Duty, Fuel, Materials of construction
Others	Provide critical information

PFD: Process Flow Diagram



The PFD can include explicit information of the process streams by means of special “flags”. These “flags” are attached to the streams which they refer to, with text boxes in different shapes to indicate the value of measures such as:



P&ID: Piping & Instrumentation Diagram

A synonymous of **P&ID** is **MFD**, Mechanical Flow Diagram. It contains the data needed to start planning the construction of the plant. Mechanical and functional data are given for each piece of equipment.

Exceptions are:

1. Operating conditions: T and P
2. Stream values
3. Equipment positioning
4. Piping: lengths and fillings
5. Supports, Foundations and Structures

The following bits of information must be reported:

For Equipment – show every piece including:	Spare units, Parallel units, Summary detail on each unit
For piping – show all lines including Drains, and specify:	Size (standard), Thickness, Materials of construction, Insulation (thickness and type)
For instruments – Identify:	Indicators, Recorders, Controllers, Show instrument lines
For utilities – Identify:	Inlet and outlet utilities, Waste treatment facilities

P&ID

Positioning of the instrumentation:

Field instrumentation

Instrumentation on the fron of Control Panel in the control room

Instrumentation on the back of Control Panel in the control room

Meaning of identifying letters

First letter: **X**		Second and third letters: **Y**	
A	Analysis	A	Alarm
B	Burner flame	B	
C	Conductivity	C	Control
D	Density or specific gravity	D	
E	Voltage	E	Element
F	Flowrate	F	
H	Hand (manually initiated)	H	High
I	Current	I	Indicator
J	Power	J	
K	Time or time schedule	K	Control station
L	Level	L	Light or low
M	Moisture or humidity	M	Middle or intermediate
O		O	Orifice

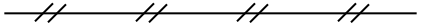
P&ID

Meaning of identifying letters

First letter: **X**		Second and third letters: **Y**	
P	Pressure or vacuum	P	Point
Q	Quantity or event	Q	
R	Radioactivity or ratio	R	Record or print
S	Speed or frequency	S	Switch
T	Temperature	T	Transmit
V	Viscosity	V	Valve, damper or louver
W	Weight	W	Well
Y		Y	Relay or compute
Z	Position	Z	Drive

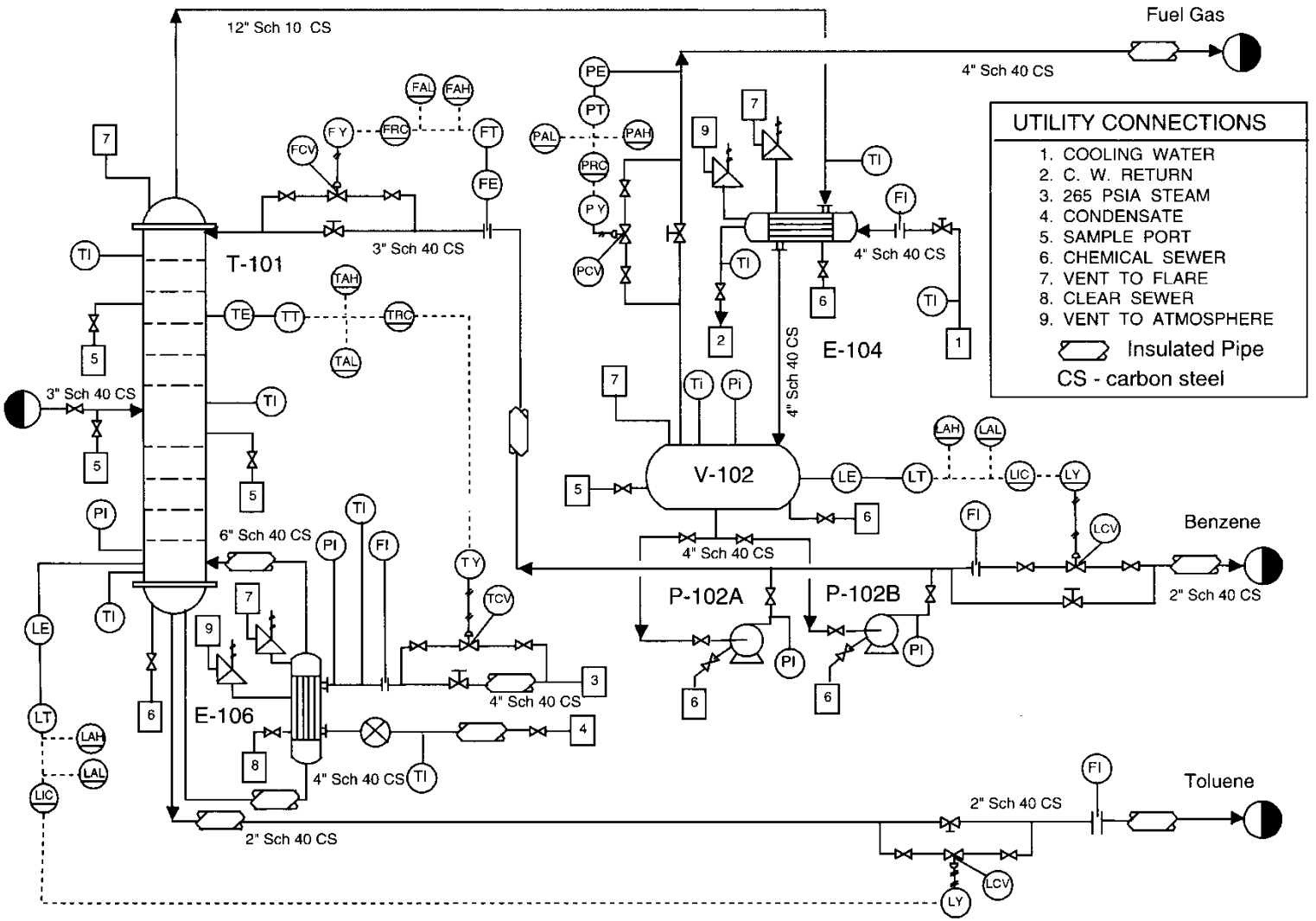
Identification of instrumental connections

Capillary

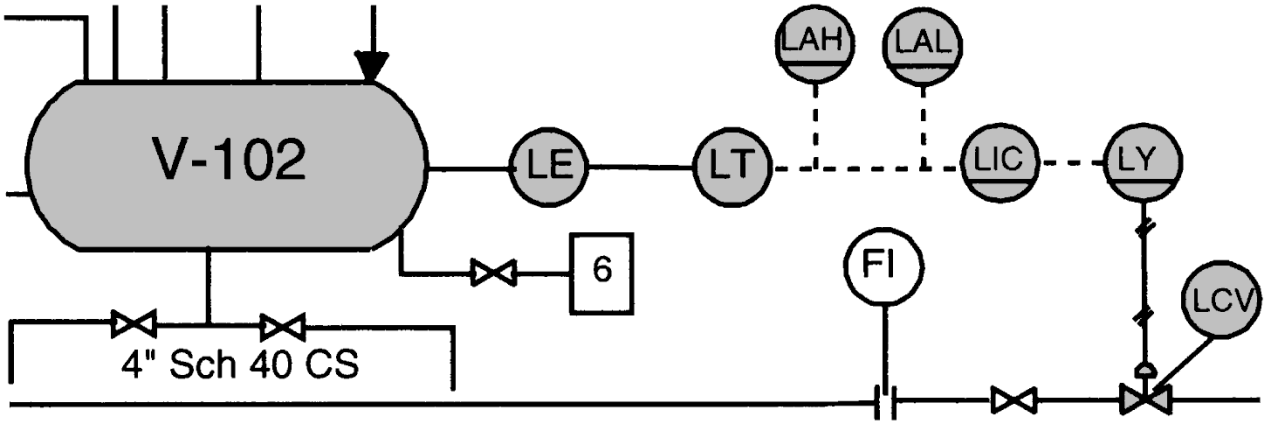

Pneumatic

Electric

P&ID


12" Sch 10 CS
Fuel Gas
4" Sch 40 CS
UTILITY CONNECTIONS
1. COOLING WATER
2. C. W. RETURN
3. 265 PSIA STEAM
4. CONDENSATE
5. SAMPLE PORT
6. CHEMICAL SEWER
7. VENT TO FLARE
8. CLEAR SEWER
9. VENT TO ATMOSPHERE
Insulated Pipe
CS - carbon steel
T-101
3" Sch 40 CS
E-104
V-102
P-102A
P-102B
E-106
6" Sch 40 CS
Benzene
2" Sch 40 CS
Toluene
FAL
FAH
FCV
FY
FRC
FT
FE
TI
TAH
TE
TT
TRC
TAL
PE
PT
PAL
PAH
PRC
PY
PCV
FI
LAH
LAL
LE
LT
LIC
LY
LCV
PI
TY
TCV

P&ID



Loop control structure for the tank level V-102

- **LE** level sensor positioned on the tank **V-102**
- **LT** level transmitter positioned on the tank **V-102**
- Transfer the signal via an electric line - - - - - - to the control room
- **LIC** level indicator and controller in the control room
- Transfer an electrical signal - - - - - - to the instrument **LY**
- **LY** instrument able to calculate the exact valve opening
- Transfer a pneumatic signal (solid line) to the control valve **LCV**
- **LAH** too high level alarm in the control room (front panel)
- **LAL** too low level alarm in the control room (front panel)


D1335
E1310

References

- R. Turton, R. Bailie, W. Whiting, J. Shaeiwitz, “Analysis, Synthesis and Design of Chemical Processes”, Prentice Hall, New Jersey, 1998