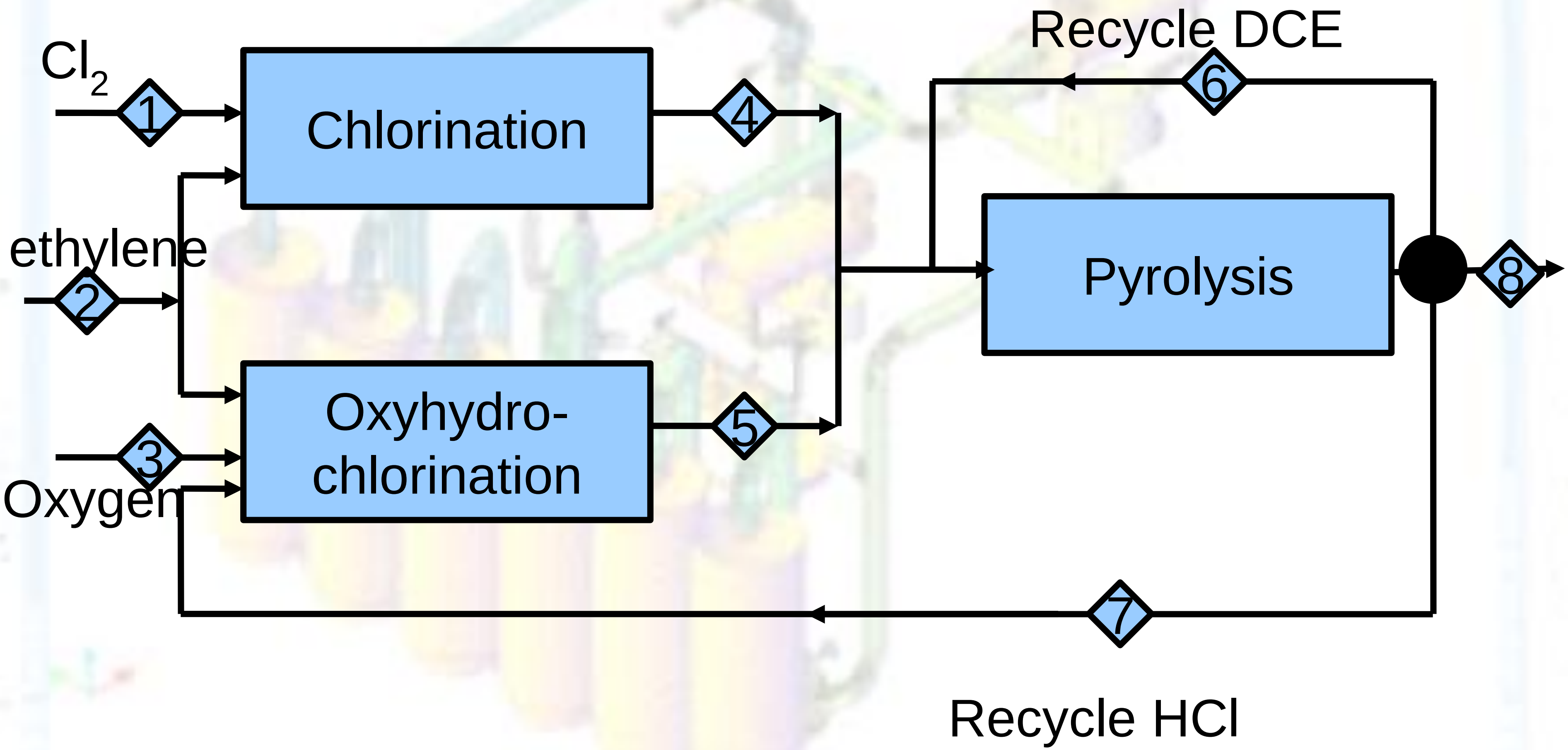
Flow Diagrams

- In general chemical engineering process are complex
- Model them as a set of flow diagrams
- These are 2D representation of 3D plant
- Useful throughout lifetime of process
  - When process is conceived in lab
  - Design and construction of plant
  - Operational lifetime of plant

Diagrams for Understanding Chemical Processes

- Block Flow Diagrams
- Process Flow Diagrams
- (Piping & Instrumentation Diagram)

Block Flow Diagrams



Production of Vinyl Chloride

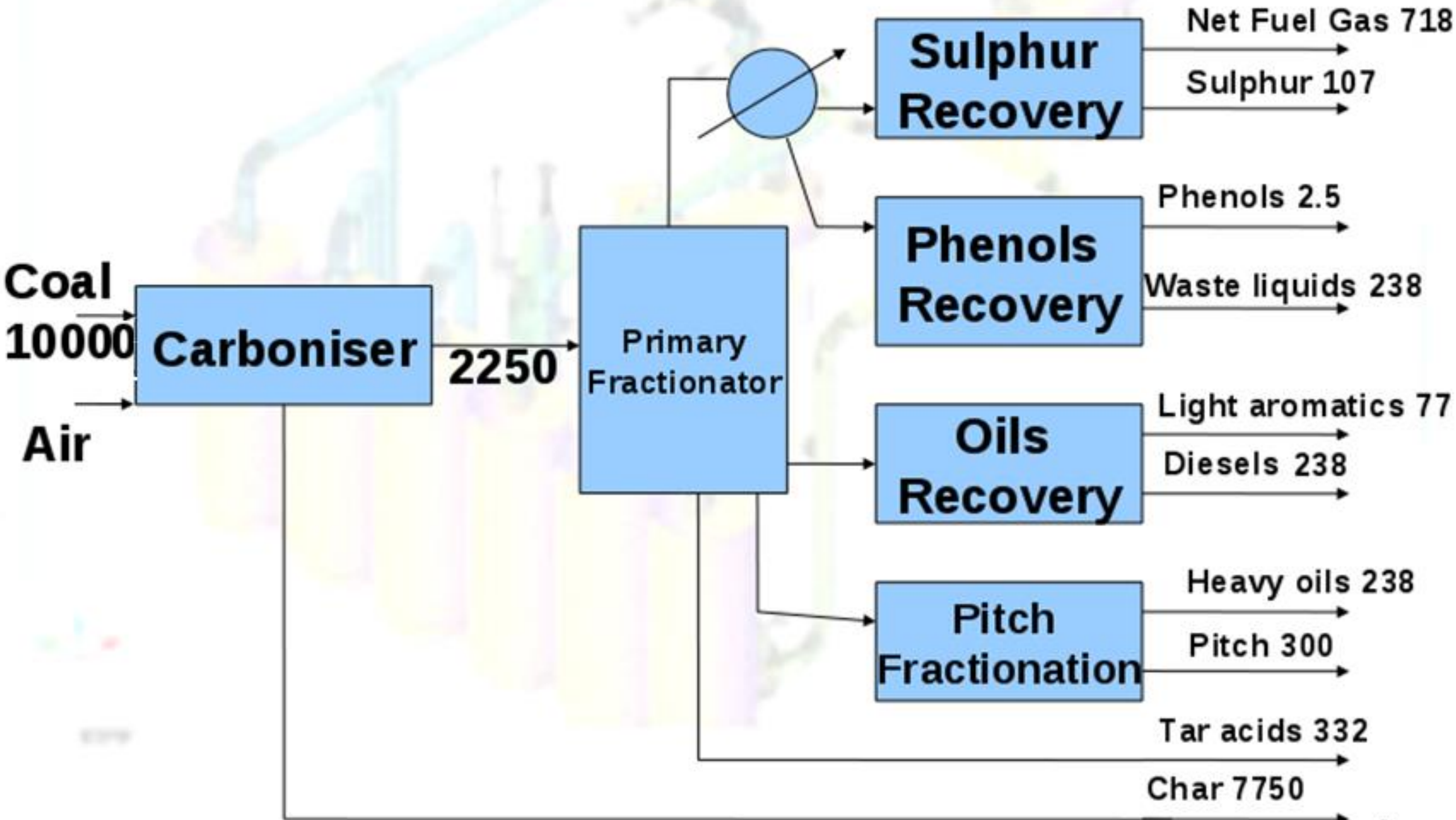
Block Flow Diagrams

- Series of blocks connected with input and output flow streams
- Activity within blocks not important
- Each block is balanced
  - Material
  - Energy
- Includes operating conditions
  - Temperature
  - Pressure

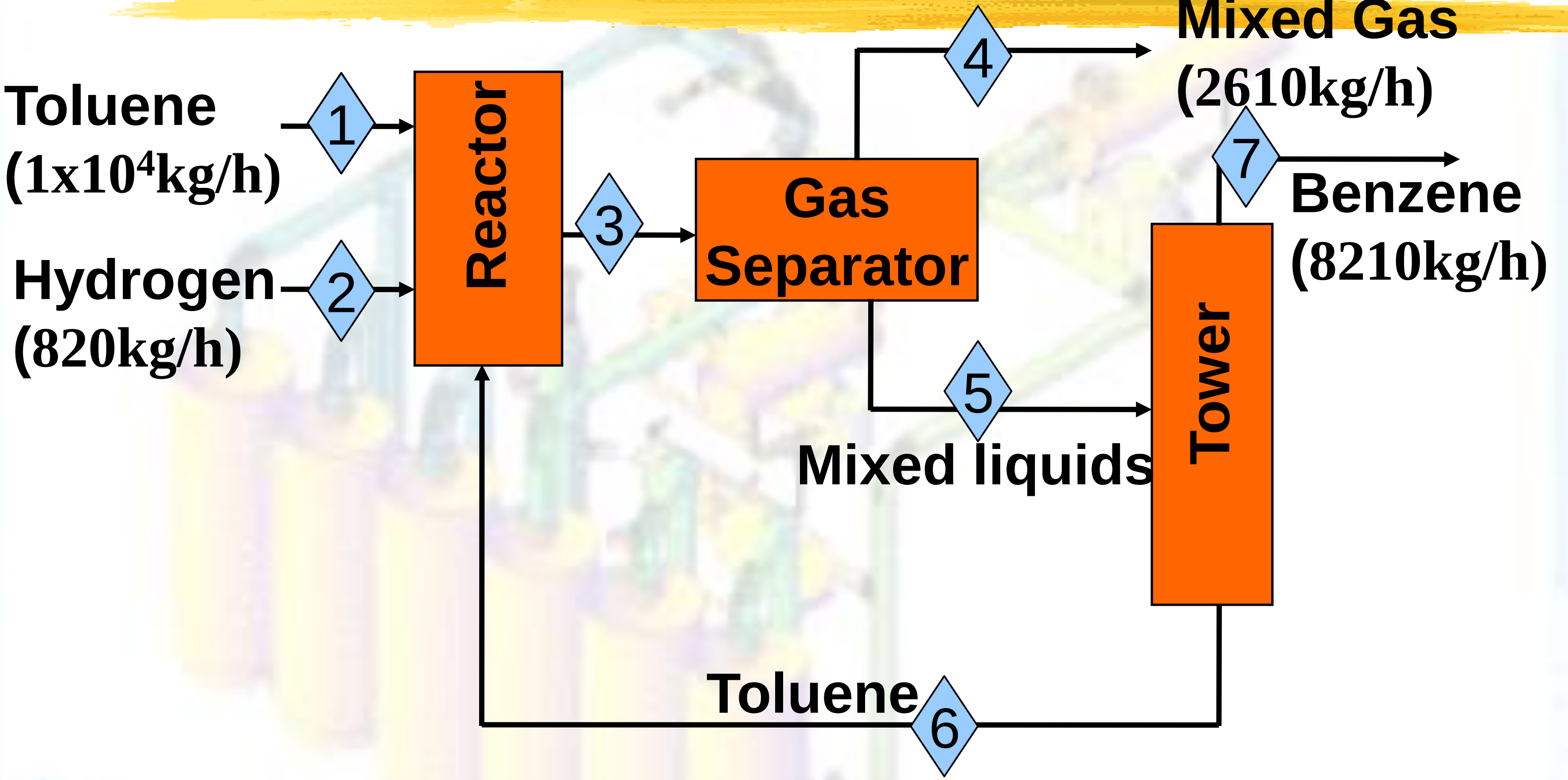
Block Flow Diagrams

- Usually used to set for the preliminary or basic processing concept without details
- The blocks represent the steps of process without details.
- Each block represents a manufacturing step in the process.
- It is used in survey studies to management, research summaries and process proposals

Block Flow Diagrams



Example of Block Flow Diagram Benzene Production



Reaction: $C_7H_8 + H_2 \rightarrow C_6H_6 + CH_4$

Block Flow Diagrams

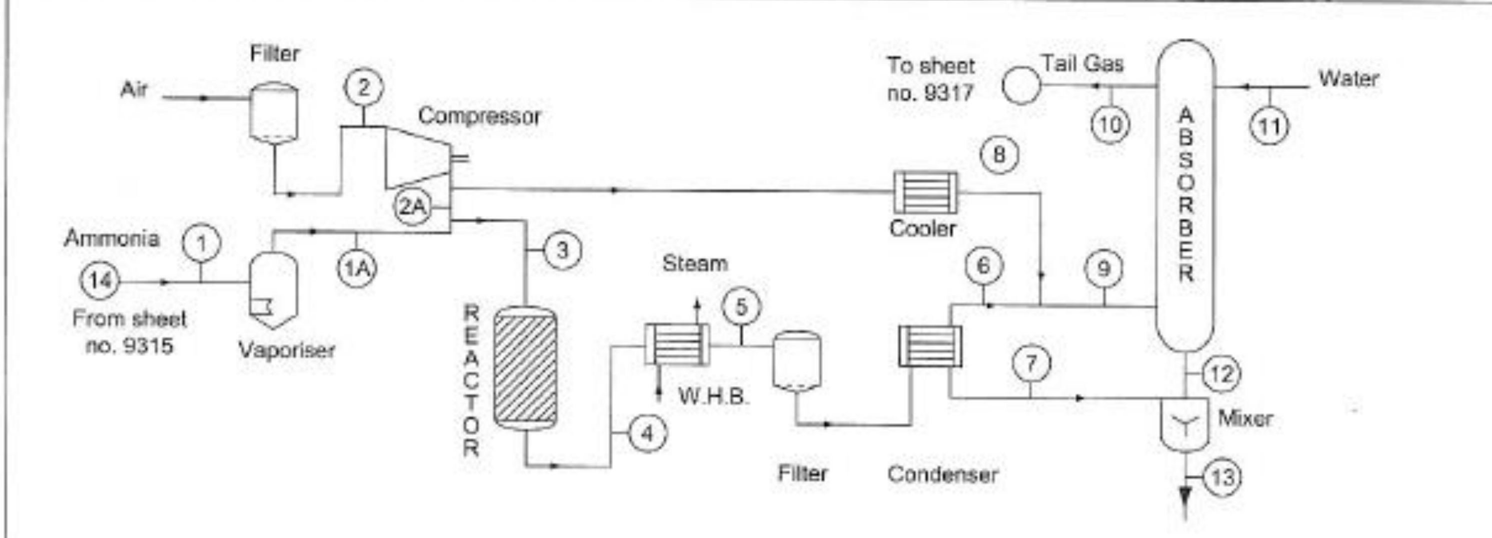
- Often Microsoft Visio does the job
  - Contains enough icons
- Simulink is better
  - Based on MatLab
  - Does material and energy balance calculations for you

Process Flow Diagrams

- Contains much more information than a BFD
- No universal standard, but tend to look the same
- Should include
  - All major pieces of equipment with
    - Description
    - Unique number
  - All process flow steams
    - Description of chemical composition (can be on flow summary table)
    - Description of process conditions (can be on flow summary table)
    - Identified by unique number
  - All utility streams
  - Basic control loops

Process Flow Diagrams

C & R Construction Inc.	Title : Nitric Acid 60 per cent	Dwg by : GRM	DATE :
	Client : BOP Chemicals SILGO	Chk by : RKS	14/12/1992



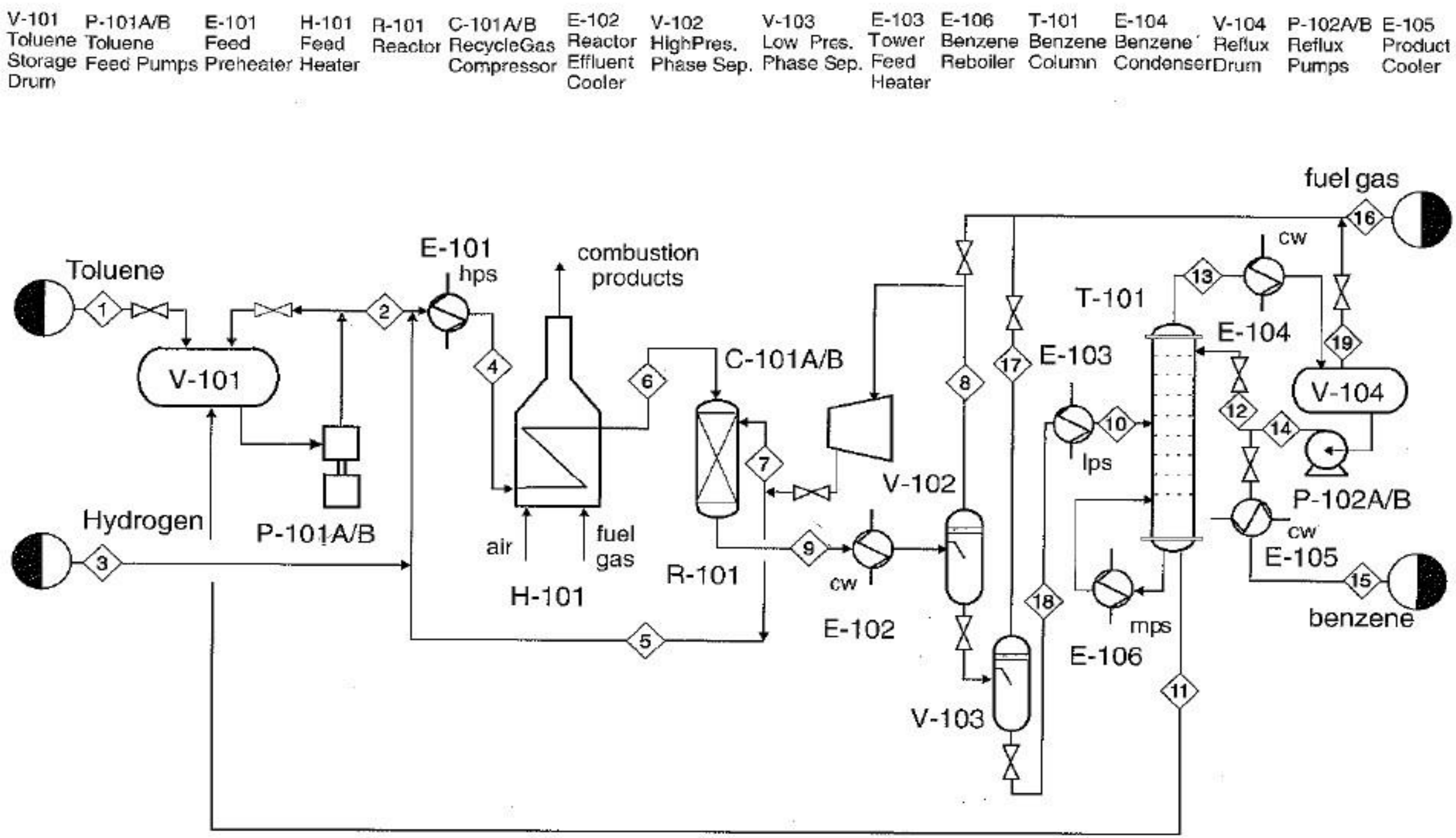
Flows (kg/h) Pressures nominal

Line No. Stream / Component	1 Ammonia Feed	1A Ammonia Vapour	2 Filtered Air	2A Oxidiser Air	3 Oxidiser Feed	4 Oxidiser Outlet	5 W.H.B. Outlet	6 Condenser Gas	7 Condenser Acid	8 Condenser Air	9 Absorber Feed	10 Tail (2) Gas	11 Water Feed	12 Absorber Acid	13 Product Acid
NH3	731.0	731.0	--	--	731.0	NIL	--	--	--	--	--	--	--	--	--
O2	--	--	3038.9	2628.2	2628.2	935.7	935.7	275.2	TRACE	408.7	683.9	371.5	--	TRACE	TRACE
N2	--	--	9990.8	8644.7	8644.7	8668.8	8668.8	8668.8	TRACE	1346.1	10014.7	10014.7	--	TRACE	TRACE
NO	--	--	--	--	--	1238.4	1238.4	202.5	--	--	202.5	21.9	--	TRACE	TRACE
NO2	--	--	--	--	--	TRACE	(7)	967.2	--	--	967.2	TRACE	--	TRACE	TRACE
HNO3	--	--	--	--	--	NIL	NIL	--	850.6	--	--	--	--	1704.0	2554.6
H2O	--	--	TRACE	TRACE	--	1161.0	1161.0	29.4	1010.1	--	29.4	26.3	1376.9	1136.0	2146.0
Total	731.0	731.0	13027.7	11272.9	12003.9	12003.9	12003.9	10143.1	1860.7	1754.8	11897.7	10434.4	1376.9	2840.0	4700.6
Press (Bar)	8	8	1	8	8	8	8	8	1	8	8	1	8	1	1
Temp (°C)	15	20	15	230	204	907	234	40	40	40	40	25	25	40	43

Process Flow Diagrams

- Used to present the heat and mass balances of the process.
- Show all production steps, starting from raw material to final products.
- Show the operating conditions of each production step in the process (operating conditions are: Temperature, Pressure, Flowrate, -----).
- Show the type and quantities of utilities that required for the process (such as: water, steam, O2, H2, -----)
- Shows the process equipments and their connection pipes.
- Gives some details for the main process equipments (such as: distillation column: its diameter, height, type of internals (trays or packing types), material of construction, thickness, ---)
- Show the main control system (type of instruments) required for the process.
- Used as data base for Piping and Instrumentation Diagram (PID) and for equipment

PFD Example – Benzene Production



⌘Spreadsheet accompanying PFD

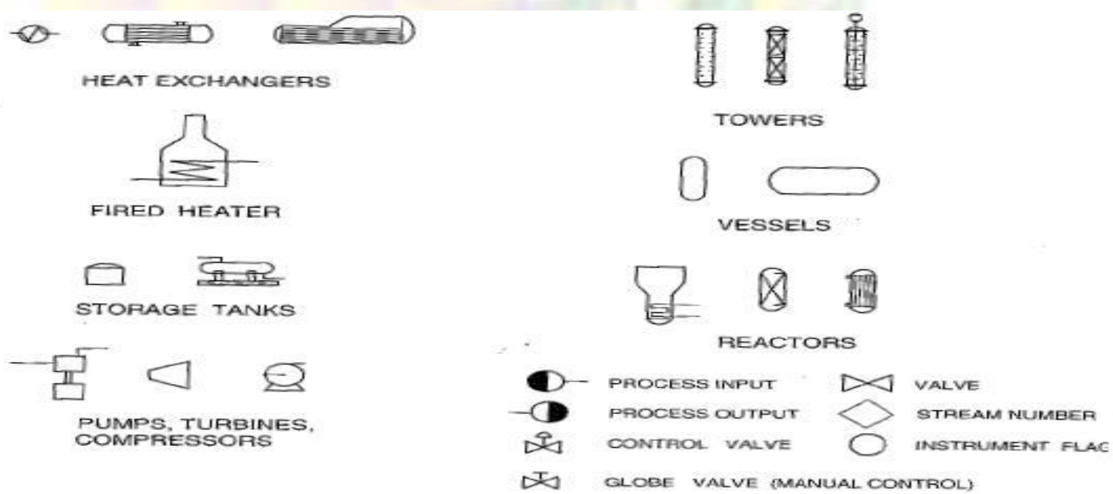
Table 1.5 Flow Summary Table for the Benzene Process Shown in Figure 1.3 (and Figure 1.5)

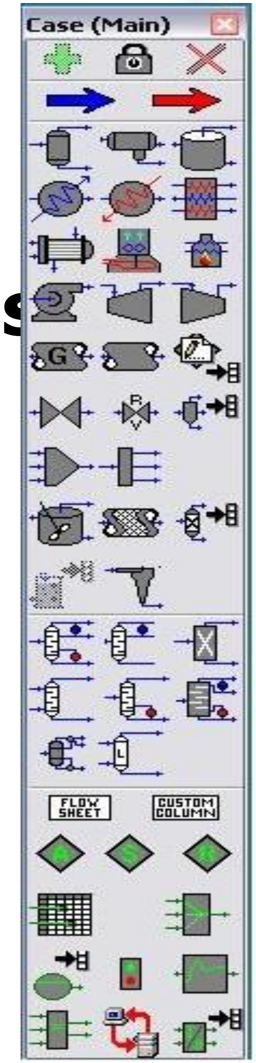
Stream Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Temperature (°C)	25	59	25	225	41	600	41	38	654	90	147	112	112	112	38
Pressure (bar)	1.90	25.8	25.5	25.2	25.5	25.0	25.5	23.9	24.0	2.6	2.8	3.3	2.5	3.3	2.3
Vapor Fraction	0.0	0.0	1.00	1.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
Mass Flow (tonne/h)	10.0	13.3	0.82	20.5	6.41	20.5	0.36	9.2	20.9	11.6	3.27	14.0	22.7	22.7	8.21
Mole Flow (kmol/h)	108.7	144.2	301.0	1204.4	758.8	1204.4	42.6	1100.8	1247.0	142.2	35.7	185.2	290.7	290.7	105.6
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	0.0	0.0	0.02	0.0	0.0
Methane	0.0	0.0	15.0	317.3	302.2	317.3	16.95	438.3	442.3	0.88	0.0	0.0	0.88	0.0	0.0
Benzene	0.0	1.0	0.0	7.6	6.6	7.6	0.37	9.55	116.0	106.3	1.1	184.3	289.46	289.46	105.2
Toluene	108.7	143.2	0.0	144.0	0.7	144.0	0.04	1.05	36.0	35.0	34.6	0.88	1.22	1.22	0.4

From Turton and Bailie

PFD – Process Topology

- Diagram above shows process topology for the toluene to benzene process
- Icons represent equipment
- ISO10628 international standard for icons
- BS1553 more typically used





PFD – Process Topology

- Each piece of equipment represented by a number, e.g. P-101A/B
  - P means pump
  - 1 means area 100
  - 01 means this is pump 01 in area 100
  - A/B means there is a backup pump installed
- Other types of equipment
  - E =heat exchanger
  - C = compressor or turbine
  - H = heater
  - R = reactor
  - T = tower
  - V = vessel

PFD – Process Topology

- **Layout of units pretty much as we'd expect on the plant floor**
- **Size of units on PFD should square with their footprints in reality...to some degree**
- **Will mean sometimes several sheets needed**
  - **Conventions for connecting sheets together**

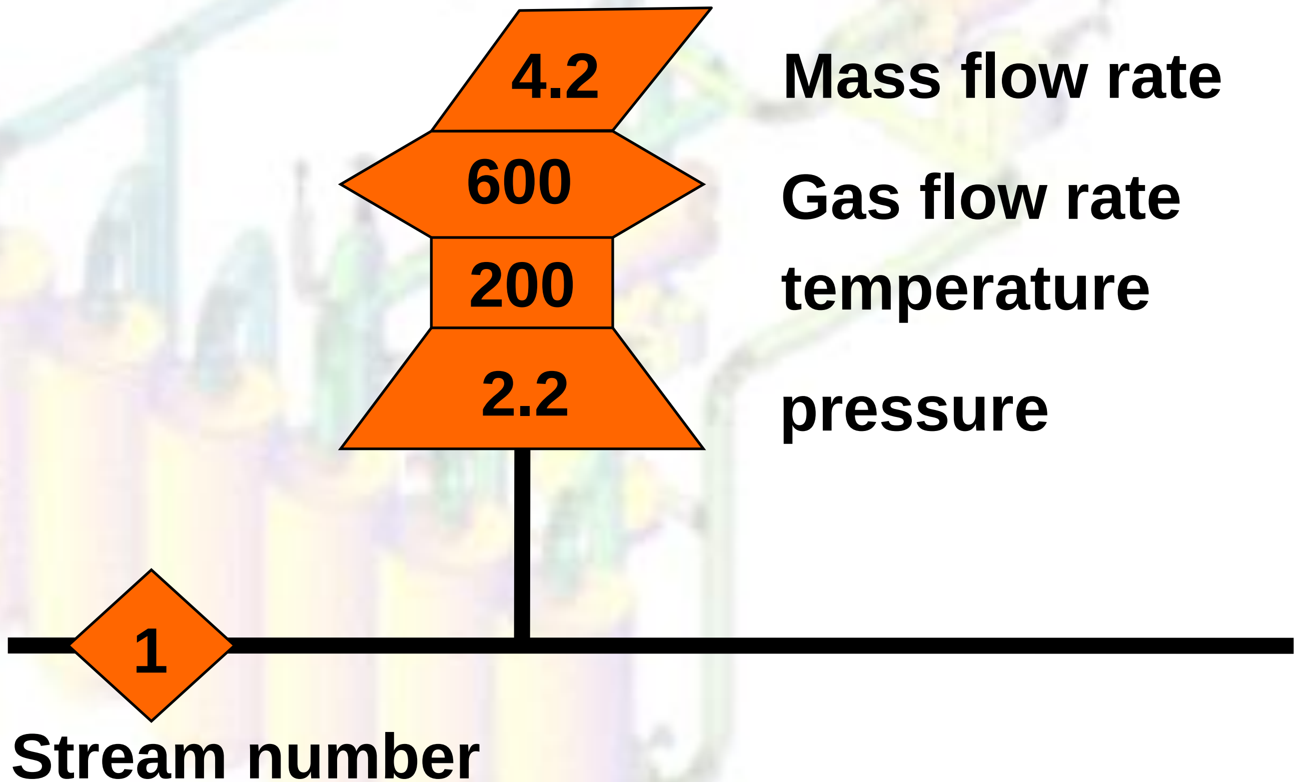
PFD – Codes for Utility Streams

- lps = low pressure steam
- mps = medium pressure steam
- hps = high pressure steam
- cw = cooling water
- rw = refrigerated water
- etc

PFD - Stream Information

- Need to note
  - Stream number
  - Temperatures
  - Pressures
  - Compositions
  - Flowrates
  - Vapour fraction
- Can be done on diagram
- Can be done on stream table (with streams numbered on diagram)

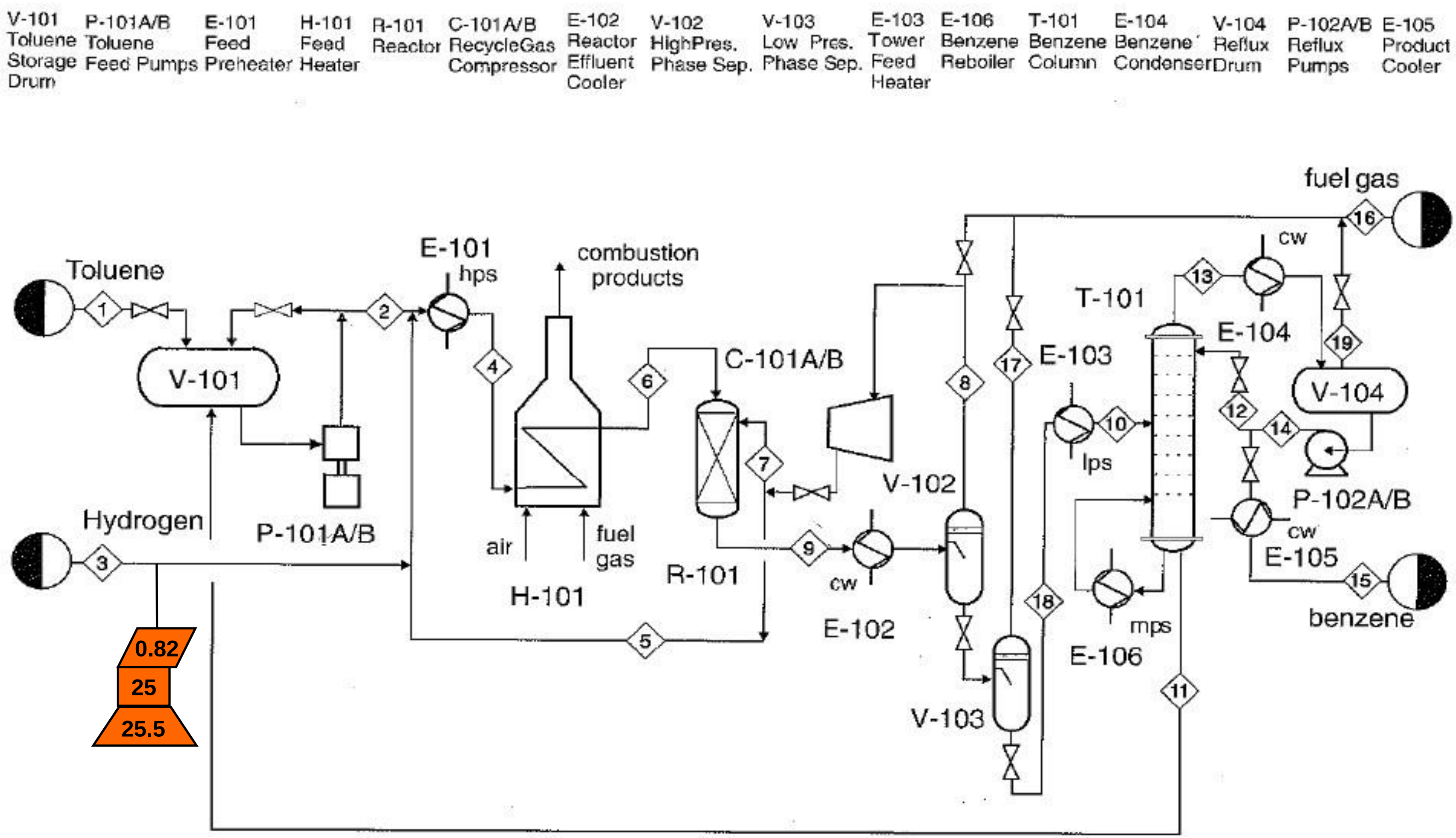
PFD - Stream Information



PFD – Equipment Information

- Information necessary for design of equipment
- For example for towers gives:
  - Number of trays
  - Type of trays
  - Height and type of packing
  - materials

PFD Example – Benzene Production



stream number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
temperature (celsius)	25	59	25	225	41	600	41	38	654	90	147	112	112	112	38	38	38	38
pressure(bar)	1.9	25.8	25.5	25.2	25.5	25	25.5	23.9	24	2.6	2.8	3.3	2.5	3.3	2.3	2.5	2.8	2.9
vapour fraction	0	0	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	0
mole flow (kmole/hr)	108.7	144.2	301	1204.4	758.8	1204.4	42.6	1100.8	1247	142.2	35.7	185.2	290.7	290.7	105.6	304.2	4.06	142.2
component mole flow(kmoe/hr)																		
hydrogen	0	0	286	735.4	449.4	735.4	25.2	651.9	652.6	0.02	0	0	0.02	0	0	178	0.67	0.02
methane	0	0	15	317.3	302.2	317.3	16.95	438.3	442.3	0.88	0	0	0.88	0	0	123.05	3.1	0.88
benzene	0	1	0	7.6	6.6	7.6	0.37	9.55	116	106.3	1.1	184.3	289.46	289.46	105.2	2.85	0.26	106.3

Developing Process Flow Diagrams

- Software helps
  - FLOSHEET from Procede the best
  - Cocosimulator from Cape Open OK
    - It's free
  - Simulator programmes like UniSym, HYSYS that we'll meet in the lab produce stuff that look like PFD's, but they're not really

Developing Process Flow Diagrams

- Five steps
  - Decide on batch or continuous
  - Identify input / output structure
  - Identify and define the recycle structure
  - Identify and design structure of separations
  - Identify and design the heat exchanger network or process energy recovery system

Batch or Continuous

- For us, almost always batch (but this changing)
- Reasons for batch
  - Smaller quantity size
  - Thorough product quality checks
  - Flexibility, making several different products
  - Unit flexibility – e.g one tank for stirrer, mixer, reactor
  - Slow reactions
  - Better for cleaning

Batch or Continuous

- **Reasons for continuous**
  - **Better efficiency**
    - **Recycle energies and materials better**
    - **Use less utilities**
  - **Lower maintenance and labour costs**
  - **Less exposure to chemicals of process**