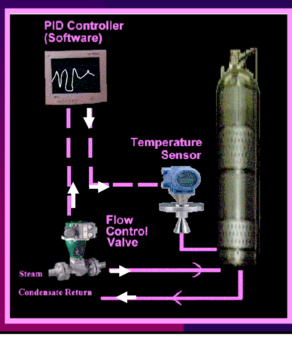
Process Flow Sheets



Prepared by staff of

Chemical and Process

Engineering Department

Presented by

Dr .(Mrs.)Olga.Gunapala

In the early days of the chemical industry Process Flow Sheets were defined as

"The schematic representation of the unit operations and reactors involved in manufacturing process at chemical plant "

My plant does not consist of an arrangement of reactors processing raw materials?!! PFD are not applicable for it

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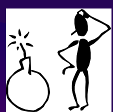
That time the manufacturing processes were simple and PFS aided in design and operating the chemical plants only.



New development complicated manufacturing processes that requested knowledge of:

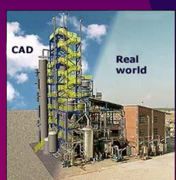
1. chemical and mechanical engineering,

2. electrical and civil engineering,

3. process control and instrumentation

4. economics marketing and Management

5. environmental engineering.

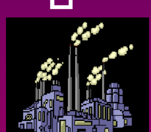


PFD were developed and supplemented with:

1.Piping diagram

2.Instrumentation diagram

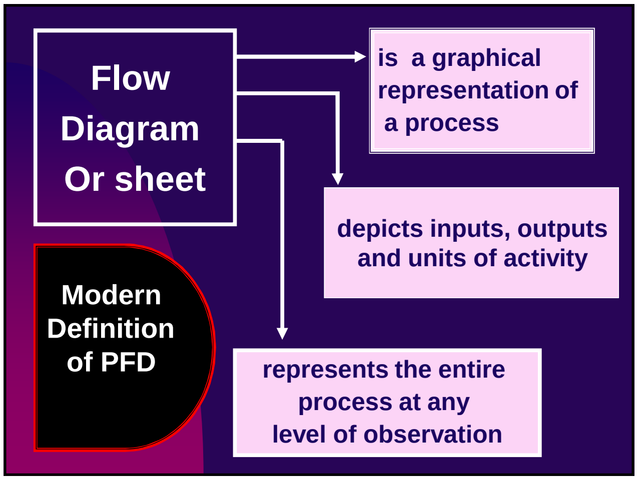
3.Electrical diagram

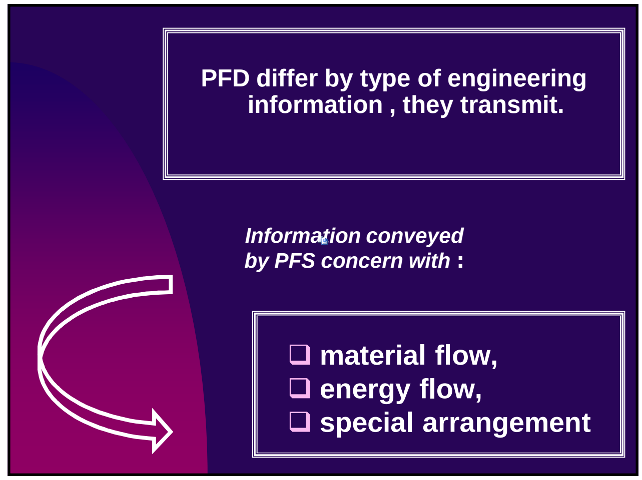


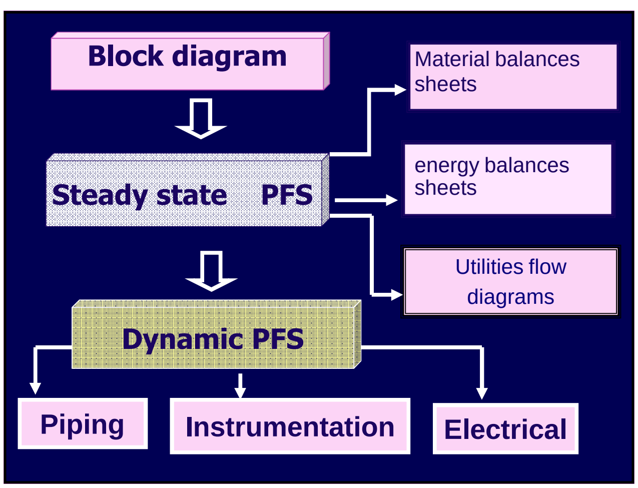
Availability of computers made it possible to develop PFD in their dynamics to show interaction inside and outside boundaries of the plant .

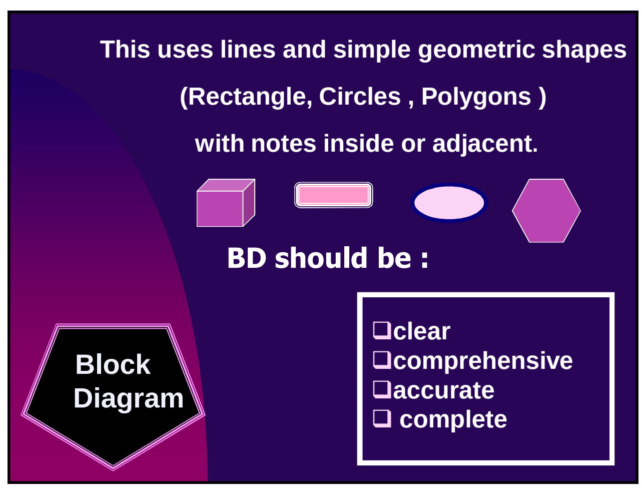
PFD as traditional tool of chemical engineering have become extremely useful tool in any industry

for transmission of engineering information by explaining the steps pictorially in a simple and easy manner.


Flow Diagram Or sheet
is a graphical representation of a process
depicts inputs, outputs and units of activity
represents the entire process at any level of observation
Modern Definition of PFD


PFD differ by type of engineering information , they transmit.
Information conveyed by PFS concern with :
❑ material flow,
❑ energy flow,
❑ special arrangement


Block diagram
Steady state PFS
Material balances sheets
energy balances sheets
Utilities flow diagrams
Dynamic PFS
Piping
Instrumentation
Electrical


This uses lines and simple geometric shapes
(Rectangle, Circles , Polygons)
with notes inside or adjacent.
BD should be :
Block Diagram
❑clear
❑comprehensive
❑accurate
❑ complete

Major processing stages such as mixing , separation ,conversion , distillation and heat exchanging are denoted by a simple block or rectangle.

Mixing

Conversion

BD rules

Separation

Where possible the diagram should be arranged so that the process materials flow from left to right, with upstream units on the left and downstream units on the right.

Manufacture of sulphuric acid from Sulphur by contact process

$S_{(s)} + O_{2(g)} \rightarrow SO_{2(g)}$

1. Conversion of Sulphur to sulphur dioxide.

$2SO_{2(g)} + O_{2(g)} \leftrightarrow 2SO_{3(g)}$

catalyst V_2O_5 Temperature $400^{\circ}C$

$\Delta H = -182\ kJ/mol$

2 Oxidation of Sulphur Dioxide to Sulphur Trioxide

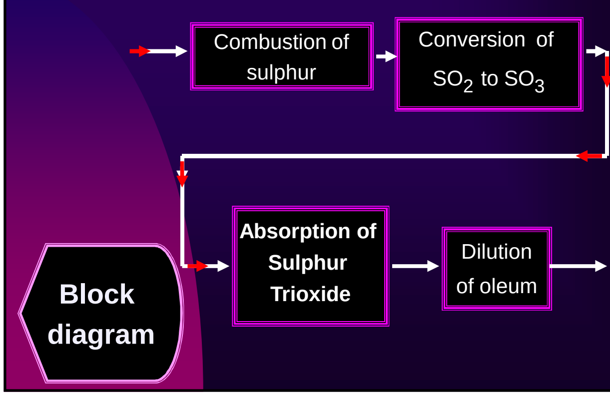
$SO_{3(g)} + H_2SO_4 \rightarrow H_2S_2O_{7(l)}$

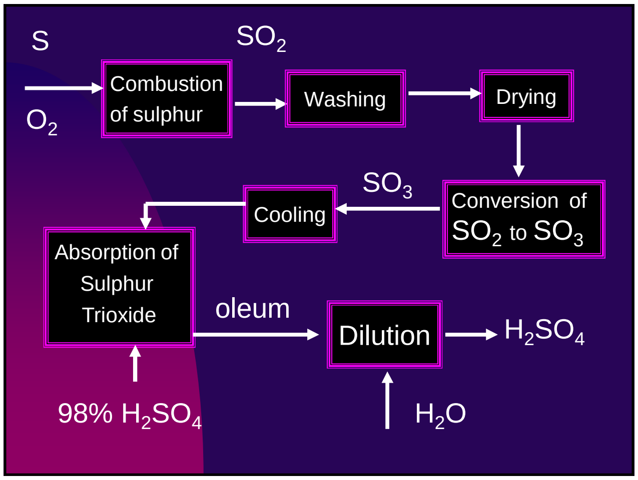
3.Absorption of Sulphur Trioxide with 98% sulphuric acid

$H_2S_2O_{7(l)} + H_2O \rightarrow 2H_2SO_4$

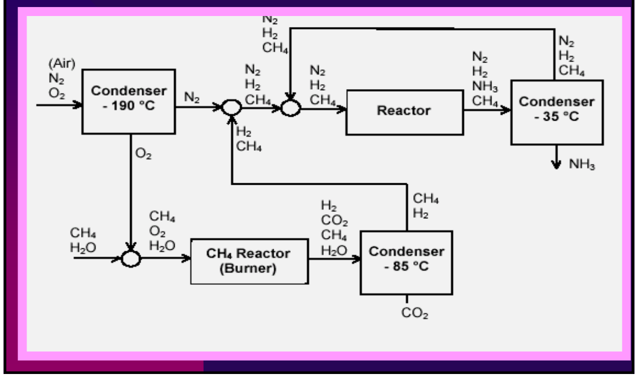
4 Dilution of oleum with water

Contact process





Ammonia Production Process



Simple and easy way for understanding:

1- main steps in the process

2 - input and output streams

3- recycling streams

What is the use of BFD?

Steady state PFS

" The Steady State Process Flow Sheet is a schematic illustration of the process using standard symbols"

A PFS tabulates process design values for the components in different operating modes, typ minimum, normal and maximum

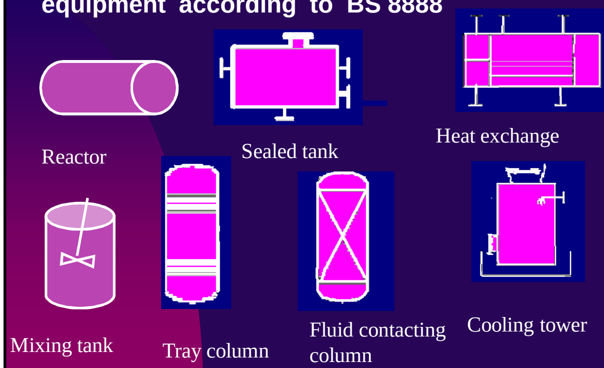
A Steady State Process Flow Diagram shows the relationships between the major components in the system.

A PFD does not show minor components, piping systems, piping ratings and designations.

Process Flow Diagrams show :

- Stream composition
- Total stream flow
- Stream temperature
- Stream pressure
- Major equipment

Standard symbols for main processing equipment according to BS 8888



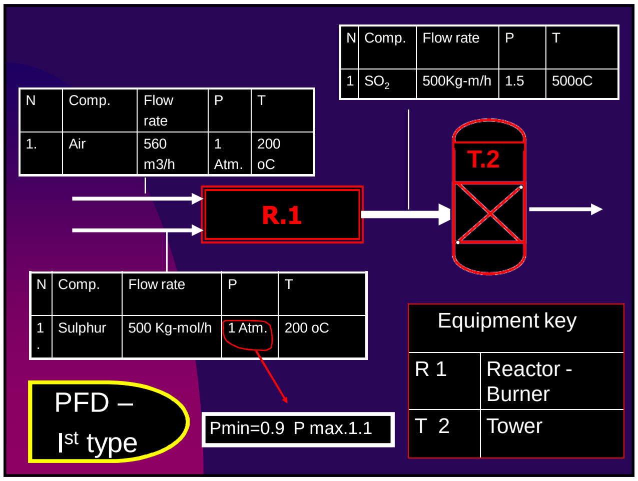
Two type of steady state PFS

a).

- information on the streams is given in the table located on lines , equipment is labeled and equipment key is given in a separated table.

b).

information on the streams is tabulated in the separated table , equipment is labeled on the diagram

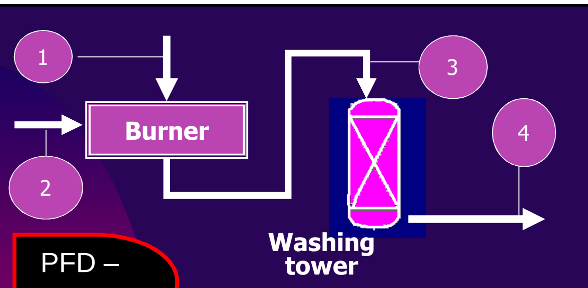


N	Comp.	Flow rate	P	T
1	SO_2	500Kg-m/h	1.5	500oC

N	Comp.	Flow rate	P	T
1.	Air	560 m3/h	1 Atm.	200 oC

N	Comp.	Flow rate	P	T
1.	Sulphur	500 Kg-mol/h	1 Atm.	200 oC

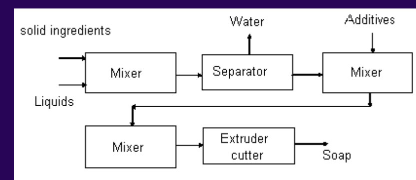
Equipment key	
R 1	Reactor - Burner
T 2	Tower

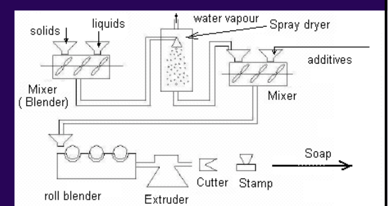


PFD – 2 nd type

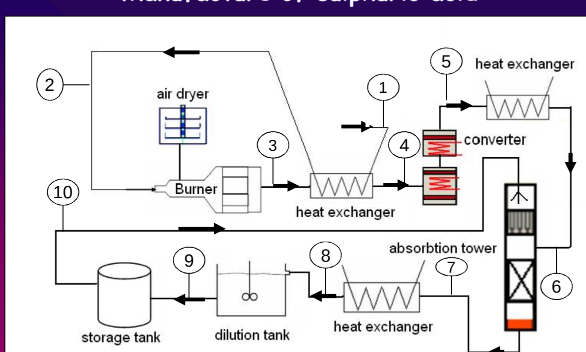
N	Comp.	Flow rate:	Temp.	P
1.	Sulphur	500 kg-mol /h	200oC	1 atm
2,	Air	560 m3/h	100oC	1.5 atm
3	$SO_{2+imp.}$	500 kg-mol/h	500oC	1.5 atm
4.	SO_2	490 kg-mol/h	25 0C	1.5 atm

Block and Process Flow Diagram for the Manufacture of Soap





PFD . Contact process. Manufacture of sulphuric acid



This sheet includes :

1.Process Piping

2.Major equipment symbols, names and identification numbers

3.Ancillaries symbols

4.Controller loops , and control valves

5. Interconnection with other systems

6.System ratings and operational values as minimum, normal and maximum flow, temperature ,pressure and composition of the stream

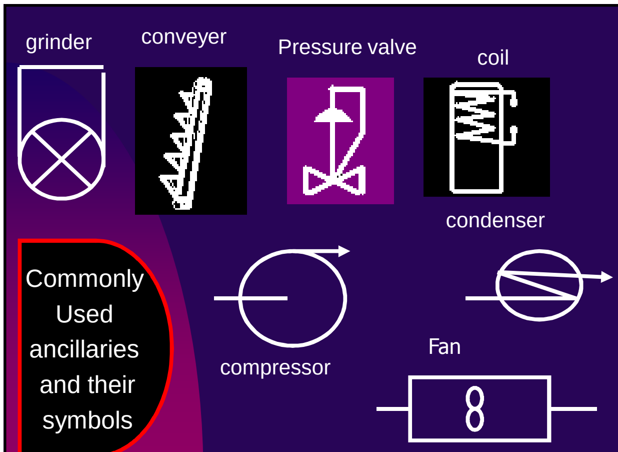
Dynamic PFS

Steady state PFD + Ancillaries
Controller loops
Process piping

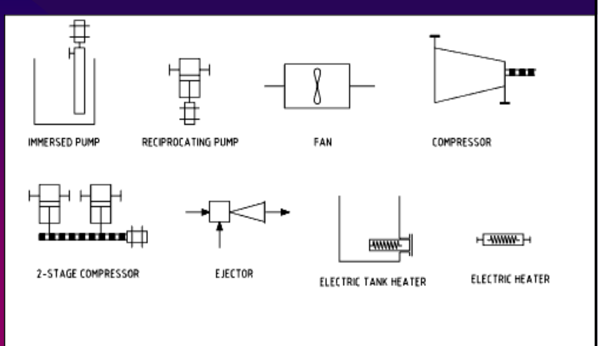
Dynamic PFS

Dynamic PFS

Commonly Used ancillaries and their symbols



Standard symbols for ancillaries according to BS 8888

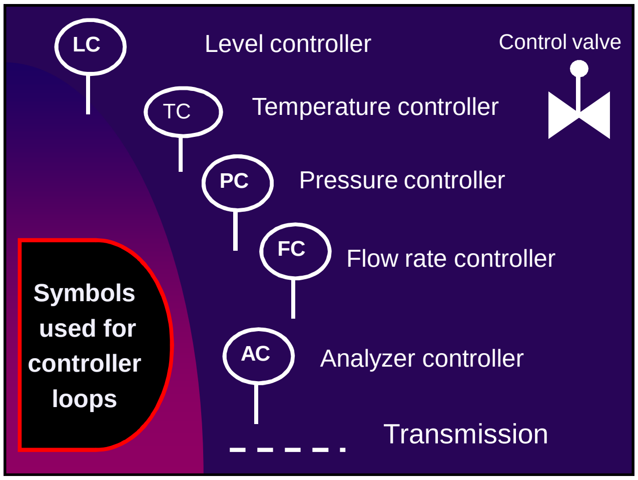


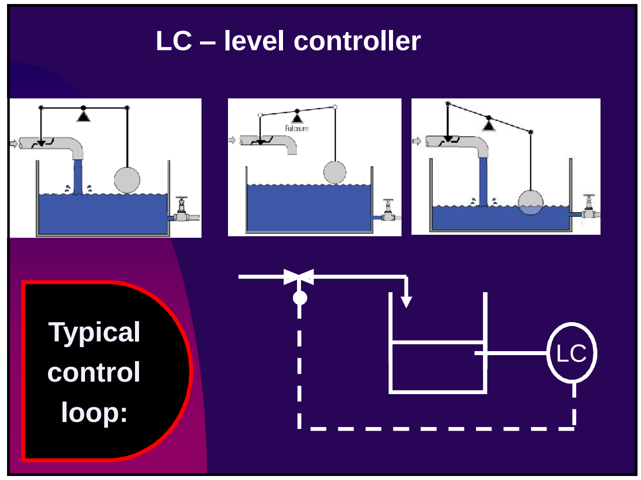
Controller loops

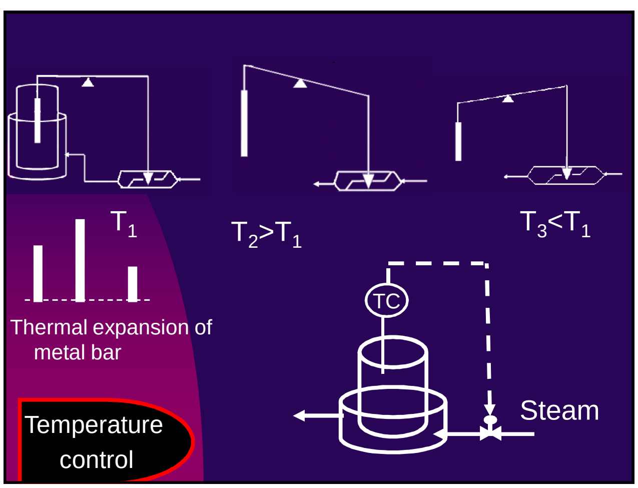
They provide monitoring process parameters:

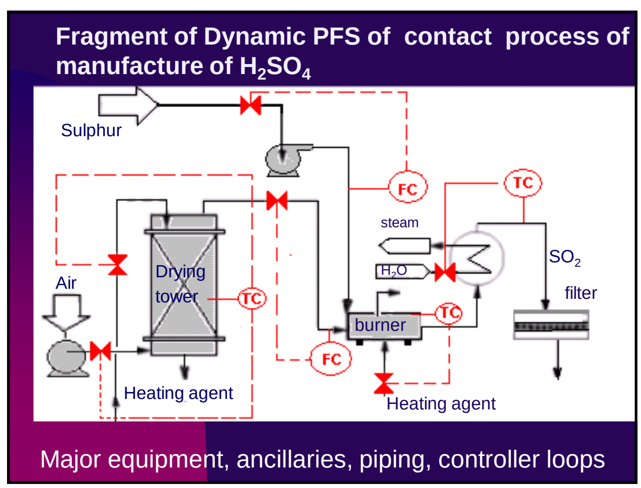
- pressure,
- temperature,
- flow rate,
- fluid level,
- composition

- to achieve desired production rate
- to maintain the product quality
- to obtain profit
- to ensure safe plant operation

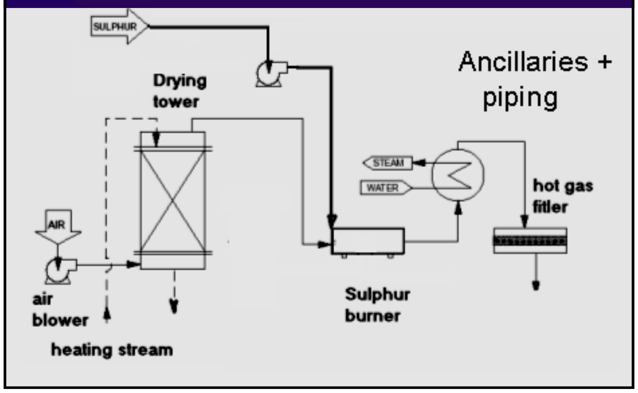

LC
Level controller
Control valve
TC
Temperature controller
PC
Pressure controller
FC
Flow rate controller
AC
Analyzer controller
Transmission
Symbols used for controller loops


LC – level controller
Typical control loop:
LC

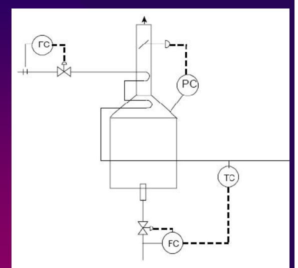

T_1
$T_2>T_1$
$T_3<T_1$
Thermal expansion of metal bar
TC
Steam
Temperature control


Fragment of Dynamic PFS of contact process of manufacture of H_2SO_4
Sulphur
FC
TC
steam
H_2O
SO_2
Air
Drying tower
TC
burner
TC
filter
FC
Heating agent
Heating agent
Major equipment, ancillaries, piping, controller loops

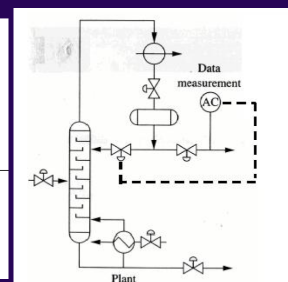
Dynamic PFS (no controller loops)



Fragments of dynamic PFS

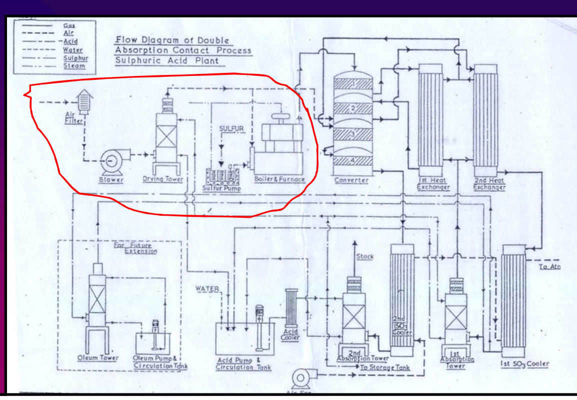


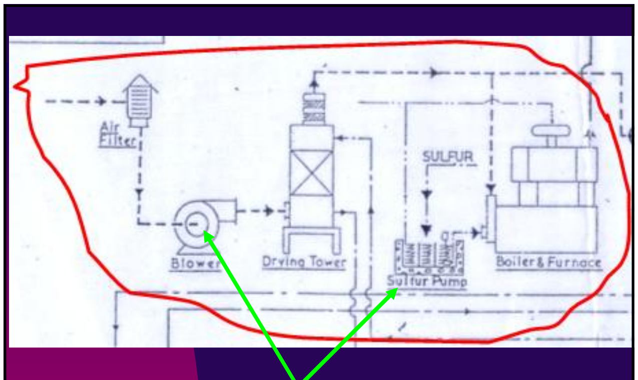
Burner



Column

Dynamic PROCESS FLOW DIAGRAM OF THE CONTACT PROCESS





Ancillaries + piping

Following data should be shown on the flow sheet :
- flow rate of each component
- total stream flow rate
- percentage composition

Material Flow Sheet

Material flow sheets have to be prepared for each unit.

Material balance sheet

Comp	10-3 g-mol/h
FeS_2	0.7083
N_2	21.983
O_2	5.8437

Pyrite burner

Comp.	10^{-3} g-mol/h
FeS_2	0.0242
Fe_2O_3	0.342
N_2	21.98
O_2	3.938
SO_2	1.368

Stream	Kg/h	M³/ h
TOTAL		

Process

Including all unit operations:
Burner.
Converter,
absorption column
Dilution tank

Stream	Kg/h	M³/h
total		

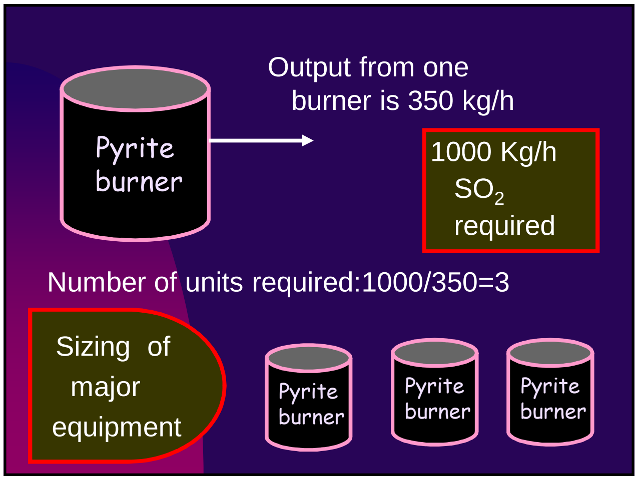
- Material flow sheets allow to size major equipment:

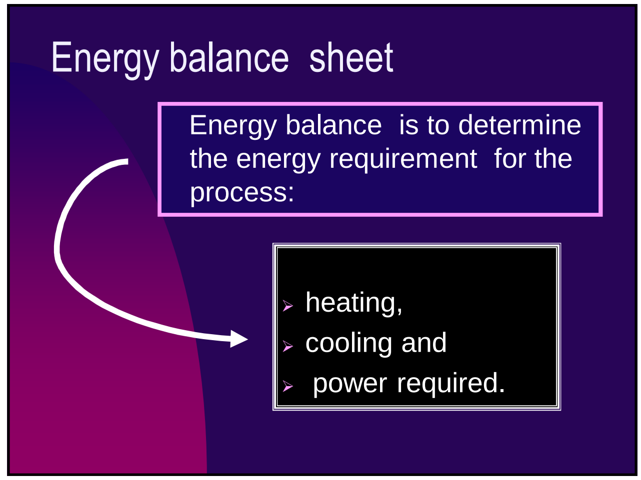
Compound 100 kg/h → Extruder → Soap 100kg/h

Production rate of commercial machine: 25 kg/h

Number of extruders required:

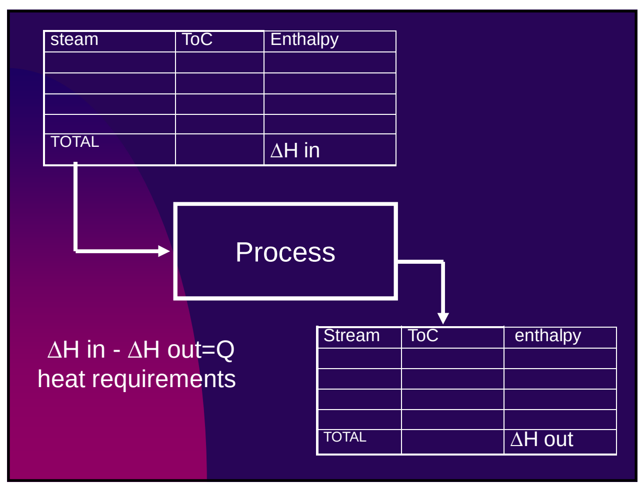
100/25 =4 machines





Energy flow sheet includes :

- inlet and outlet energy flow rates. They should be shown separately for each piece of equipment
- energy (calculated by total enthalpy from or using specific heat capacity data) of each component in all (inlet and outlet) streams'
- process conditions of all (inlet and outlet) streams
- process conditions of the specific equipment



- Energy balance sheet is to be prepared for each unit.

Plant

Unit 1	Unit 2	Unit 3
Q_1	Q_2	Q_3

Heat required for the plant = $Q_1 + Q_2 + Q_3$

They represent flow of :

Utilities or services flow sheets

1. Steam for heating in process
2. Compressed air (conditions for same chemical reaction, blowing , forming)
3. Vacuum(conditions for same reactions, transportation of materials, shaping…)
4. Water:

4.1 Distilled water

4.2 Cooling – heating or circulating water

4.3 Exposed water

---

5. Refrigerators flow (for low temperature cooling)

They are: ammonia
sulphur dioxide
carbon dioxide

6. Gases:

Fuel gas, LP gas } for heating

O_2, N_2, Inerts } for same processes

Electricity belongs to utilities , but is often given on electrical diagram

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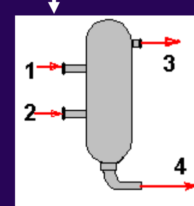
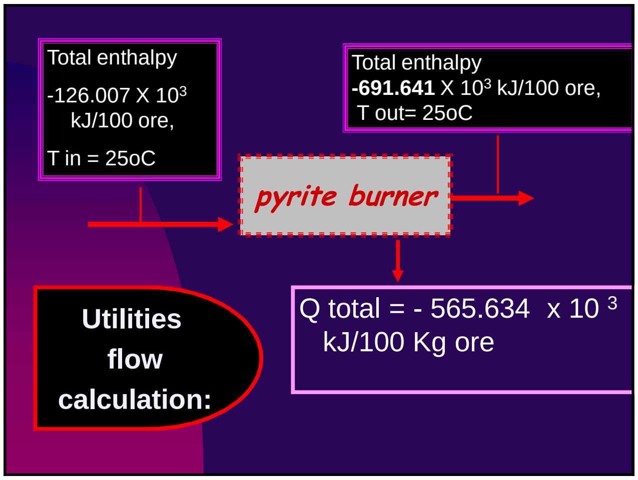
Stream	Flow rate	Characteristics, P Cp H ToC
1 2		
Total		



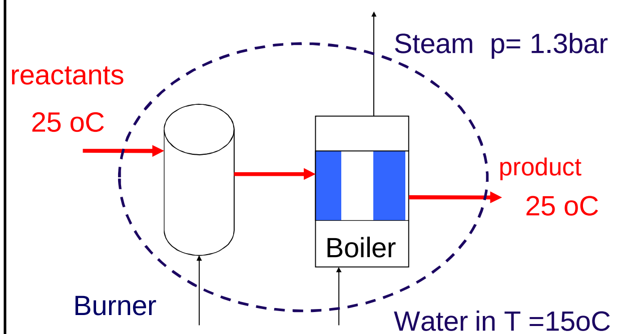
Stream	Flow rate	Characteristics, P Cp H ToC
3 4		
Total		

1.2,3 and 4 -utilities .

Not materials being processed



Heat is given to water ,that is heated to boiling and evaporated



$-Q_{\text{reaction}} = + Q_{\text{water}} = \Delta H =$

$H_{\text{sensible water}} (1) + \Delta H_{\text{latent heat of vaporization}} (2)$

ΔH sensible water =Cp ΔT m

m=mass of water

ΔT= T boiling –15 oC

From steam table :

At p= 1,3 bar T boiling= 124.90 oC

Cp,(water) = 4.18 kJ/kg ℃

ΔH sensible water = 4.18(124.9 -15)x m (1)

P bar	P kPa	ToC	H kJ/kg	Specific volume
1.3	130.0	124.90	2713.3	0.773
……………………	…………………….	……………………	…………………….	…………………….

Steam tables

pressure is given by gauge

ΔH latent heat of vaporization = mass x H'
H' – specific latent heat of vaporization.
From steam table: H' =2713.3 kJ/kg
ΔH latent heat of vaporization = 2713.3 x m(2)

ΔH =4.18(124.9 -15)x m + 2713.3 x m
Q water = - Q from process =
- (-565.634 x 10 ³) kJ/100 Kg ore

From where :

Mass of cooling water= 565.634 x 10 ³ /
4.18(124.9 -15) + 2713 =
200 kg water /100 kg ore

Piping and Instrumentation Diagram

- This is a schematic illustration of piping, and instrumentation.
- This diagram shows all piping including the physical sequence of branches, reducers, valves.

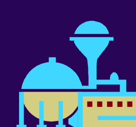
They are used to operate the process system.

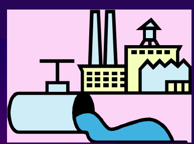
Piping and Instrumentation Diagram should include

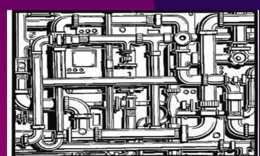
- Instrumentation and designations
- All valves and their identifications
- Process piping, sizes and identification
- Miscellaneous - vents, drains, special fittings, sampling lines, reducers, increasers
- Permanent start-up and flush lines
- Flow directions

Optional information

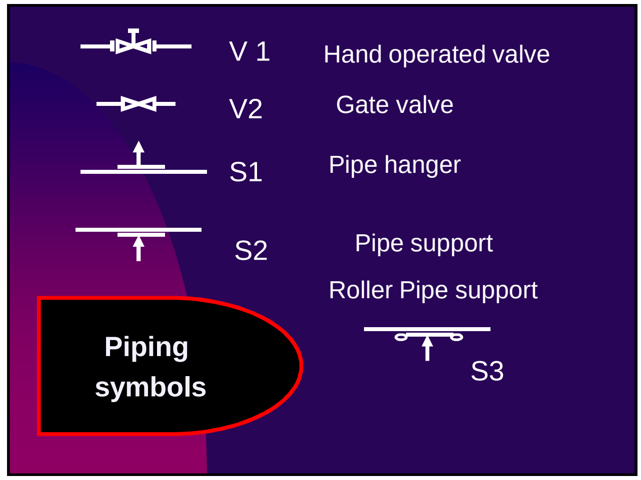
- Inter connections references
- Control inputs and outputs
- Seismic category
- Quality level
- Computer control system input
- Vendor and contractor interfaces

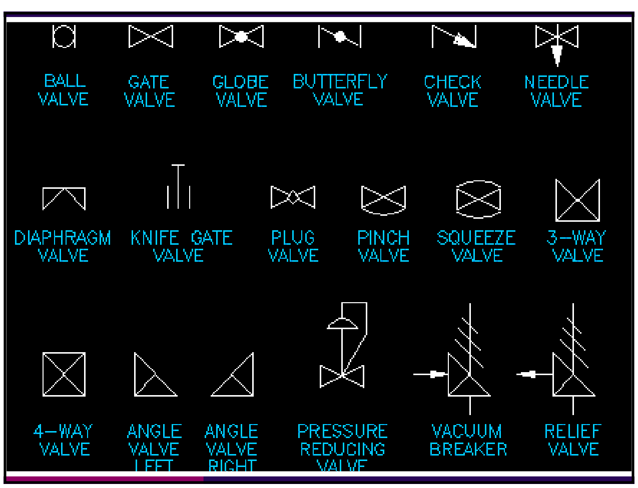




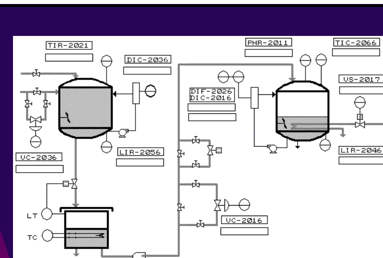


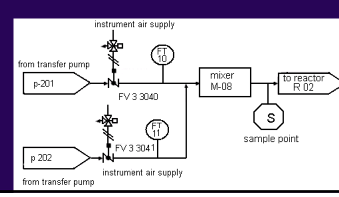
- Main and service pipe are arranged on the racks
- Large diameter pipes are carried be separated supports
- If ToC of the pipe is above 45oC it should be insulated

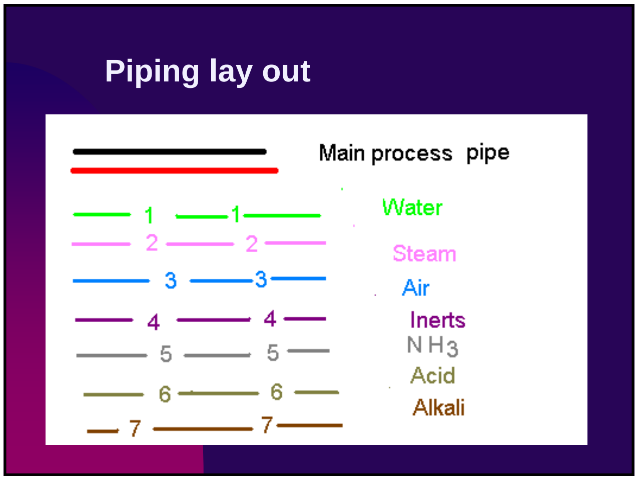


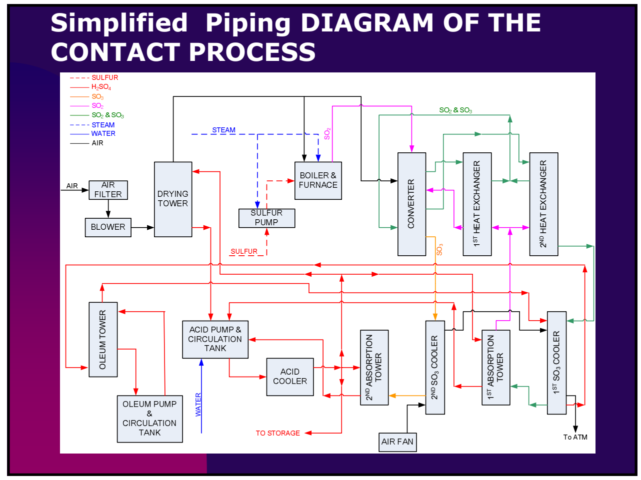


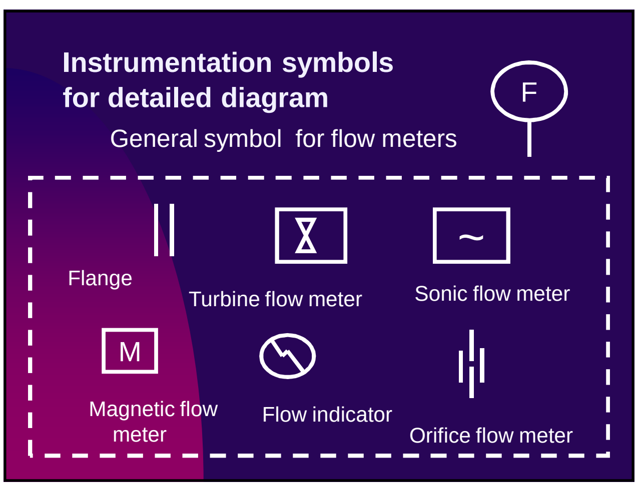
Fragment of PID

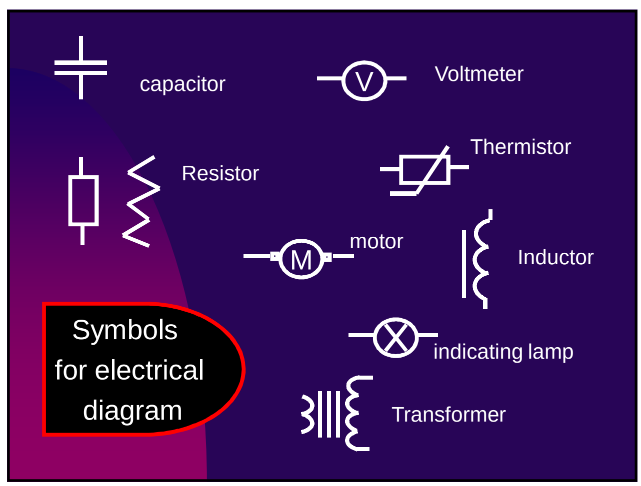




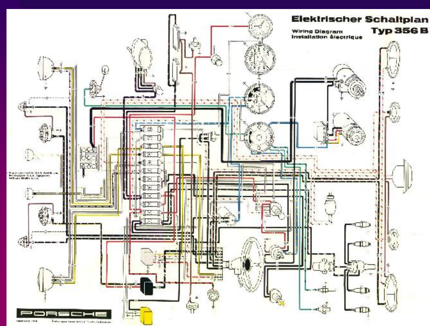

Piping lay out
Main process pipe
1 1
Water
2 2
Steam
3 3
Air
4 4
Inerts
5 5
N H3
6 6
Acid
7 7
Alkali


Simplified Piping DIAGRAM OF THE CONTACT PROCESS
SULFUR
H2SO4
SO3
SO2
SO2 & SO3
STEAM
WATER
AIR
AIR FILTER
BLOWER
DRYING TOWER
SULFUR PUMP
BOILER & FURNACE
CONVERTER
1ST HEAT EXCHANGER
2ND HEAT EXCHANGER
OLEUM TOWER
OLEUM PUMP & CIRCULATION TANK
ACID PUMP & CIRCULATION TANK
ACID COOLER
2ND ABSORPTION TOWER
2ND SO3 COOLER
1ST ABSORPTION TOWER
1ST SO3 COOLER
TO STORAGE
AIR FAN
To ATM

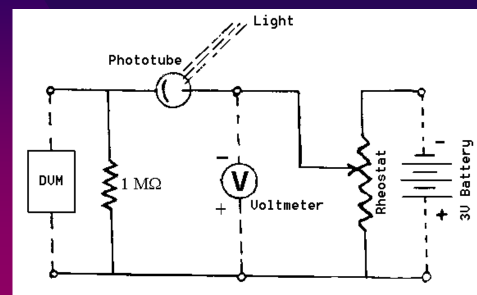

Instrumentation symbols for detailed diagram
General symbol for flow meters
F
Flange
Turbine flow meter
Sonic flow meter
M
Magnetic flow meter
Flow indicator
Orifice flow meter


capacitor
V
Voltmeter
Resistor
Thermistor
M
motor
Inductor
Symbols for electrical diagram
indicating lamp
Transformer

Electrical diagram



Electrical diagram

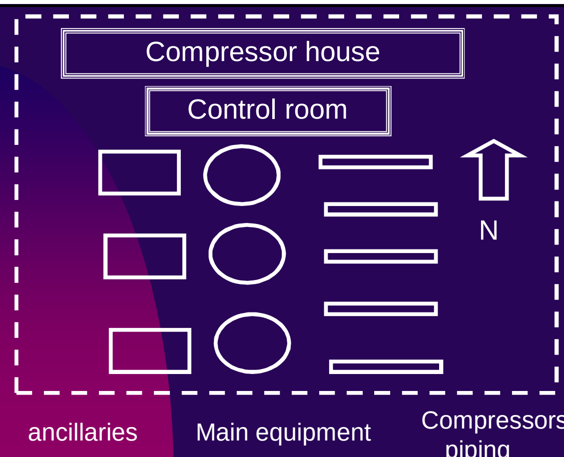


They show

- Main equipment to scale in correct positions.
- Ancillaries items (not to scale)
- Installed spared, parallel units
- All flows including main process materials + utilities and connections,
- Instrumentation and connections.

Quantitative (scaled) FS or Lay out

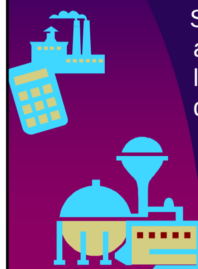
Or they show interaction between major and minor equipment inside the plant.



Plot plan or factory lay out

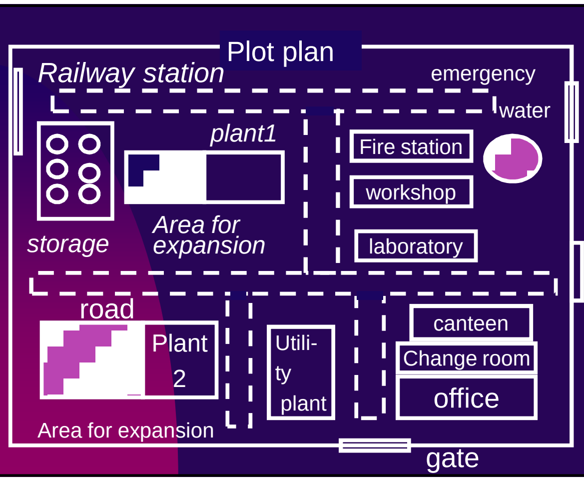
- Plot plan or lay out should be drawn to scale, clearly indicating direction **North**.
- Layout should show the facilities/operations as they exist on the floor.
- The locations of various utilities (e.g., boiler house), laboratories, canteens, administrative blocks, storage areas (especially of hazardous substances) should be clearly indicated.

- Areas that are marked for future expansion should also be shown.
- The compound wall should be indicated, clearly showing the entry and exit gates.



Special thematic forms of layout can also be prepared to show water supply lines, steam lines, cabling, effluent drains, storm water channels etc

Normally plants are arrange such a way to give economical flow of materials



Key benefits of Process Flow Diagrams :

1. Identification & Documentation of the manufacturing Processes.
2. Creation of Process
3. Monitoring , Analysis & Improvement of the manufacturing Processes
4. Integration of Process Management to Organization
5. Getting Results Fast

Summary