

الجامعة التكنولوجية

قسم الهندسة الكيماوية



المرحلة الثالثة

تصميم معدات

د. نضال محمود, د. رياض صادق

## Reference

1. Sinnott R. and Towler C; 2009 " chemical Engineering Design" 5<sup>th</sup> edition Butterworth-Heinemann
2. Coke,A.K ;2007"Ludwig s Applied Process Design of Chemical and petrochemical Plant" vol. 1 4<sup>th</sup> edition Gulf professional Publisher
- 3.Branan C. 2005 " rules of Thumbs for Chemical Engineers" 4<sup>th</sup> edition Gulf professional Publisher
- 4.Couper ,J.;Penny, W R ;Fair J and Walas 2010 "Chemical Process Equipment" 2<sup>nd</sup> edition
- 5.Peters,M; timmerhause k.D;and West R. 2003 " plant Design and economics for Chemical Engineers '5<sup>th</sup> edition McGraw-Hill
- 6.Perry R and Green D; 1997 " Perry s Chemical Engineers Handbook " 7<sup>th</sup> edition MaGraw -hill

# **Chapter one**

## **Nature of Design**

Design is a creative activity, and as such can be one of the most rewarding and satisfying activities undertaken by an engineer. It is the synthesis, the putting together, of ideas to achieve a desired purpose. The design does not exist at the commencement of the project.

The designer starts with a specific objective in mind, a need, and by developing and evaluating possible designs, arrives at what he considers the best way of achieving that objective; be it a better chair, a new bridge, or for the chemical engineer, a new chemical product or a stage in the design of a production process.

When considering possible ways of achieving the objective the designer will be constrained by many external factors see fig (1-1):-

- 1-Economic considerations are obviously a major constraint on any engineering design: plants must make a profit.
- 2-Time will also be a constraint. The time available for completion of a design will usually limit the number of alternative designs that can be
- 3 Physical law
- 4- Resources
- 5-Safety Regulations
- 6- Standard and codes

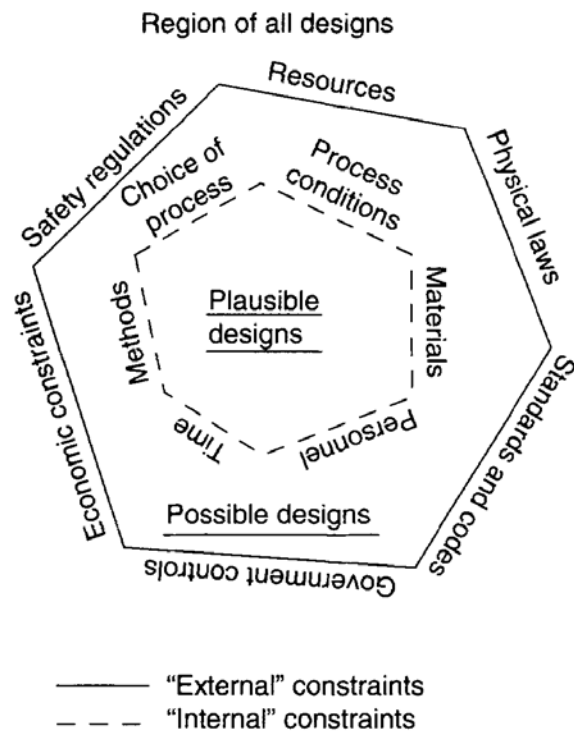
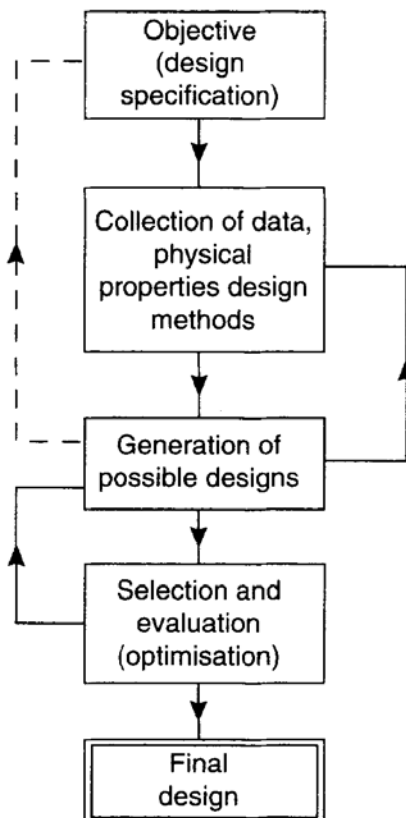


Figure 1.1. Design constraints



## **Generation of Possible Design concepts**

Chemical engineering projects can be divided into three types, depending on the novelty involved:

1. Modifications, and additions, to existing plant; usually carried out by the plant design group.
2. New production capacity to meet growing sales demand, and the sale of established processes by contractors. Repetition of existing designs, with only minor design changes.
3. New processes, developed from laboratory research, through pilot plant, to a commercial process. Even here, most of the unit operations and process equipment will use established designs.

The selection process can be considered to go through the following stages:

Possible designs (credible) - within the external constraints.

Plausible designs (feasible) - within the internal constraints.

Probable designs - likely candidates.

Best design (optimum) -judged the best solution to the problem

### **Setting the Design Basis**

The most important step in starting a process design is translating the customer need into a design basis . It will normally include the production rate of the main product together with the information on constraints that will influence the design such as :-

- 1- The system of the unit to be used
- 2- The national the local or company design codes that must be followed
- 3- Details of raw materials that available
- 4- Information on potential sites where the plant might be located
- 5- Information on the condition , availability and prices of utility services

## . THE ANATOMY OF A CHEMICAL MANUFACTURING PROCESS

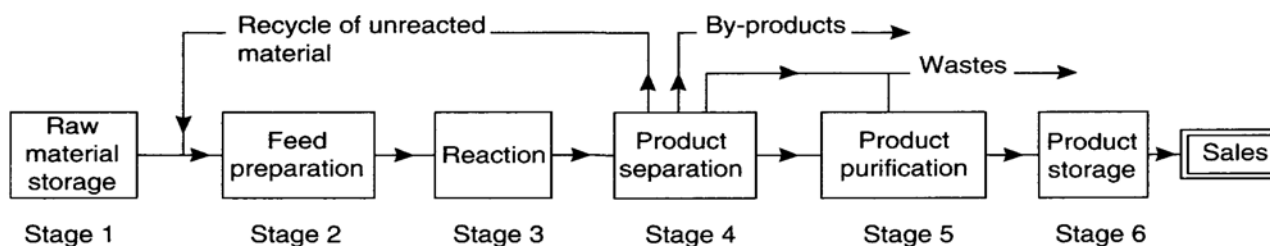


Figure 1.3. Anatomy of a chemical process

### **Stage 1. Raw material storage**

Unless the raw materials (also called essential materials, or feed stocks) are supplied as intermediate products (intermediates) from a neighboring plant, some provision will have to be made to hold several days, or weeks, storage to smooth out fluctuations and interruptions in supply.

### **Stage 2. Feed preparation**

Some purification, and preparation, of the raw materials will usually be necessary before they are sufficiently pure, or in the right form, to be fed to the reaction stage.

### **Stage 3, Reactor**

The reaction stage is the heart of a chemical manufacturing process. In the reactor the raw materials are brought together under conditions that promote the production of the desired product; invariably, by-products and unwanted compounds (impurities) will also be formed.

### **Stage 4. Product separation**

In this first stage after the reactor the products and by-products are separated from any unreacted material. If in sufficient quantity, the unreacted material will be recycled to the reactor. They may be returned directly to the reactor, or to the feed purification and preparation stage. The by-products may also be separated from the products at this stage.

### **Stage 5. Purification**

Before sale, the main product will usually need purification to meet the product specification. If produced in economic quantities, the by-products may also be purified for sale.

### **Stage 6. Product storage**

Some inventory of finished product must be held to match production with sales. Provision for product packaging and transport will also be needed, depending on the nature of the product. Liquids will normally be dispatched in drums and in bulk tankers (road, rail and sea), solids in sacks, cartons or bales.

The stock held will depend on the nature of the product and the market.

### **Ancillary processes**

In addition to the main process stages shown in Figure 1.3, provision will have to be made for the supply of the services (utilities) needed; such as, process water, cooling water, compressed air, steam. Facilities will also be needed for maintenance, fire fighting, offices and other accommodation, and laboratories

### **Continuous and batch processes**

**Continuous processes** are designed to operate 24 hours a day, 7 days a week, throughout the year. Some down time will be allowed for maintenance and, for some processes, catalyst regeneration. The plant attainment; that is, the percentage of the available hours in a year that the plant operates, will usually be 90 to 95%. , hours operated ,Continuous processes will usually be more economical for large scale production.

**Batch processes** are designed to operate intermittently. Some, or all, the process units being frequently shut down and started up. Batch processes are used where some flexibility is wanted in production rate or product specification.

### **Choice of continuous versus batch production**

The choice between batch or continuous operation will not be clear cut, but the following rules can be used as a guide.

## **Continuous**

*L* Production rate greater than  $5 \times 10^6$  kg/h

2. Single product
3. No severe fouling
4. Good catalyst life
5. Proven processes design
6. Established market

## **Batch**

1. Production rate less than  $5 \times 10^6$  kg/h
2. A range of products or product specifications
3. Severe fouling
4. Short catalyst life
5. New product
6. Uncertain design



## **CODES AND STANDARDS**

IN engineering practice they cover:

1. Materials, properties and compositions.
2. Testing procedures for performance, compositions, quality.
3. Preferred sizes; for example, tubes, plates, sections.
4. Design methods, inspection, fabrication.
5. Codes of practice, for plant operation and safety.

All of the developed countries, and many of the developing countries, have national standards organisations, responsible for the issue and maintenance of standards for the manufacturing industries, and for the protection of consumers.

**In the United Kingdom** preparation and promulgation of national standards are the responsibility of the British Standards Institution (BSI). The Institution has a secretariat and a number of technical personnel, but the preparation of the standards is largely the responsibility of committees

**In the United States** the government organization responsible for coordinating information on standards is the National Bureau of Standards; standards are issued by Federal, State and various commercial organizations. The principal ones of interest to chemical engineers are those issued by the American National Standards Institute (ANSI), the American Petroleum Institute (API), the American Society for Testing Materials (ASTM), and the American Society of Mechanical Engineers (ASME)

The international organization for standardization (ISO) coordinates the publication of international standard , ISO is a net work of the national standards institutes of 157 countries and had published over 16500 international standards

## **FACTORS OF SAFETY (DESIGN FACTORS)**

Design is an inexact art; errors and uncertainties will arise from uncertainties in the design data available and in the approximations necessary in design calculations. To ensure that the design specification is met, factors are included to give a margin of safety in the design; safety in the sense that the equipment will not fail to perform satisfactorily, and that it will operate safely: will not cause a hazard. "Design factor" is a better term to use, as it does not confuse safety and performance factors.

## **The Flow sheet**

is the key document in process design. It shows the arrangement of the equipment selected to carry out the process; the stream connections; stream flow-rates and compositions; and the operating conditions. It is a diagrammatic model of the process.

The flow-sheet will be used by the specialist design groups as the basis for their designs. This will include piping, instrumentation, equipment design and plant layout. It will also be used by operating personnel for the preparation of operating manuals and operator training. During plant start-up and subsequent operation, the flow-sheet forms a basis for comparison of operating performance with design.

The flow-sheet is drawn up from material balances made over the complete process and each individual unit. Energy balances are also made to determine the energy flows and the service requirements.

The various types of flow-sheet are

### **1-Block diagrams**

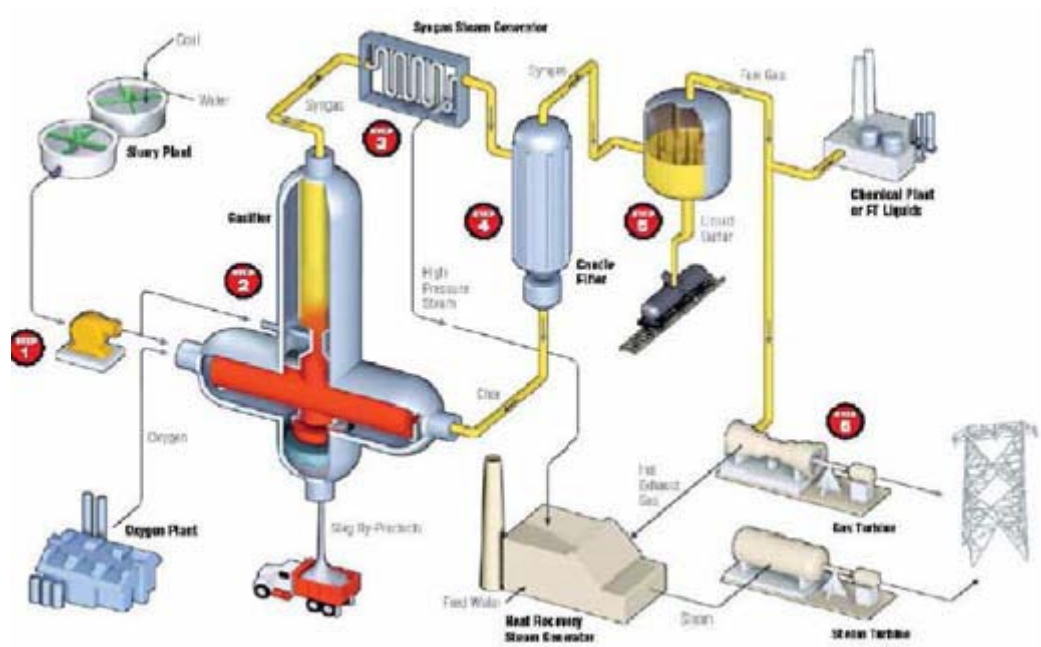
A block diagram is the simplest form of presentation. Each block can represent a single piece of equipment or a complete stage in the process. They are useful for showing simple processes. With complex processes, their use is limited to showing the overall process, broken down into its principal stages;

Block diagrams are useful for representing a process in a simplified form in reports and textbooks, but have only a limited use as engineering documents.

The stream flow-rates and compositions can be shown on the diagram adjacent to the stream lines, when only a small amount of information is to be shown, or tabulated separately

## 2-Pictorial representation

On the detailed flow-sheets used for design and operation, the equipment is normally drawn in a stylized pictorial form. For tender documents or company brochures, actual scale drawings of the equipment are sometimes used, but it is more usual to use a simplified representation.



### 3. Process Flow Diagram (PFD)

- A.** Used to present the heat and mass balances of the process.
- B.** Show all production steps, starting from raw material to final products.
- C.** Show the operating conditions of each production step in the process (operating conditions are: Temperature, Pressure, Flowrate, -----).
- D.** Show the type and quantities of utilities that required for the process (such as: water, steam, O<sub>2</sub>, H<sub>2</sub>, -----)
- E.** Shows the process equipments and their connection pipes.
- F.** 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, ---)
- G.** Show the main control system (type of instruments) required for the process.
- H.** Used as data base for Piping and Instrumentation Diagram (**PID**) and for equipment schedule (equipment summary).

#### 3-1. information to be included

The amount of information shown on a flow-sheet will depend on the custom and practice of the particular design office. The list given below has therefore been divided into essential items and optional items. The essential items must always be shown, the optional items add to the usefulness of the flow-sheet but are not always included.

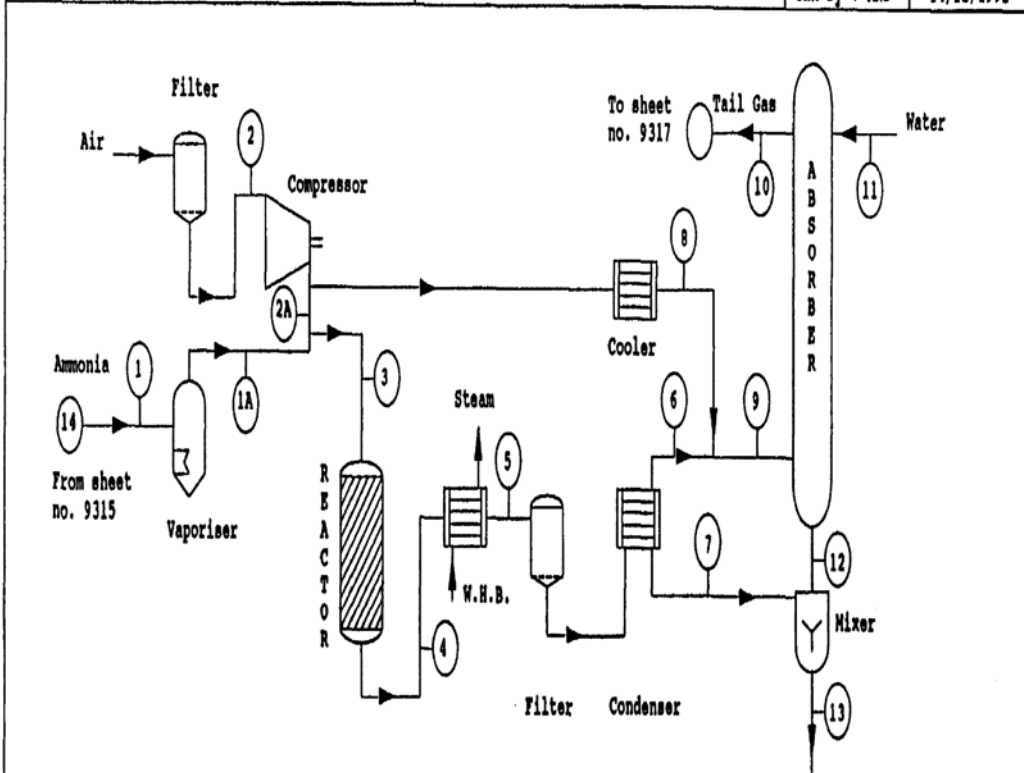
#### *Essential information*

1. Stream composition, either:
  - (i) the flow-rate of each individual component, kg/h, which is preferred, or
  - (ii) the stream composition as a weight fraction.
2. Total stream flow-rate, kg/h.
3. Stream temperature, degrees Celsius preferred.
4. Nominal operating pressure (the required operating pressure)

#### *Optional information*

1. Molar percentages composition.
2. Physical property data, mean values for the stream, such as:
  - (i) density, kg/m<sup>3</sup>,
  - (ii) viscosity, mN s/m<sup>2</sup>.
3. Stream name, a brief, one or two-word, description of the nature of the stream

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.	1	1A	2	2A	3	4	5	6	7	8	9	10	11	12	13
Stream	Ammonia	Ammonia	Filtered	Oxidiser	Oxidiser	Oxidiser	W.H.B.	Condenser	Condenser	Condenser	Absorber	Tail (2)	Water	Absorber	Product
Component	Feed	Vapour	Air	Air	Feed	Outlet	Outlet	Gas	Acid	Air	Feed	Gas	Feed	Acid	Acid
NR3	731.0	731.0	--	--	731.0	NIL	--	--	--	--	--	--	--	--	--
O2	--	--	3036.9	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	(?)	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	1794.8	11897.7	10434.4	1376.9	2840.0	4700.6
Press (Bar)	0	0	1	0	0	0	0	0	1	0	0	1	0	1	1
Temp (°C)	15	20	15	230	204	907	234	40	40	40	40	25	25	40	43

Figure 4.2a. Flow-sheet drawn using FLOSHEET

### **3-2 Basis of the calculation**

It is good practice to show on the flow-sheet the basis used for the flow-sheet calculations. This would include: the operating hours per year; the reaction and physical yields; and the datum temperature used for energy balances. It is also helpful to include a list of the principal assumptions used in the calculations. This alerts the user to any limitations that may have to be placed on the flow-sheet information.

### **3-3 Batch processes**

Flow-sheets drawn up for batch processes normally show the quantities required to produce one batch. If a batch process forms part of an otherwise continuous process, it can be shown on the same flow-sheet, providing a clear break is made when tabulating the data between the continuous and batch sections; the change from kg/h to kg/batch.

A continuous process may include batch make-up of minor reagents, such as the catalyst for a polymerisation process.

### **3-4 Services (utilities)**

To avoid cluttering up the flow-sheet, it is not normal practice to show the service headers and lines on the process flow-sheet. The service connections required on each piece of equipment should be shown and labelled. The service requirements for each piece of equipment can be tabulated on the flow-sheet.

### **3-5 Equipment identification**

Each piece of equipment shown on the flow-sheet must be identified with a code number and name. The identification number (usually a letter and some digits) will normally be that assigned to a particular piece of equipment as part of the general project control procedures, and will be used to identify it in all the project documents. If the flow-sheet is not part of the documentation for a project, then a simple, but consistent, identification code should be devised. The easiest code is to use an initial letter to identify the type of equipment, followed by digits to identify the particular piece. For example, H — heat exchangers, C — columns, R — reactors. The key to the code should be shown on the flow-sheet.

## 4- Piping and instrument diagram (PID)

The P and I diagram shows the arrangement of the process equipment, piping, pumps:- ,

- 1-Prepared by chemical engineer with the aid of mechanical and control Engineers.
- 2-Regarded as a data base for mechanical engineer for manufacturing of vessels, Heat exchangers, Machines and controllers.
- 3-This diagram flows the PFD configuration.
- 4- All process equipment identified by an equipment number.
- 5- The equipment should be drawn roughly in proportion, and the location of nozzles shown.
- 6-All pipes, identified by a line number. The pipe size and material of construction should be shown. The material may be included as part of the line identification number.
- 7-All valves, control and block valves, with an identification number.
- 8-The type and size should be shown. The type may be shown by the symbol used for the valve or included in the code used for the valve number.
- 9-Ancillary fittings that are part of the piping system, such as inline sight-glasses, strainers and steam traps; with an identification number.
- 10-Pumps, identified by a suitable code number.
- 11-All control loops and instruments, with an identification number.

### Basic symbols

The symbols illustrated below are those given in BS 1646.

#### *Control valve*

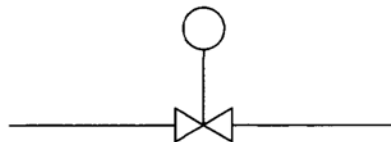
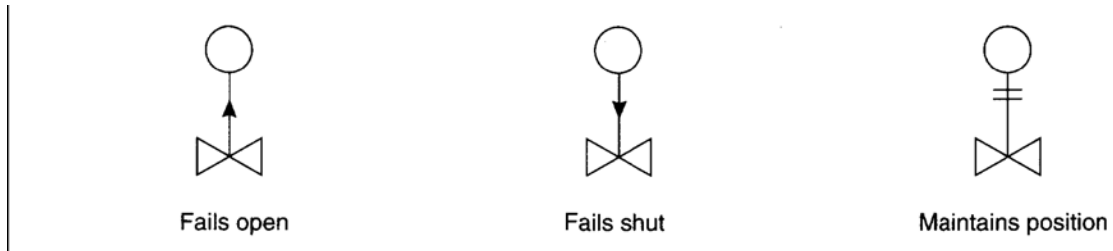


Figure 5.1.

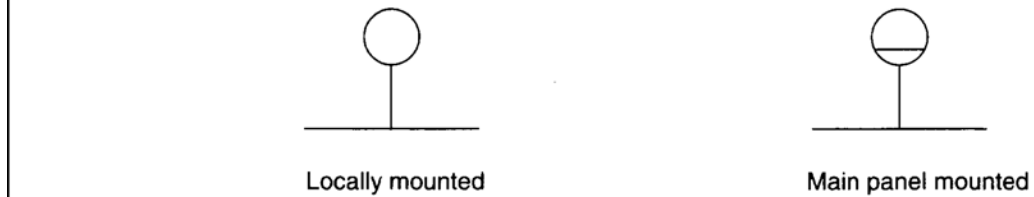
This symbol is used to represent all types of control valve, and both pneumatic and electric actuators.

### **Failure mode**

The direction of the arrow shows the position of the valve on failure of the power supply.



### **Instruments and controllers**



**Locally mounted** means that the controller and display is located out on the plant near to the sensing instrument location. *Main panel* means that they are located on a panel in the control room. Except on small plants, most controllers would be mounted in the control room.



## Type of instrument

This is indicated on the circle representing the instrument-controller by a letter code (see Table 5.1).

Table 5.1. Letter Code for Instrument Symbols (Based on BS 1646: 1979)

Property measured	First letter	Indicating only	Recording only	Controlling only	Indicating and controlling	Recording and controlling
Flow-rate	F	FI	FR	FC	FIC	FRC
Level	L	LI	LR	LC	LIC	LRC
Pressure	P	PI	PR	PC	PIC	PRC
Quality, analysis	Q	QI	QR	QC	QIC	QRC
Radiation	R	RI	RR	RC	RIC	RRC
Temperature	T	TI	TR	TC	TIC	TRC
Weight	W	WI	WR	WC	WIC	WRC
Any other property (specified in a note)	X	XI	XR	XC	XIC	XRC

### Notes:

- (1) The letter A may be added to indicate an alarm; with H or L placed next to the instrument circle to indicate high or low.
- (2) D is used to show difference or differential; eg. PD for pressure differential.
- (3) F, as the second letter indicates ratio; eg. FFC indicates a flow ratio controller.

Consult the standard for the full letter code.

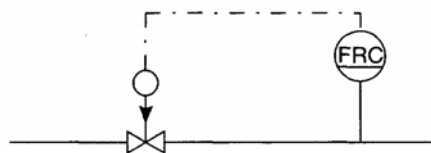
The first letter indicates the property measured; for example, F = flow. Subsequent letters indicate the function; for example,

I = indicating

RC = recorder controller

The suffixes E and A can be added to indicate emergency action and/or alarm functions.

The instrument connecting lines should be drawn in a manner to distinguish them from the main process lines. Dotted or cross-hatched lines are normally used.



## **5- Model**

- 1- It is a small three dimensional sample of the original plant shows all instruments, pipes and carrying pipes.
- 2- It has a great advantage in the designing faults correction of instruments location and pipes; directions and pathways before project establishing.
- 2- Useful in the training purposes as well as explaining the project to the visitors after its done.




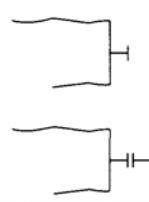

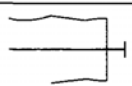

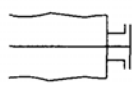







# Graphical Symbols for Piping Systems and Plant

BASED ON BS 1553: PART 1: 1976


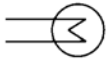
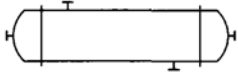
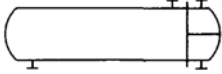
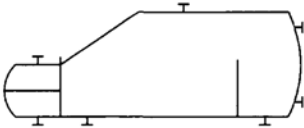
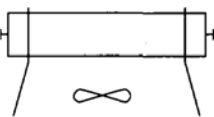
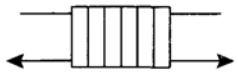
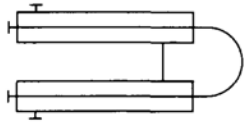
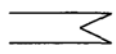
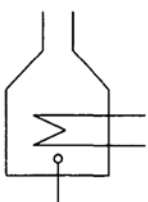
## Scope

This part of BS 1553 specifies graphical symbols for use in flow and piping diagrams for process plant.


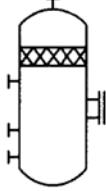
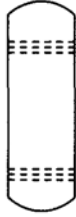
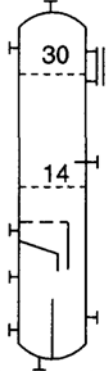
## **Symbols (or elements of symbols) for use in conjunction with other symbols**


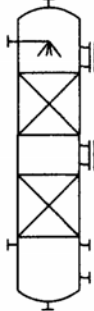
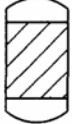
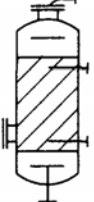
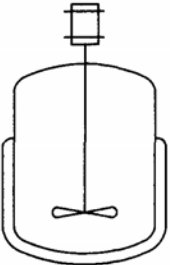
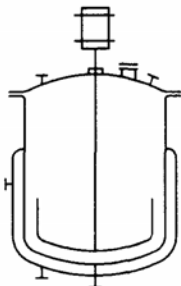
Mechanical linkage		Access point	
Weight device		Equipment branch: general symbol Note. The upper representation does not necessarily imply a flange, merely the termination point. Where a breakable connection is required the branch/pipe would be as shown in the lower symbol	
Electrical device		Equipment penetration (fixed)	
Vibratory or loading device (any type)		Equipment penetration (removable)	
Spray device		Boundary line	
Rotary movement		Point of change	
Stirring device		Discharge to atmosphere	
Fan			


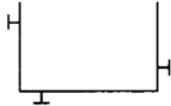
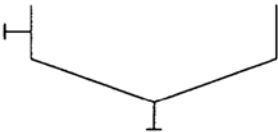
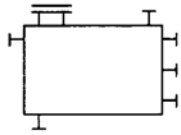
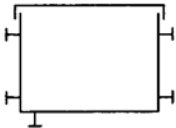
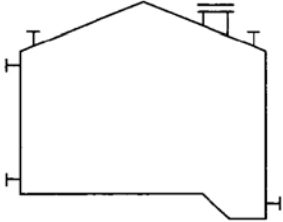
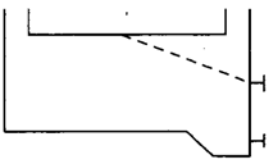
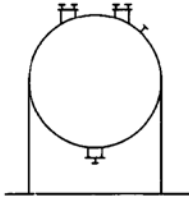

**Basic and developed symbols for plant and equipment**

Heat transfer equipment	
Heat exchanger (basic symbols)	
Alternative:	
Shell and tube: fixed tube sheet	
Shell and tube: U tube or floating head	
Shell and tube: kettle reboiler	
Air - blown cooler	
Plate type	
Double pipe type	
Heating/cooling coil (basic symbol)	
Fired heater/boiler (basic symbol)	

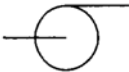
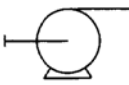
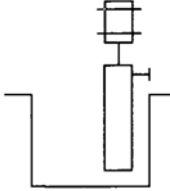

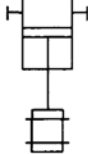
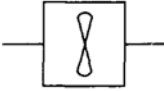
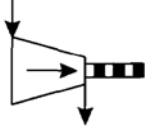
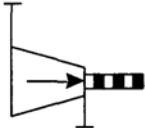
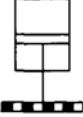
Vessels and tanks

<p>Drum or simple pressure vessel (basic symbol)</p>	
<p>Knock-out drum (with demister pad)</p>	
<p>Tray column (basic symbol)</p>	
<p>Tray column Trays should be numbered from the bottom; at least the first and the last should be shown. Intermediate trays should be included and numbered where they are significant.</p>	

<p>Fluid contacting vessel (basic symbol)</p>	
<p>Fluid contacting vessel Support grids and distribution details may be shown</p>	
<p>Reaction or absorption vessel (basic symbol)</p>	
<p>Reaction or absorption vessel Where it is necessary to show more than one layer of material alternative hatching should be used</p>	
<p>Autoclave (basic symbol)</p>	
<p>Autoclave</p>	

Open tank (basic symbol)	
Open tank	
Clarifier or settling tank	
Sealed tank	
Covered tank	
Tank with fixed roof (with draw-off sump)	
Tank with floating roof (with roof drain)	
Storage sphere	
Gas holder (basic symbol for all types)	

Pumps and compressors

<p>Rotary pump, fan or simple compressor (basic symbol)</p>	
<p>Centrifugal pump or centrifugal fan</p>	
<p>Centrifugal pump (submerged suction)</p>	
<p>Positive displacement rotary pump or rotary compressor</p>	
<p>Positive displacement pump (reciprocating)</p>	
<p>Axial flow fan</p>	
<p>Compressor: centrifugal / axial flow ( basic symbol )</p>	
<p>Compressor: centrifugal / axial flow</p>	
<p>Compressor: reciprocating ( basic symbol )</p>	
<p>Ejector / injector ( basic symbol )</p>	