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قسم الهندسة الكيميائية

المرحلة الثالثة
تصميم معدات
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Save from: http://www.uotechnology.edu.iq/dep-chem-eng/index.htm
Reference

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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

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 drams 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%. 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**

1. 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.
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 network 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 are required for the process (such as: water, steam, O₂, H₂, ----)
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 database 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/m³,
   (ii) viscosity, mN s/m².
3. Stream name, a brief, one or two-word, description of the nature of the stream.
Figure 4.2a. Flow-sheet drawn using FLOWSHEET
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.](image)

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.

- **Fails open**
- **Fails shut**
- **Maintains position**

**Instruments and controllers**

- **Locally mounted**
- **Main panel mounted**

**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)

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

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

<table>
<thead>
<tr>
<th>Mechanical linkage</th>
<th>Access point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight device</td>
<td>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</td>
</tr>
<tr>
<td>Electrical device</td>
<td>Equipment penetration (fixed)</td>
</tr>
<tr>
<td>Vibratory or loading device (any type)</td>
<td>Equipment penetration (removable)</td>
</tr>
<tr>
<td>Spray device</td>
<td>Boundary line</td>
</tr>
<tr>
<td>Rotary movement</td>
<td>Point of change</td>
</tr>
<tr>
<td>Stirring device</td>
<td>Discharge to atmosphere</td>
</tr>
<tr>
<td>Fan</td>
<td></td>
</tr>
</tbody>
</table>
**Basic and developed symbols for plant and equipment**

<table>
<thead>
<tr>
<th>Heat transfer equipment</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat exchanger (basic symbols)</td>
<td></td>
</tr>
<tr>
<td>Alternative:</td>
<td></td>
</tr>
<tr>
<td>Shell and tube: fixed tube sheet</td>
<td></td>
</tr>
<tr>
<td>Shell and tube: U tube or floating head</td>
<td></td>
</tr>
<tr>
<td>Shell and tube: kettle reboiler</td>
<td></td>
</tr>
<tr>
<td>Air - blown cooler</td>
<td></td>
</tr>
<tr>
<td>Plate type</td>
<td></td>
</tr>
<tr>
<td>Double pipe type</td>
<td></td>
</tr>
<tr>
<td>Heating/cooling coil (basic symbol)</td>
<td></td>
</tr>
<tr>
<td>Fired heater/boiler (basic symbol)</td>
<td></td>
</tr>
</tbody>
</table>
## Vessels and tanks

<table>
<thead>
<tr>
<th>Description</th>
<th>Diagram</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drum or simple pressure vessel (basic symbol)</td>
<td><img src="image1" alt="Diagram" /></td>
</tr>
<tr>
<td>Knock-out drum (with demister pad)</td>
<td><img src="image2" alt="Diagram" /></td>
</tr>
<tr>
<td>Tray column (basic symbol)</td>
<td><img src="image3" alt="Diagram" /></td>
</tr>
<tr>
<td>Tray column</td>
<td><img src="image4" alt="Diagram" /></td>
</tr>
<tr>
<td>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.</td>
<td><img src="image5" alt="Diagram" /></td>
</tr>
<tr>
<td>Description</td>
<td>Diagram</td>
</tr>
<tr>
<td>-------------------------------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>Fluid contacting vessel (basic symbol)</td>
<td><img src="image1" alt="Diagram" /></td>
</tr>
<tr>
<td>Fluid contacting vessel</td>
<td><img src="image2" alt="Diagram" /></td>
</tr>
<tr>
<td>Support grids and distribution details may be shown</td>
<td><img src="image3" alt="Diagram" /></td>
</tr>
<tr>
<td>Reaction or absorption vessel (basic symbol)</td>
<td><img src="image4" alt="Diagram" /></td>
</tr>
<tr>
<td>Reaction or absorption vessel</td>
<td><img src="image5" alt="Diagram" /></td>
</tr>
<tr>
<td>Where it is necessary to show more than one layer of material alternative hatching should be used</td>
<td><img src="image6" alt="Diagram" /></td>
</tr>
<tr>
<td>Autoclave (basic symbol)</td>
<td><img src="image7" alt="Diagram" /></td>
</tr>
<tr>
<td>Autoclave</td>
<td><img src="image8" alt="Diagram" /></td>
</tr>
<tr>
<td>Description</td>
<td>Diagram</td>
</tr>
<tr>
<td>--------------------------------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>Open tank (basic symbol)</td>
<td><img src="image1" alt="Diagram" /></td>
</tr>
<tr>
<td>Open tank</td>
<td><img src="image2" alt="Diagram" /></td>
</tr>
<tr>
<td>Clarifier or settling tank</td>
<td><img src="image3" alt="Diagram" /></td>
</tr>
<tr>
<td>Sealed tank</td>
<td><img src="image4" alt="Diagram" /></td>
</tr>
<tr>
<td>Covered tank</td>
<td><img src="image5" alt="Diagram" /></td>
</tr>
<tr>
<td>Tank with fixed roof (with draw-off sump)</td>
<td><img src="image6" alt="Diagram" /></td>
</tr>
<tr>
<td>Tank with floating roof (with roof drain)</td>
<td><img src="image7" alt="Diagram" /></td>
</tr>
<tr>
<td>Storage sphere</td>
<td><img src="image8" alt="Diagram" /></td>
</tr>
<tr>
<td>Gas holder (basic symbol for all types)</td>
<td><img src="image9" alt="Diagram" /></td>
</tr>
<tr>
<td><strong>Pumps and compressors</strong></td>
<td></td>
</tr>
<tr>
<td>--------------------------</td>
<td></td>
</tr>
<tr>
<td><strong>Rotary pump, fan or simple compressor (basic symbol)</strong></td>
<td><img src="image" alt="Rotary pump symbol" /></td>
</tr>
<tr>
<td><strong>Centrifugal pump or centrifugal fan</strong></td>
<td><img src="image" alt="Centrifugal pump symbol" /></td>
</tr>
<tr>
<td><strong>Centrifugal pump (submerged suction)</strong></td>
<td><img src="image" alt="Centrifugal pump (submerged suction) symbol" /></td>
</tr>
<tr>
<td><strong>Positive displacement rotary pump or rotary compressor</strong></td>
<td><img src="image" alt="Positive displacement rotary pump symbol" /></td>
</tr>
<tr>
<td><strong>Positive displacement pump (reciprocating)</strong></td>
<td><img src="image" alt="Positive displacement pump (reciprocating) symbol" /></td>
</tr>
<tr>
<td><strong>Axial flow fan</strong></td>
<td><img src="image" alt="Axial flow fan symbol" /></td>
</tr>
<tr>
<td><strong>Compressor: centrifugal / axial flow (basic symbol)</strong></td>
<td><img src="image" alt="Compressor: centrifugal / axial flow symbol" /></td>
</tr>
<tr>
<td><strong>Compressor: centrifugal / axial flow</strong></td>
<td><img src="image" alt="Compressor: centrifugal / axial flow symbol" /></td>
</tr>
<tr>
<td><strong>Compressor: reciprocating (basic symbol)</strong></td>
<td><img src="image" alt="Compressor: reciprocating symbol" /></td>
</tr>
<tr>
<td><strong>Ejector / injector (basic symbol)</strong></td>
<td><img src="image" alt="Ejector / injector symbol" /></td>
</tr>
</tbody>
</table>