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SCHOOL OF BIO AND CHEMICAL ENGINEERING

DEPARTMENT OF CHEMICAL ENGINEERING

UNIT – 1 PROCESS DESIGN DEVELOPMENT-SCH1403

UNIT 1: PROCESS DESIGN DEVELOPMENT

Why Economics with Design

Special emphasis is placed on the economic and engineering principles involved in the design of chemical plants and equipment. An understanding of these principles is a prerequisite for any successful chemical engineer, no matter whether the final position is in direct design work or in production, administration, sales, research, development, or any other related field. The expression *plant design* immediately connotes industrial applications; consequently, the **dollar sign** must always be kept in mind when carrying out the design of a plant. The theoretical and practical aspects are important, of course; but, in the final analysis, the answer to the question ***"Will we realize a profit from this venture?"*** almost always determines the true value of the design. **The chemical engineer, therefore, should consider plant design and applied economics as one combined subject.**

The scope of Design:

Design should be viewed as the focal point of chemical engineering practice. Far more than the development of a set of specifications for a new chemical plant, design is that creative activity through which engineers continuously improve the operation of facilities to create products that enhance the quality of life. Whether developing the grass roots plant, proposing and guiding process modifications, or troubleshooting and implementing operational strategies for existing equipment, engineering design requires a broad spectrum of knowledge and intellectual skills to be able to analyze the big picture and the minute details and, most importantly, to know when to concentrate on each.

Plant Design

Engineering design of new chemical and petrochemical plants and the expansion or revision of existing ones require the use of engineering principles and theories combined with a practical realization of the limits imposed by industrial conditions. A successful engineer needs more than a knowledge and understanding of the fundamental sciences and the related engineering subjects such as thermodynamics, reaction kinetics, and computer technology. The engineer must also have the ability to apply this knowledge to practical situations for the purpose of accomplishing something that will be beneficial to society. There are three parameters that must be defined namely:

1-Design: design is a creative activity and is defined as the synthesis, the putting together of ideas to achieve a desired purpose. Also it can be defined as the creation of manufacturing process to fulfill a particular need. The need may be public need or commercial opportunity.

2-Process Design: process design establishes the sequence of chemical and physical operations; operating conditions; the duties, major specifications, and materials of construction (where critical) of all process equipment (as distinguished from utilities and building auxiliaries); the general arrangement of equipment needed to ensure proper functioning of the plant; line sizes; and principal instrumentation. The process design is summarized by a process flowsheet.

Process design is intended to include:

1. Flowsheet development.
2. Process material and heat balances.
3. Auxiliary services material and heat balances (utilities requirements).
4. Chemical engineering performance design for specific items of equipments required for a flowsheet.
5. Instrumentation as related to process performance.
6. Preparation of specifications (specification sheets) in proper form for use by the project team as well as for the purchasing function.
7. Evaluation of bids and recommendation of qualified vendor.

3-Plant Design: includes items related directly to the complete plant, such as plant layout, general service facilities, and plant location.

Design Development Stages:

The stages in the development of a design, from the initial identification of the objectives to the final design are shown in Fig.(1).

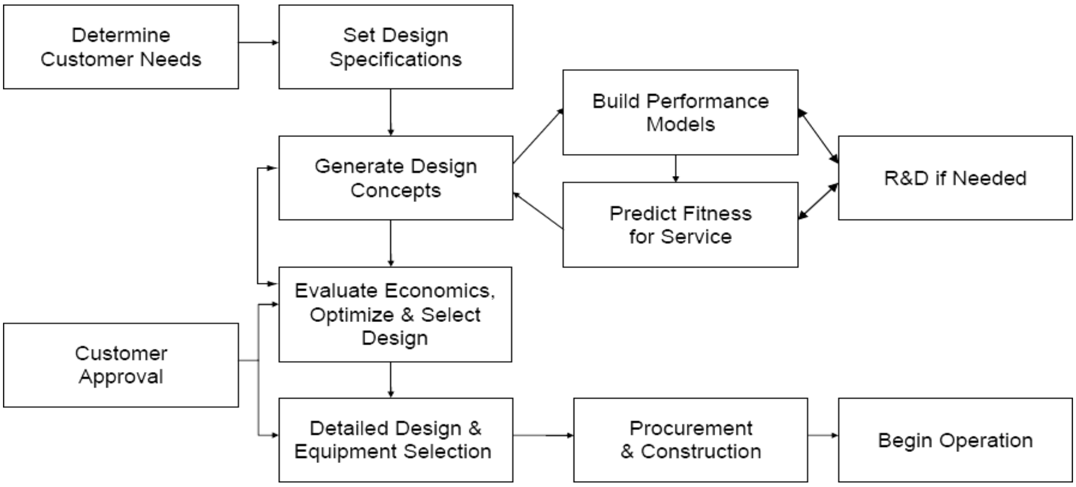


Fig.(1) The design process.

(I) The Design Objectives (The Need)

Engineering projects can be divided into three types:

A. New process development.

B. New production capacity to meet growing sales.

C. Modification and addition to existing plant.

In the design of a chemical process the need is the public need for the product, the commercial opportunity as foreseen by the sales and marketing organization.

(II) Setting The Design Basis (Data Collection)

The most important step in starting a process design is translating the customer need into a design basis. The design basis is a more precise statement of the problem that is to be solved. It will normally include the production rate and purity specifications of the main product, together with information on constraints that will influence the design, such as:

1. Information on possible processes and the system of units to be used.
2. The national, local or company design codes that must be followed.
3. Details of raw materials that are available.
4. Information on potential sites where the plant might be located, including climate data, seismic conditions, and infrastructure availability.
5. Information on the conditions, availability, and price of utility services such as

fuel (gas), steam, cooling water, process air, process water, and electricity, that will be needed to run the process.

(III) Generation of Possible Design Concepts (Solutions)

It is the creative part of the design process. This part is concerned with the generation of possible solutions for analysis, evaluation, and selection (ways of meeting objective problems).

Source of solutions:

a- Past experiences.

b- Tried and tested methods.

(IV) Build Performance Model and Fitness Testing

When design alternatives are suggested, they must be tested for fitness of purpose. In other words, the design engineer must determine how well each design concept meets the identified need. In the field of chemical engineering, it is usually prohibitively expensive to build several designs to find out which one works best (a practice known as **''prototyping''** which is common in other engineering disciplines). Instead, the design engineer builds a mathematical model of the process, usually in the form of computer simulations of the process, reactors, and other key equipment. In some cases, the performance model may include a pilot plant or other facility for predicting plant performance and collecting the necessary design data.

The design engineer must assemble all of the information needed to model the process so as to predict its performance against the identified objectives. For process design this will include information on possible processes, equipment performance, and physical property data

If the necessary design data or models do not exist, then research and development work is needed to collect the data and build new models. Once the data has been collected and a working model of the process has been established, then the design engineer can begin to determine equipment sizes and costs. At this stage it will become obvious that some designs are uneconomical and they can be rejected without further analysis. From this step a few candidate designs that meet the customer objective are identified.

(V) Economic Evaluation, Optimization, and Selection

Once the designer has identified a few candidate designs that meet the customer objective, then the process of design selection can begin. The primary criterion for design selection is usually economic performance, although factors such as safety and environmental impact may also play a strong role. The economic evaluation usually entails analyzing the capital and operating costs of the process to determine the return on investment (R.O.I).

The economic analysis of the product or process can also be used to **optimize the design**. Every design will have several possible variants that make economic sense under certain conditions. For example, the extent of process heat recovery is a tradeoff between the cost of energy and the cost of heat exchangers (usually expressed as a cost of heat exchange area). In regions where energy costs are high, designs that use a lot of heat exchange surface to maximize recovery of waste heat for reuse in the process will be attractive. In regions where energy costs are low, it may be more economical to burn more fuel and reduce the capital cost of the plant.

When all of the candidate designs have been optimized, the best design can be selected. Very often, the design engineer will find that several designs have very close economic performance, in which case the **safest design** or that which has the best commercial track record will be chosen. At the selection stage an experienced engineer will also look carefully at the candidate designs to make sure that they are safe, operable, and reliable, and to ensure that no significant costs have been overlooked.

(VI) Detailed Design and Equipment Selection

Here the detailed specifications of equipment such as vessels, exchangers, pumps, and instruments are determined. During the detailed design stage there may still be some changes to the design, and there will certainly be ongoing optimization as a better idea of the project cost structure is developed. The detailed design decisions tend to focus mainly on equipment selection though, rather than on changes to the flowsheet. For example, the design engineer may need to decide whether to use a U-tube or a floating-head exchanger, or whether to use trays or packing for a distillation column.

(VII) Procurement, Construction, and Operation

When the details of the design have been finalized, the equipment can be purchased and the plant can be built. Procurement and construction are usually carried out by an EPC firm (Engineering, Procurement, and Construction) unless the project is very small. Because they work on many different projects each year, the EPC firms are able to place bulk orders for items such as piping, wire, valves, etc., and can use their purchasing power to get discounts on most equipment. The EPC companies also have a great deal of experience in field construction, inspection, testing, and equipment installation. They can therefore normally contract to build a plant for a client cheaper (and usually also quicker) than the client could build it on its own. Finally, once the plant is built and readied for **startup**, it can begin operation. The design engineer will often then be called upon to help resolve any startup issues and teething problems with the new plant.

Design Constraints

When considering possible ways of achieving the objective the designer will be constrained by many factors which are called the design constraints.

Design constraints are divided into two types Fig.(2):

A. Internal constraints: over which the designer has some control.

B. External constraints: fixed, invariable.

What is meant by design constraints? What are the different types? Give examples? What are the main items that should be included in the process design?

Draw a block diagram showing the main steps involved in the development of a design process?

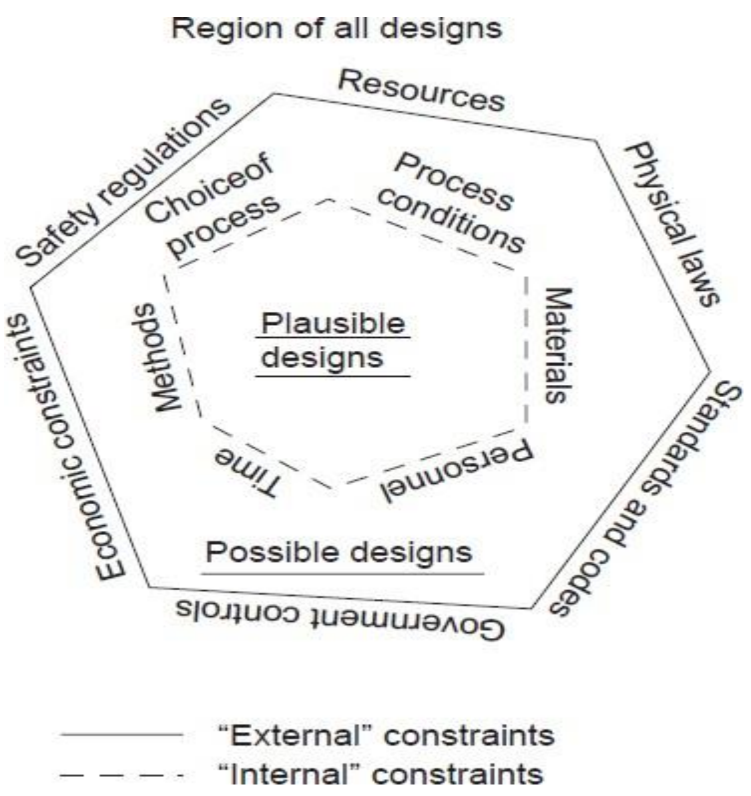


Fig.(2) Design constraints.

Flow-sheeting (special language conveying information)

Process design normally starts with a process scheme (flowsheet). The flowsheet is the key document or road map in process design. It's a diagrammatic model of the process describe the process steps in a proper sequence using symbols to represent the various components (equipment, lines, and control instrumentation) that make up the unit.

The Flow-sheet Importance

- Shows the arrangement of the equipment selected to carry out the process.
- Shows the streams concentrations, flow rates & compositions.
- Shows the operating conditions.
- During plant start up and subsequent operation, the flow sheet from a basis for comparison of operating performance with design. It's also used by operating personnel for the preparation of operating manual and operator training.

Flowsheet Presentation 1- Block diagram

- Represent the process in a simplified form.
- No details involved.
- Don't describe how a given step will be achieved.

When is it used?

- In survey studies.
- Process proposal for packaged steps.
- Talk out a processing idea.

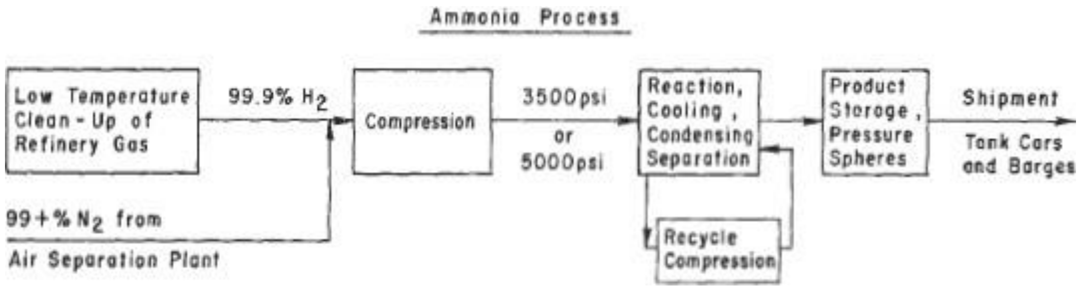


Fig.(3) Block diagram.

2- Pictorial Flow Sheet

The equipments are normally drawn in a stylized pictorial form. For tender documents or company brochures actual scale drawing of the equipment are sometimes used.

Types of pictorial flow-sheets

a) Process Flow Diagram (PFD)

A PFD is a simplified flow diagram of a single process unit, a utility unit, a complete process module. The purpose of a PFD is to provide a preliminary understanding of the process system indicating only the main items of equipment, the main pipelines and the essential instruments, switches and control valves.

A PFD also indicates operating variables, such as mass flow, temperatures and pressures, which are tabulated at various points in the system.

The PFD is a document containing information on:

- Process conditions and physical data of the main process streams.
- Main process equipment with design data.
- Main Process lines.
- Mass (material) balance.
- Heat balance (if applicable).

NOTE: If the PFD doesn't contain any data about the flow rates, it is called a **qualitative flowsheet**, while if the flow rates are involved the PFD is called a **combined flowsheet** in which qualitative information and quantitative data are combined on the basis of one flowsheet.

b) Piping and Instrumentation Diagram (P & ID) (mechanical flow diagram)

A P&ID diagram shows the arrangement of the process equipment, piping, pumps, instruments, valves and other fittings. It should include:

- All process equipment identified by an equipment number.
- All pipes identified by a line size, material code and line number.
- All valves with an identified size and number.
- Fittings.
- All pumps identified by a suitable code number.
- All control loops and instruments.

c) Utility Flowsheet (Process Engineering Utility Flow Diagram (PEUFD))

Used to summarize and detail the interrelationship of utilities such as air, water (various types), steam (various types), heat transfer mediums, process vents and purges, safety relief blow-down,etc., to the basic process. The amount of detail is often too great to combine on other sheets, so separate sheets are prepared.

The PEUFD is a document containing information on:

- Main distribution or arrangement of each individual utility system, expect electrical systems.

PEUFD Function:

A typical process uses utilities such as water, air and electric power. Water may be used either in the process, or for cooling and/or production of steam. Air may also be used in the process or for instrument applications. Electric power of course is typically used at various points in the process and throughout the site.

It is always useful to develop diagrams that show the flow and utilization of each utility. An example of a water balance/utility diagram is shown below.

The PEUFD shall state characteristics and consumption figures of the particular utility concerned, cooling water, fire water, drinking water, steam, plant air, instrument air, fuel oil/gas, inert gas and similar utilities.

d) Process Safeguarding Flow Diagram (PSFD)

The PSFD is a document highlighting information on:

- Types and levels of protection offered by the devices installed and their inter relation to demonstrate the plant’s safety.

The P&ID contains all information required for a PSFD; however, the PSFD highlights protection in case of extreme conditions and measures to be taken to safeguard personnel and environment.

Note: In general these schemes will only be made for complex installations like offshore process platforms. For simple applications the information shown on the P&ID is usually sufficient to highlight safety devices and aspects.

- ✓ **What is meant by the following identifications? PFD, P&ID, PEUFD and PSFD**
- ✓ **State the information you can get from the following schemes: PFD, P&ID, PEUFD and PSFD?**

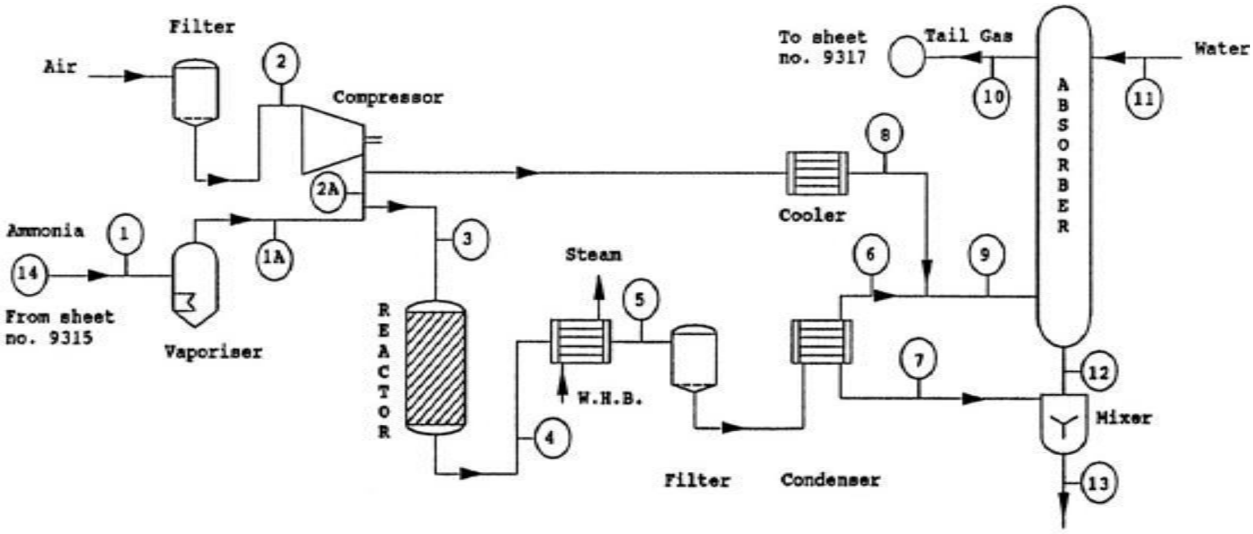
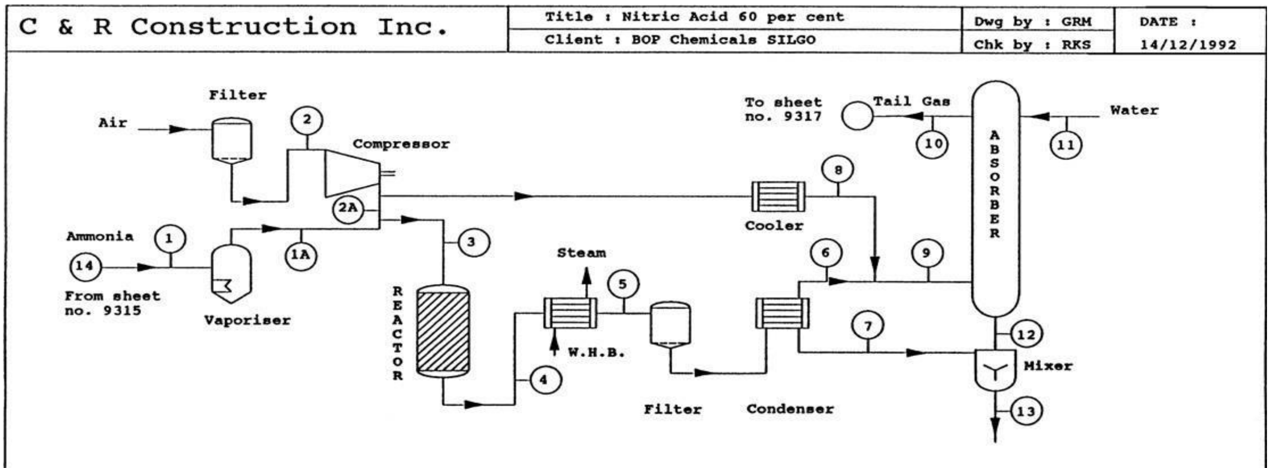


Fig.(4) PFD [Qualitative flow diagram for the manufacture of nitric acid by the ammonia-oxidation process].



Flows (kg/h) Pressures nominal

Line No.	1	1A	2	2A	3	4	5	6	7	8	9	10	11	12	13
Stream / Component	Ammonia Feed	Ammonia Vapour	Filtered Air	Oxidiser Air	Oxidiser Feed	Oxidiser Outlet	W.H.B. Outlet	Condenser Gas	Condenser Acid	Condenser Air	Absorber Feed	Tail (2) Gas	Water Feed	Absorber Acid	Product Acid
NH3	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	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

Fig.(5) PFD [Combined flow diagram for the manufacture of nitric acid by the ammonia-oxidation process].

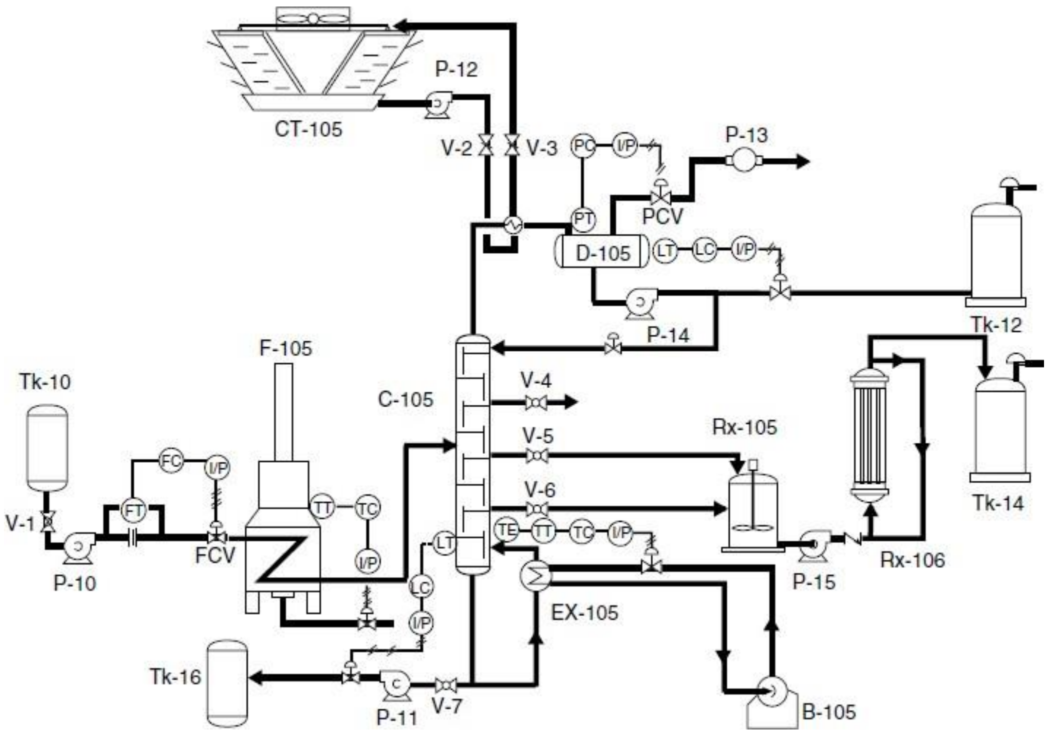


Fig.(6) Process and Instrument Diagram (P&ID)

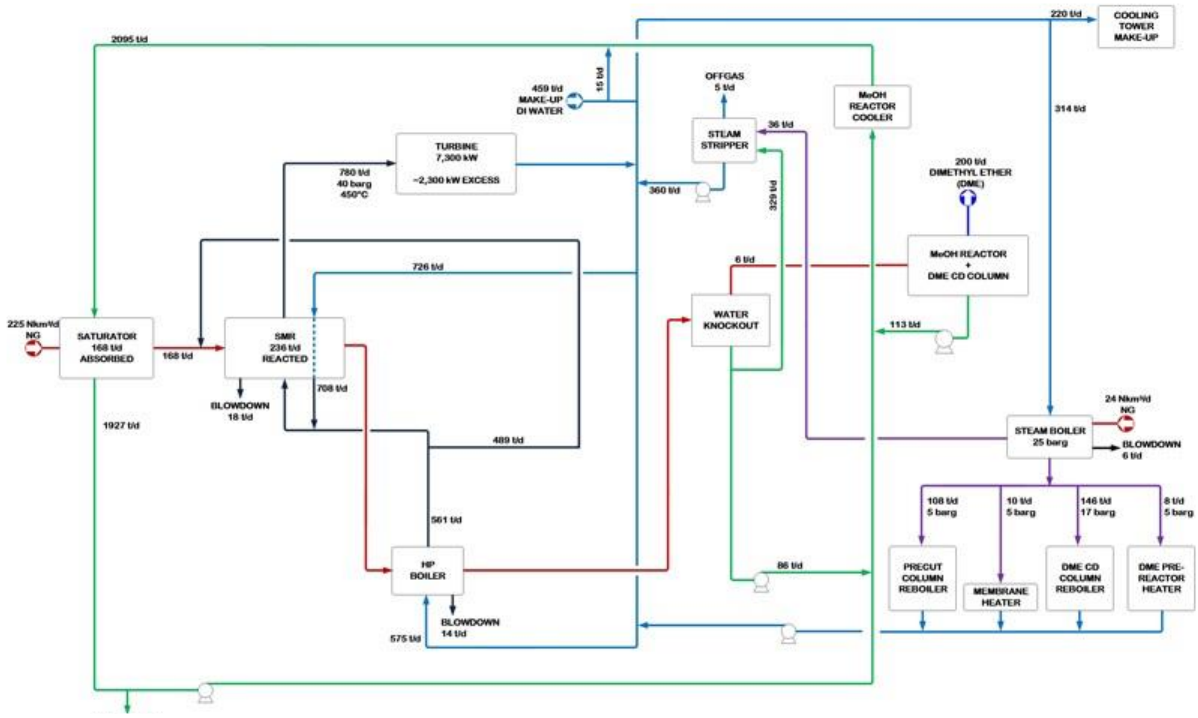


Fig.(7) Typical utility flow diagram.

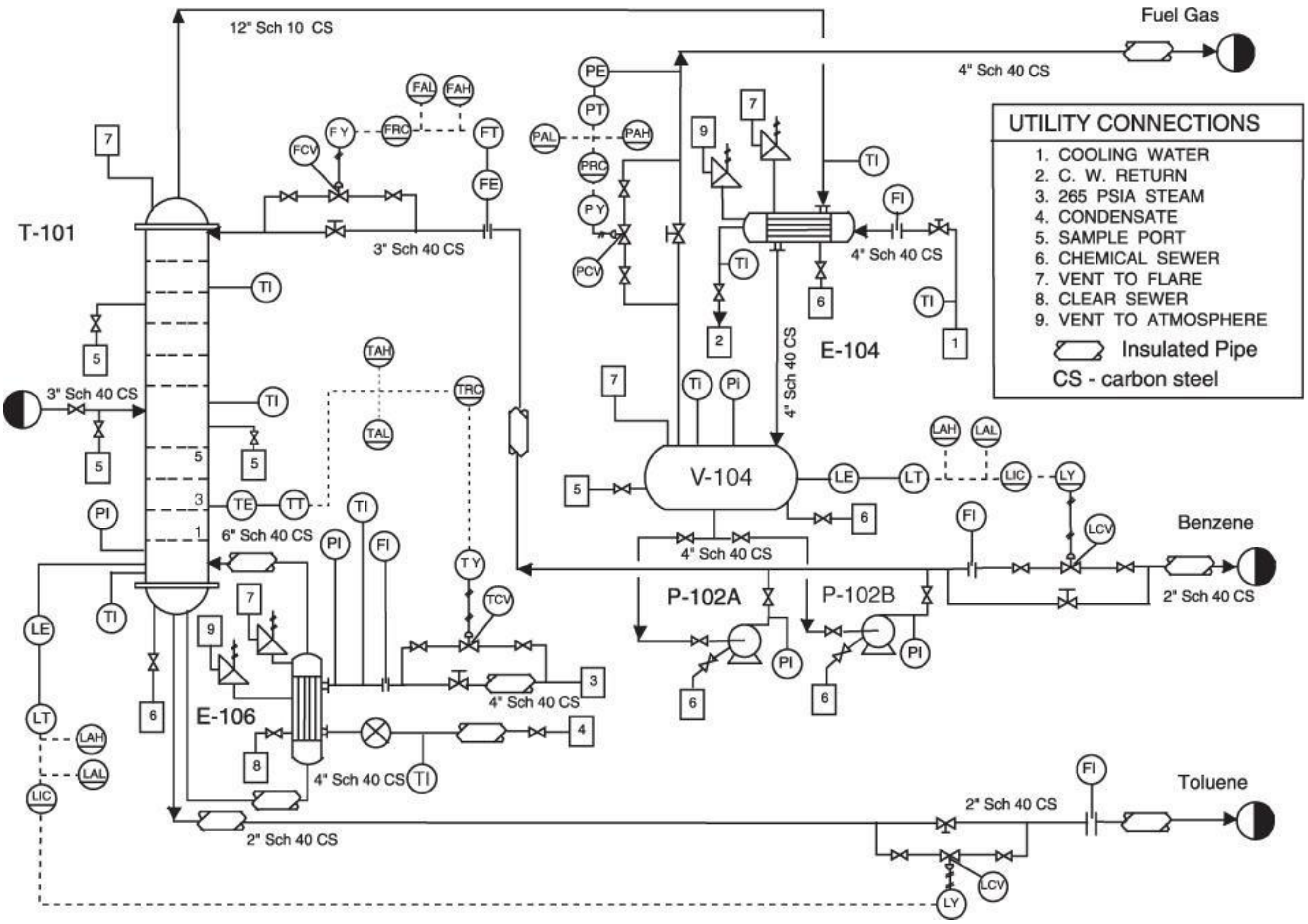


Fig.(8) Engineering P&ID flowsheet

Flowsheet Symbols

To reduce detailed written descriptions on flowsheets, it is usual practice to develop or adopt a set of symbols and codes which suit the purpose. Many symbols are pictorial which is helpful in representing process as well as control and mechanical operations. See Fig.(9)

Line Symbols and Designation

The two types of lines on a flowsheet are (1) those representing outlines and details of equipment, instruments, etc., and (2) those representing pipe carrying process or utility liquids, solids, or vapors and electrical or instrument connections. The latter must be distinguished among themselves as suggested by Figure (10).

The usual complete line designation contains the following: (1) line size (nominal); (2) material cod; (3) sequence number; and (4) materials of construction.

Examples: 2"-CL6-CS40

3"-CL6a-CS40

Equipment Designation

Equipment code designations can be developed to suit the particular process, or as is customary a master coding can be established and followed for all projects. A suggested designation list (not all inclusive for all processes) for the usual process plant equipment is given in Table (1). The various items are usually numbered by type and in process flow order as set forth on the flowsheets. For example:

Item code	Designation
S-1	First separator in a process
S-2	Second separator in a process
C-1	First compressor in a process

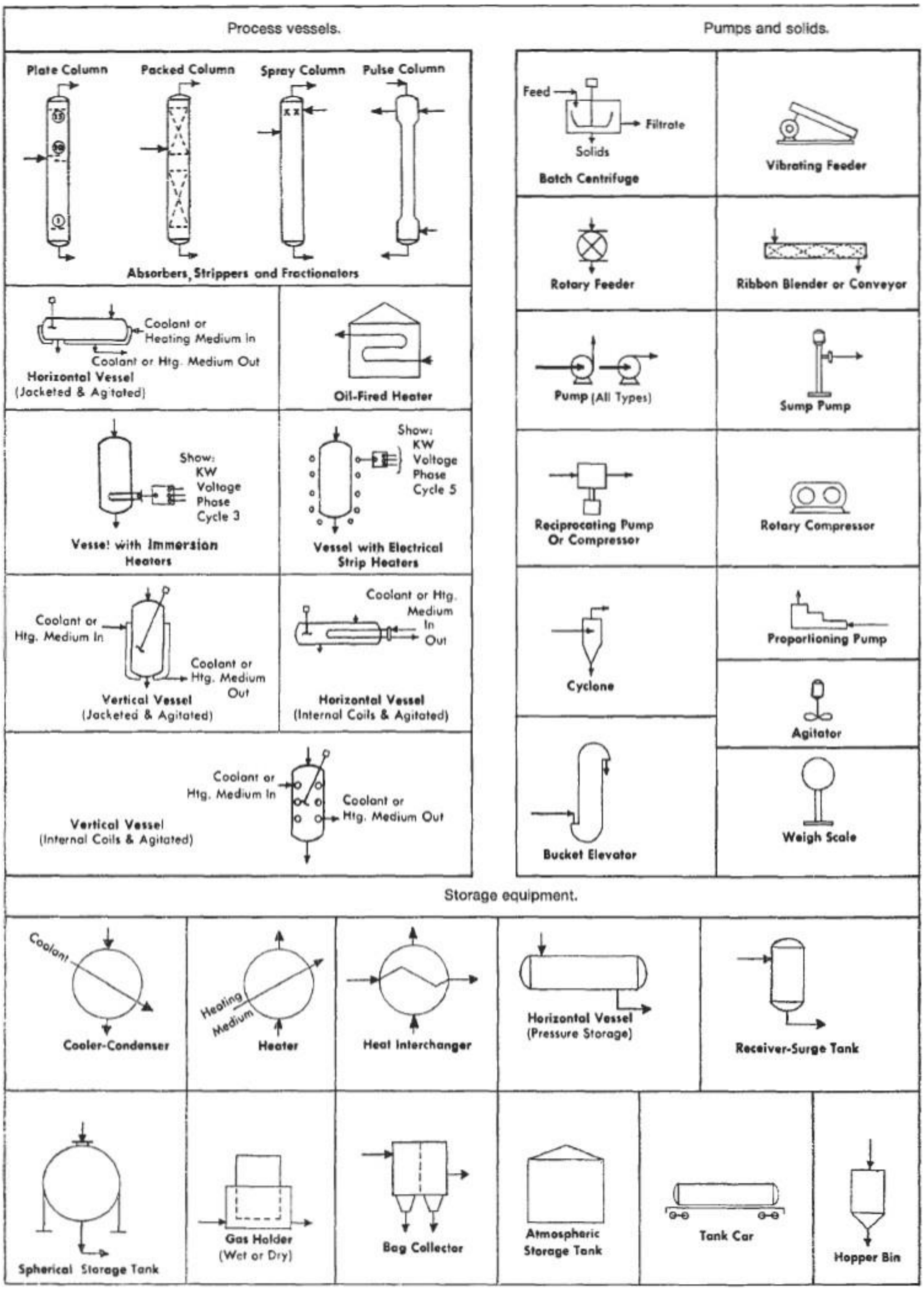


Fig. (9.a) Flowsheet symbols.

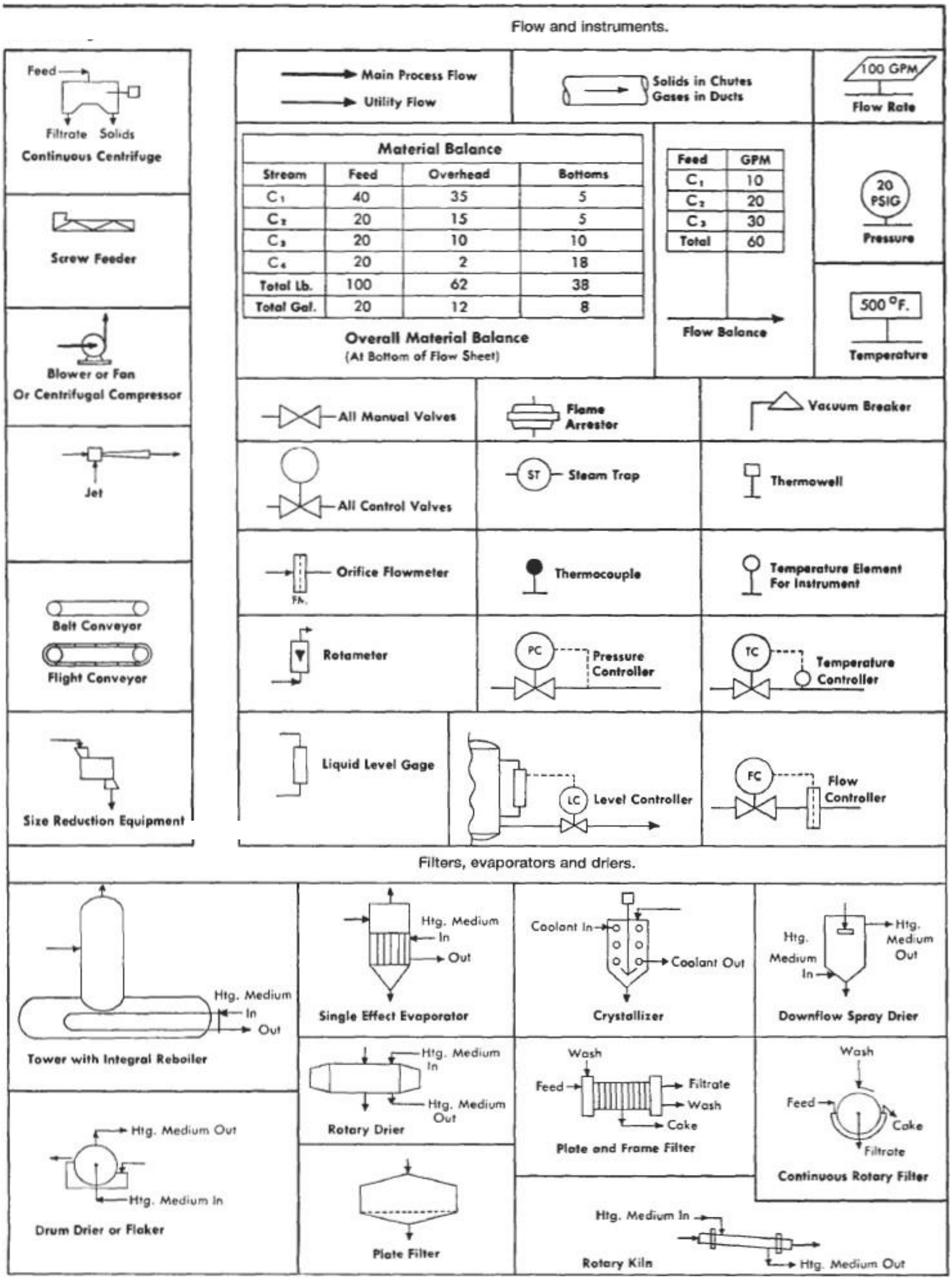


Fig. (9.b) Flowsheet symbols contd.

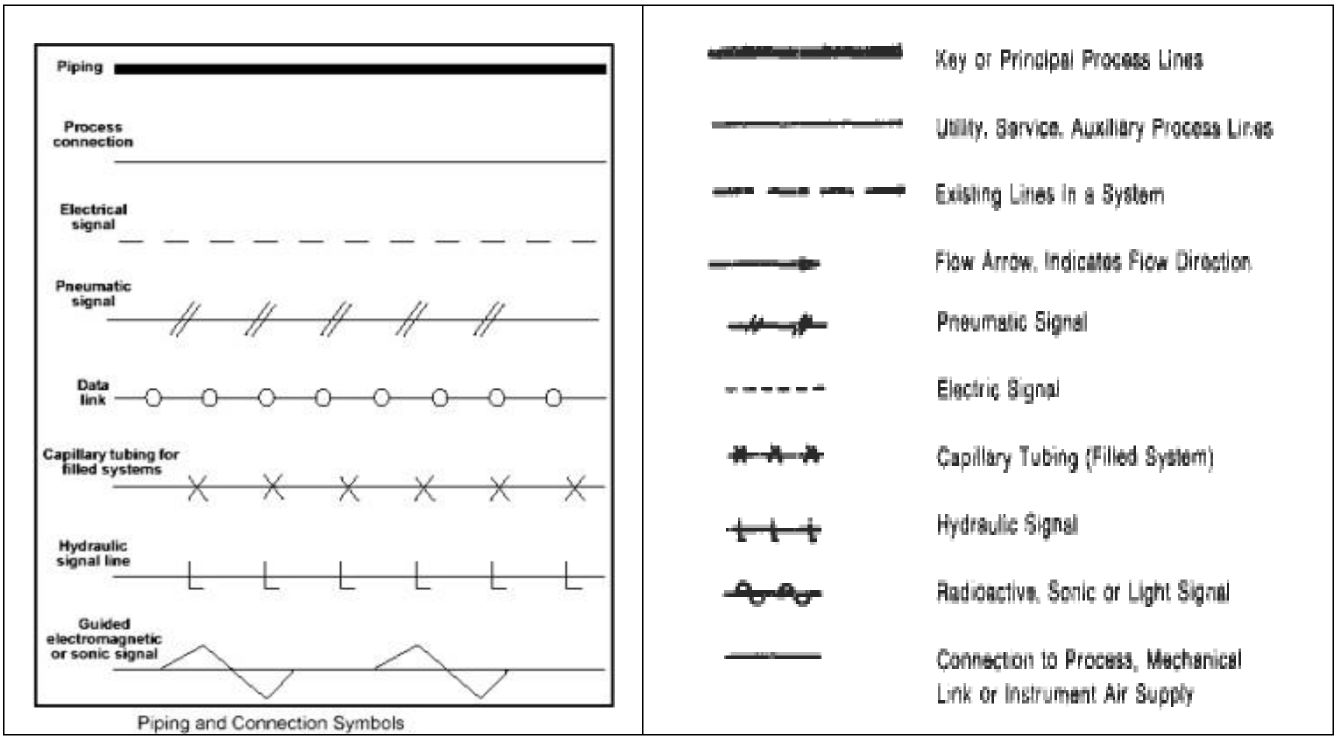


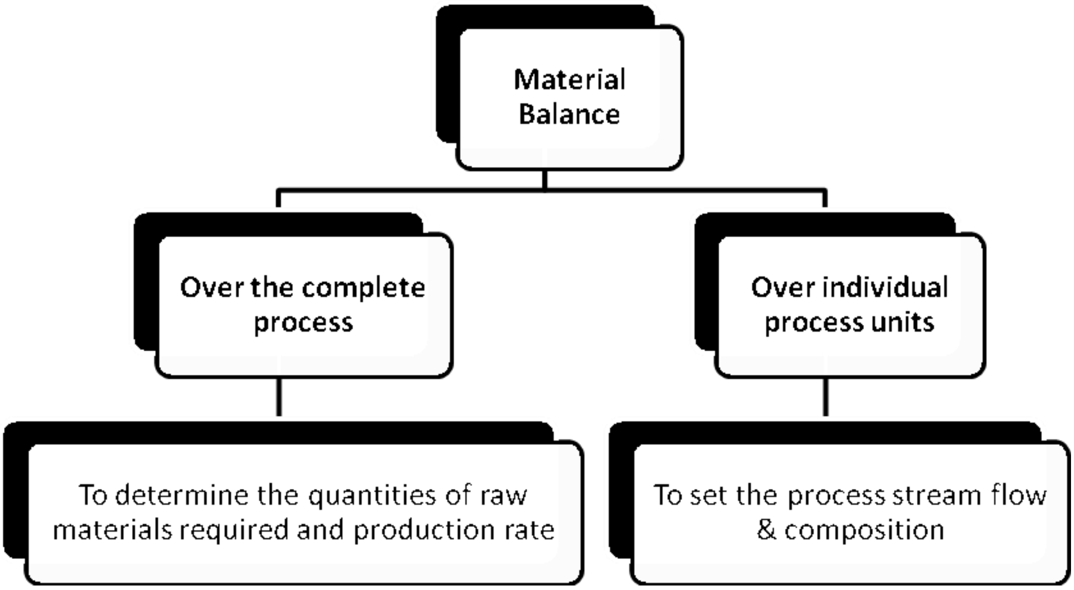
Fig.(10) piping and connection symbols from different sources(Line symbols)

A System of Equipment Designations

AD — Air Drier
AF — Air Filter
Ag — Agitator
B — Blower
BR — Barometric Refrigeration Unit
C — Compressor
CP — Car Puller
CT — Cooling Tower
CV — Conveyor
D — Drum or tank
DS — Desuperheater
E — Heat Exchanger, condenser, reboiler, etc.
Ej — Jet Ejector
Ex — Expansion Joint
F — Fan
FA — Flame Arrestor
Fi — Filter (line type, tank, centrifugal)
GT — Gas Turbine
MB — Motor for Blower
MC — Motor for Compressor
MF — Motor for Fan
MP — Motor for Pump
P — Pump
PH — Process Heater or Furnace
R — Reactor
S — Separator
St — Strainer
ST — Steam Turbine
Str — Steam trap
SV — Safety Valve
Tr — Trap
V — Valve
VRV — Vacuum Relief Valve

Fundamentals of Material Balance

Material balances are the basis of process design



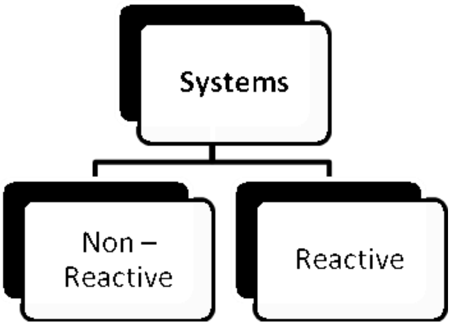
Material balance is also useful tool for the following:

1. The study of the plant operation & troubleshooting.
2. Check performance against design.
3. Check the instrument calibration.

Conservation of Mass:

The general mass balance equation:

Input – output + generation – consumption = Accumulation



For steady-state non reactive system: Input = Output [Number of equations = Number of co

For steady-state reactive system: Input – output + generation – consumption = 0.0

Some Important Parameters for Reactive System:

Limiting Reactant:

It's the reactant that would be completely consumed if the reaction proceeded to completion. As it disappears the reaction stops. It's also called the rate determining component since its concentration determines the reaction rate. All other reactants must either be fed in stoichiometric proportion to the limiting reactant (the feed rates are in the ratio of the stoichiometeric coefficients) or in excess of the limiting reactant (in greater than stoichiometric proportion to it).

Stoichometry:

It's used to balance chemical reaction equations. The stoichiometric equation for a chemical reaction states the number of molecules of the reactants and products that take part, from which the quantities can be calculated.

For simple reactions → can be done by inspection. بمجرد النظر

For complex reactions → take a base of 1 mole of one component and make an atomic balance on each element (It's better to choose one with many atoms as possible).

Fractional Conversion:

It's the ratio of amount reacted to amount fed. The fractional conversions of different reactants are generally different unless the reactants are fed in stoichiometric proportion.

$$\text{Fractional Conversion} = \frac{\text{Amount reacted from the limiting reactant}}{\text{Amount fed from the limiting reactant}}$$

$$= \frac{\text{Input of the limiting reactant} - \text{Output of the limiting reactant}}{\text{Input of the limiting reactant}}$$

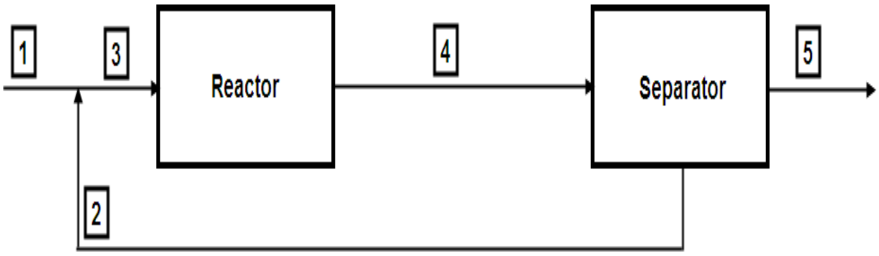
Note: In case of reaction process with recycling of unreacted reactants, there are 2 types of conversion:

a- **Single pass conversion**

$$= \frac{\text{Input to the reactor} - \text{Output from the reactor}}{\text{Input to the reactor}} = \frac{3-4}{3}$$

b- **Overall conversion**

$$= \frac{\text{Input to the process} - \text{Output from the process}}{\text{Input to the process}} = \frac{1-5}{1}$$



The overall conversion should be >>> single pass conversion [one of the recycle functions is to maximize conversion]

Selectivity:

It's a measure of the efficiency of the reactor in converting reagent to the desired product. It is the fraction of the reacted material that was converted into the desired product. If no byproducts are formed, then the selectivity is 100%.

$$\text{Selectivity} = \frac{\text{moles of desired product actually formed}}{\text{moles of desired product theoretically could be formed}}$$

$$= \frac{\text{moles of desired product actually formed}}{\text{moles of reagent consumed} \times \text{stoichiometric factor}}$$

Yield:

It's a measure of the performance of a reactor or a plant.

There are 2 types of yield:

a- Reaction yield (Chemical yield)

Reaction yield = Conversion $\times$ Selectivity

$$= \frac{\text{Moles product produced}}{\text{Moles reagent converted}} \times \text{Stoichiometric factor}$$

Where moles reagent converted includes that consumed in both main & side reactions.

Note: Reaction yield = conversion when there is no side reactions take place.

b- Plant Yield

Plant yield is a measure of the overall performance of the plant and includes all chemical & physical losses (during separation process).

Plant Yield = $\frac{\text{Moles product produced}}{\text{Moles reagent supplied to the process}} \times \text{Stoichiometric factor}$

Stoichiometric factor = theoretical moles of reagent required per moles of product produced in the reaction balanced equation.

Excess:

A reagent may be supplied in excess to promote the desired reaction to:

1- Maximize the use of an expensive reagent.

2- Ensure complete reaction of a reagent, as in combustion.

$$\% \text{ Excess} = \frac{\text{Actual Feed} - \text{Theoritical Feed}}{\text{Theoritical Feed}} \times 100$$

$$= \frac{\text{Actual Feed} - \text{Stoichiometric Feed}}{\text{Stoichiometric Feed}} \times 100$$

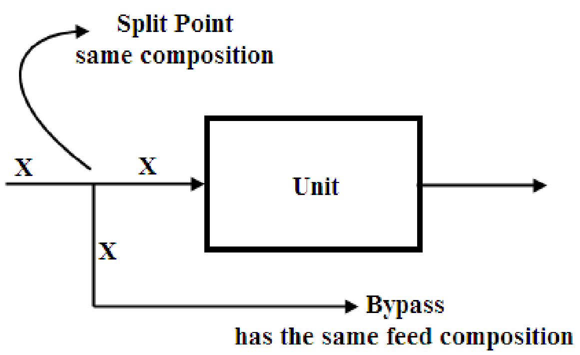
Note: Excess component actual feed = Theoretical feed $\times$ (1+ fraction excess)

Tie Component:

If one component passes unchanged through a process unit (inert component), it can be used to tie the inlet & outlet compositions. Since its amount is the same in input & output so the total amount of input & output can be calculated if their compositions are known. Example: Nitrogen in combustion reactions.

Bypass:

A flow stream may be divided and some part diverted (bypassed) around some units. This procedure is often used to control stream composition or temperature.



Recycle:

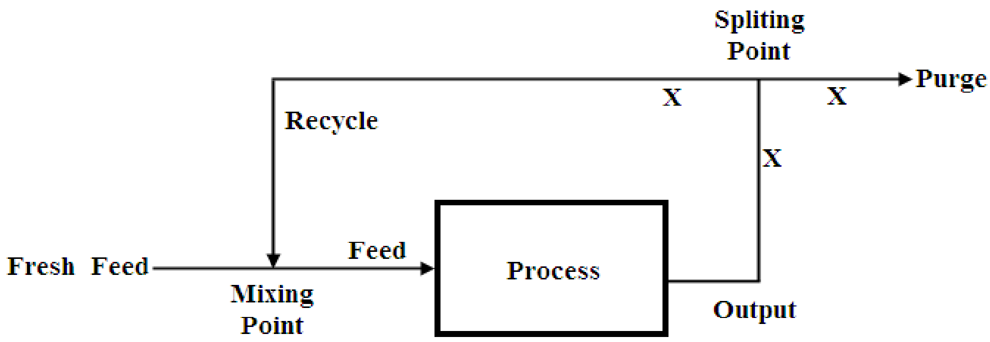
It's used to send unused raw materials emerging from a process unit back to the unit. Overall system balances are usually (but not always) convenient starting points for analyzing process with recycle.

Purge:

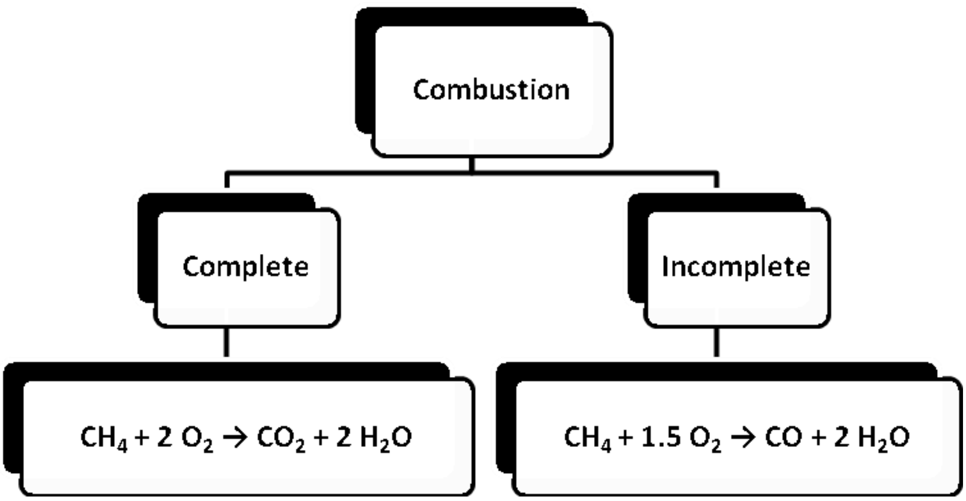
A stream that's withdrawn from a process when a species enters in the process feed and is completely recycled. If this species weren't removed in the purge, it would keep accumulating in the process system and eventually lead to shutdown.

Purge stream used to:

- Maintain the steady state conditions in the system
- Prevent the accumulation of inert or undesired materials [To rid the process of the undesired material]



Combustion Reactions:



Excess air is used in combustion to:

1- Ensure complete combustion.
2- Minimize Co & smoke formation.

Note: % excess air = % excess oxygen Air = 79% N_2 + 21% O_2 by moles Air = 77% N_2 + 23% O_2 by mass

The calculated amount of excess air doesn't depend on how much material is actually burned but what can be burned. Excess O_2 (air) is calculated from the complete combustion equation, i.e. based on conversion of all C→ CO_2, S→ SO_2 & H→ H_2O.

Choice of a basis for Calculations:

A basis of calculation for a process is an amount or flow rate of one of the process streams, preferably that stream with known composition. The basis may be a period of time for example, hours, or a given mass of material.

1- For continuous process (production or feed rate is given as kg/hr, ton/day, ….. etc) ► Basis is1 hr or 1 operating day (unit of Time)
2- For batch process (production or feed rate is given as kg/batch , ton/batch, … etc) ► Basis is 1 batch.
3- If the flow rates are not given ►

- For composition given as mass fraction (in case of liquids or solids), basis is often 1 or 100 lbm or kg.
- For composition given as mole fraction (in case of gases), basis is often 1 or 100 lbmol or kmol.

Note: It's important that your basis be indicated near the beginning of the problem.

General Procedures for Material Balance Problems:

1- Draw a block diagram of the process.

2- List all the available data.
3- List all the information required from the balance.
4- Write out all the chemical reactions involved.
5- Decide the basis of your calculations.
6- Decide the system boundary.

Types of Designs

The methods for carrying out a design project may be divided into the following classifications, depending on the accuracy and detail required:

1. Preliminary or quick-estimate designs

Used as a basis for determining whether further work should be done on the proposed process. This type of design is based on approximate process methods, and rough cost estimates are prepared. Few details are included, and the time spent on calculations is kept at a minimum.

2. Detailed-estimate designs

In this type of design, the cost and profit potential of an established process is determined by detailed analysis and calculations. However, exact specifications are not given for the equipment, and drafting-room work is minimized. The following factors should be established within narrow limits before a detailed-estimate design is developed:

- Manufacturing process
- Material and energy balances
- Temperature and pressure ranges
- Raw-material and product specifications
- Yields, reaction rates, and time cycles
- Materials of construction
- Utilities requirements
- Plant site

i.e the above factors should be determined after a preliminary design.

3. Firm process designs or detailed designs

When the detailed-estimate design indicates that the proposed project should be a commercial success, the final step before developing construction plans for the plant is the preparation of a firm process design. In this type complete specifications are presented for all components of the plant, without any change in the process flowsheet and accurate costs based on quoted prices are obtained. The firm process design includes blueprints and sufficient information to permit immediate development of the final plans for constructing the plant.

Design Information (literature survey)

General information and specific data required to the development of a design project can be obtained from many different sources such as:

A. Textbooks

A large number of textbooks covering the various aspects of chemical engineering principles and design are available. In addition, many handbooks have been published giving physical properties and other basic data which are very useful to the design engineer.A primary source of information on all aspects of chemical engineering principles, design, costs, and applications is "The Chemical Engineers' Handbook" published by McGraw-Hill Book Company with R. H. Perry and D. W. Green as editors and Encyclopedia of Chemical Technology by Kirk Othmer.

B. Technical journals

Regular features on design-related aspects of equipment, costs, materials of construction, and unit processes are published in Chemical Engineering. In addition to this publication, there are many other periodicals that publish articles of direct interest to the design engineer. The following periodicals are suggested as valuable sources of information for the chemical engineer who wishes to keep abreast of the latest developments in the field:

- American Institute of Chemical Engineers journal (AICHE)
- Chemical Engineening Progress
- Chemical and Engineering News
- Chemical Engineering Science
- Industrial and Engineering Chemistry Fundamentals
- Industrial and Engineering Chemistry Process Design and Development
- Journal of the American Chemical Society, Journal of Physical Chemisty
- Journal of the American Chemical Society
- Hydrocarbon Processing
- Oil and Gas Journal

- Engineering News-Record
- Canadian Journal of Chemical Engineering

C. Trade bulletins

Trade bulletins are published regularly by most manufacturing concerns, and these bulletins give much information of direct interest to the chemical engineer preparing a design. Some of the trade- bulletin information is condensed in an excellent reference book on chemical engineering equipment, products, and manufacturers. This book is known as the "Chemical Engineering Catalog," and contains a large amount of valuable descriptive material. New information is constantly becoming available through publication in periodicals, books, trade bulletins, government reports, university bulletins, and many other sources. Many of the publications are devoted to shortcut methods for estimating physical properties or making design calculations, while others present compilations of essential data in the form of nomographs or tables. The effective design engineer must make every attempt to keep an up-to-date knowledge of the advances in the field.

D. Patents

A patent is essentially a contract between an inventor and the public. In consideration of full disclosure of the invention to the public, the patentee is given exclusive rights to control the use and practice of the invention. A patent gives the holder the power to prevent others from using or practicing the invention for a period of 17 years from the date of granting. In contrast, trade-secrets and certain types of confidential disclosures can receive protection under common-law rights only as long as the secret information is not public knowledge. A new design should be examined to make certain no patent infringements are involved. If the investigation can uncover even one legally expired patent covering the details of the proposed process, the method can be used with no fear of patent difficulties.

THE PRELIMINARY DESIGN

In order to amplify the remarks made earlier concerning the design-project procedure, it is appropriate at this time to look more closely at a specific preliminary design. Only a brief presentation of the design will be attempted at this point. However, sufficient detail will be given to outline the important steps which are necessary to prepare such a preliminary design. The problem presented is a practical one of a type frequently encountered in the chemical industry; it involves both process design and economic considerations.

Problem Statement

A conservative petroleum company has recently been reorganized and the new management has decided that the company must diversify its operations into the petrochemical field if it wishes to remain competitive. The research division of the company has suggested that a very promising area in the petrochemical field would be in the development and manufacture of biodegradable synthetic detergents using some of the hydrocarbon intermediates presently available in the refinery. A survey by the market division has indicated that the company could hope to attain 2.5 percent of the detergent market if a plant with an annual production of 15 million pounds were to be built. To provide management with an investment comparison, the design group has been instructed to proceed first with a preliminary design and an updated cost estimate for a non biodegradable detergent producing facility similar to ones supplanted by recent biodegradable facilities.

Literature Survey

A survey of the literature reveals that the majority of the non biodegradable detergents are alkyl benzene sulfonates (ABS). Theoretically, there are over 80,000 isomeric alkyl benzenes in the range of C10 to C15 for the alkyl side chain. Costs, however, generally favor the use of dodecene (propylene tetramer) as the starting material for ABS.

There are many different schemes in the manufacture of ABS. Most of the schemes are variations of the one shown in Fig. (11) for the production of sodium dodecylbenzene sulfonate. A brief description of the process is as follows:

This process involves:

i. Reaction of dodecene with benzene in the presence of aluminum chloride catalyst (alkylation)
ii. Fractionation of the resulting crude mixture to recover the desired boiling range of dodecylbenzene.
iii. Sulfonation of the dodecylbenzene.
iv. Neutralization of the sulfonic acid with caustic soda.
v. Blending the resulting slurry with chemical “builders”; and drying.

Process Description

Dodecene is charged into a reaction vessel containing benzene and aluminum chloride. The reaction mixture is agitated and cooled to maintain the reaction temperature of about **115°F** maximum. An excess of benzene is used to suppress the formation of by-products. Aluminum chloride requirement is **5 to 10 wt%** of dodecene. After removal of aluminum chloride sludge, the reaction mixture is fractionated to recover excess benzene (which is recycled to the reaction vessel), a light alkylaryl hydrocarbon, dodecylbenzene, and a heavy alkylaryl hydrocarbon.

Sulfonation of the dodecylbenzene may be carried out continuously or batch-wise under a variety of operating conditions using sulfuric acid (100 percent), oleum (usually 20 percent SO3), or anhydrous sulfur trioxide. The optimum sulfonation temperature is usually in the range of **100 to 140°F** depending on the strength of acid employed, mechanical design of the equipment, etc. Removal of the spent sulfuric acid from the sulfonic acid is facilitated by adding water to reduce the sulfuric acid strength to about **78 percent**. This dilution prior to neutralization results in a final neutralized slurry having approximately **85 percent** active agent based on the solids. The inert material in the final product is essentially Na2SO4.

The sulfonic acid is neutralized with **20 to 50 percent** caustic soda solution to a pH of 8 at a temperature of about **125°F**. Chemical "builders" such as trisodium phosphate, tetrasodium pyrophosphate, sodium silicate, sodium chloride, sodium sulfate, carboxymethyl cellulose, etc., are added to enhance the detersive, wetting, or other desired properties in the finished product. A flaked,

dried product is obtained by drum drying or a bead product is obtained by spray drying.

The basic reactions which occur in the process are the following.

Alkylation:

$$C_6H_6 + C_{12}H_{24} \xrightarrow{AlCl_3} C_6H_5 \cdot C_{12}H_{25}$$

Sulfonation:

$$C_6H_5 \cdot C_{12}H_{25} + H_2SO_4 \longrightarrow C_{12}H_{25} \cdot C_6H_4 \cdot SO_3H + H_2O$$

Neutralization:

$$C_{12}H_{25} \cdot C_6H_4 \cdot SO_3H + NaOH \longrightarrow C_{12}H_{25} \cdot C_6H_4 \cdot SO_3Na + H_2O$$

A literature search indicates that yields of **85 to 95 percent** have been obtained in the alkylation step, while yields for the sulfonation process are substantially **100 percent**, and yields for the neutralization step are always **95 percent** or greater. All three steps are exothermic and require some form of jacketed cooling around the stirred reactor to maintain isothermal reaction temperatures.

Laboratory data for the sulfonation of dodecylbenzene, described in the literature, provide additional information useful for a rapid material balance.

This is summarized as follows:

1. Sulfonation is essentially complete if the ratio of 20 percent oleum to dodecylbenzene is maintained at 1.25.
2. Spent sulfuric acid removal is optimized with the addition of 0.244 lb of water to the settler for each 1.25 lb of 20 percent oleum added in the sulfonation step.
3. A 25 percent excess of 20 percent NaOH is suggested for the neutralization step.

Operating conditions for this process, as reported in the literature, vary somewhat depending upon the particular processing procedure chosen.

Required:

1- Making material and energy balances. 2- Equipment sizing and selection.

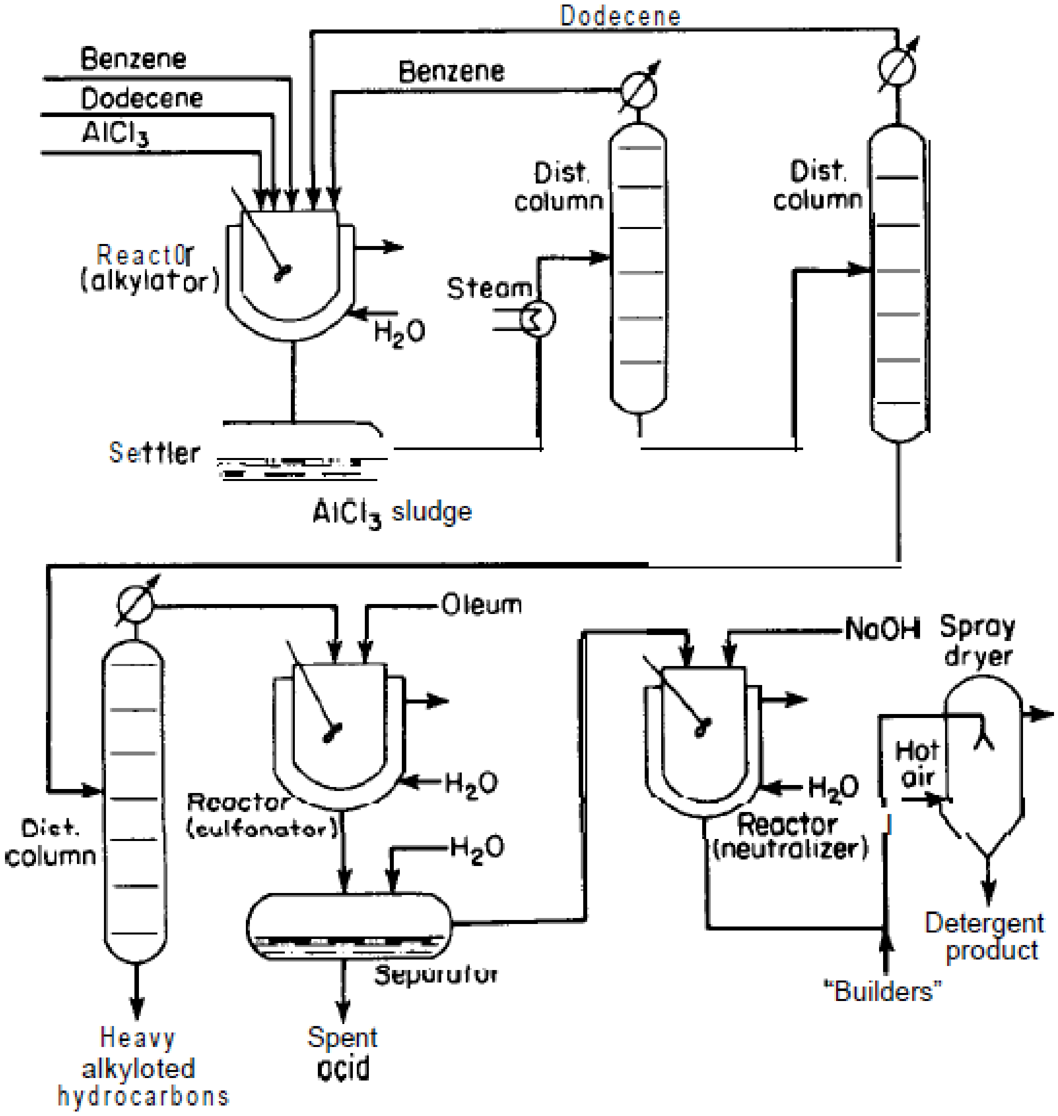


Fig. (11) Qualitative flow diagram for the manufacture of sodium dodecylbenzene sulfonate.

Economic Evaluation

The design project can be economically evaluated through the following steps:

1. Estimmation of the total capital investment.

Total capital investment = fixed capital + working capital

2. Estimation of the total annual product cost.

Total product cost = direct cost + indirect cost

3. Estimation of the expected annual profit.

Annual net profit = (total annual sales – total product cost) (1 – income taxes rate)

4. Using profitability estimation methods such as R.O.I to evaluate the attractivness of the proposed projet.

Safety Factors (Design Margins)

Definition: These factors represent the amount of overdesign that would be used to account for the changes in the operating performance with time (fouling in H.X) and potential increases in capacity requirements.

Experienced designers include a degree of over-design known as a ‘‘design factor,’’ ‘‘design margin,’’ or ‘‘safety factor,’’ to ensure that the design that is built meets product specifications and operates safely.

Design factors are applied in process design to give some tolerance in the design. For example, the process stream average flows calculated from material balances are usually increased by a factor, typically 10%, to give some flexibility in process operation. This factor will set the maximum flows for equipment, instrumentation, and piping design. Where design factors are introduced to give some contingency in a process design, they should be agreed upon within the project organization and clearly stated in the project documents (drawings, calculation sheets, and manuals). If this is not done, there is a danger that each of the specialist design groups will add its own ‘‘factor of safety,’’ resulting in gross and unnecessary over-design. Companies often specify design factors in their design manuals. When selecting the design factor, a balance has to be made between the desire to make sure the design is adequate and the need to design to tight margins to remain competitive (economic consideration). Greater uncertainty in the design methods and data requires the use of bigger design factors.

In general design work, the magnitudes of safety factors are dictated by:

- Economic or market considerations,
- Accuracy of the design data and calculations,
- Potential changes in the operating performance,
- Background information available on the overall process.

Each safety factor must be chosen on basis of the existing conditions, and the chemical engineer should not hesitate to use a safety factor of zero if the situation warrants it. Some examples of recommended safety factors for equipment design are shown in Table (2).

What is meant by design margins and what are the factors that control its values?

Specification Sheets

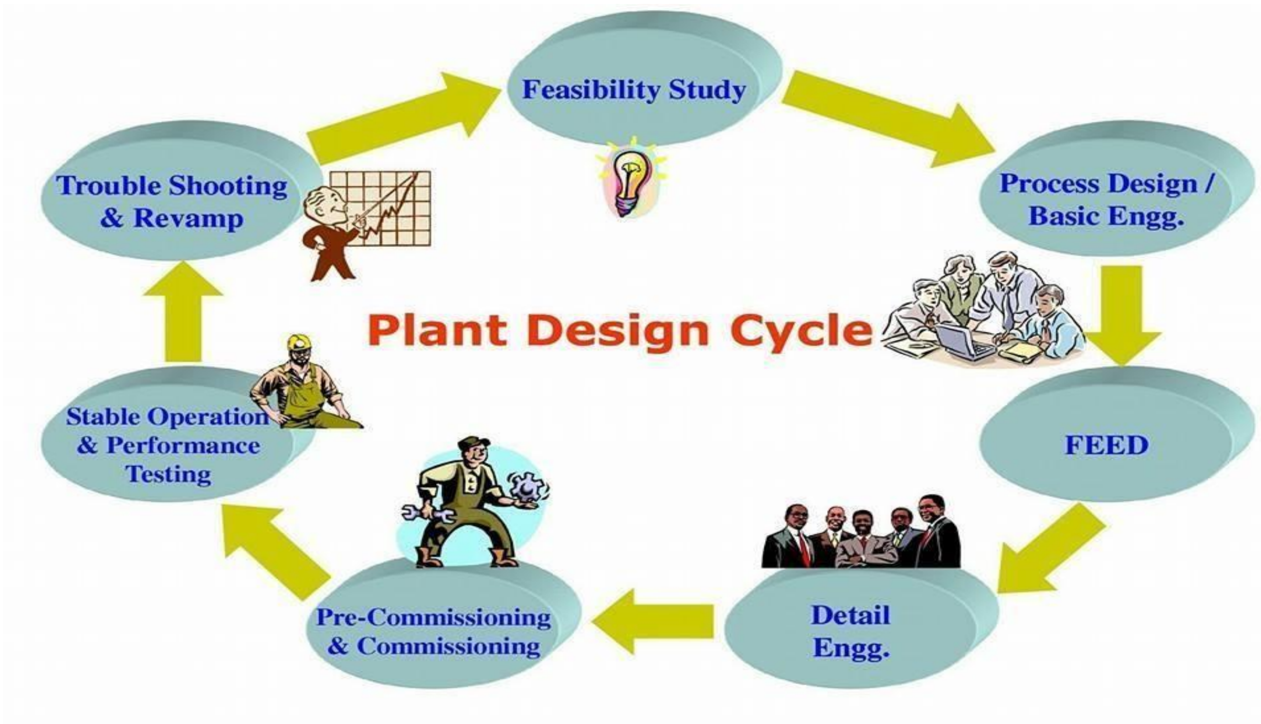
Standard specification sheets are normally used to transmit the information required for the detailed design, or purchase, of equipment items, such as heat exchangers, pumps, columns, pressure vessels, etc. As well as ensuring that the information is clearly and unambiguously presented, standard specification sheets serve as check lists to ensure that all the information required is included. A generalization for equipment design is that standard equipment should be selected whenever possible. If the equipment is standard, the manufacturer may have the desired size in stock. In any case, the manufacturer can usually quote a lower price and give better guarantees for standard equipment than for special equipment.

Before a manufacturer is contacted, the engineer should evaluate the design needs and prepare a preliminary specification sheet for the equipment. This preliminary specification sheet can be used by the engineer as a basis for the preparation of the final specifications, or it can be sent to a manufacturer with a request for suggestions and fabrication information. Preliminary specifications for equipment should show the following:

1) Identification 2) Function 3) Operation 4) Materials handled 5) Basic design data

6) Essential controls 7) Insulation requirements 8) Allowable tolerances

9) Special information and details pertinent to the particular equipment, such as materials of construction including gaskets, installation, necessary delivery date, supports, and special design details or comments. Figures 12 and 13 show typical types of specification sheets for equipment. These sheets apply for the normal type of equipment encountered by a chemical engineer in design work. The details of mechanical design, such as shell or head thicknesses, are not included, since they do not have a direct effect on the performance of the equipment. However, for certain types of equipment involving unusual or extreme operating conditions, the engineer may need to extend the specifications to include additional details of the mechanical design.



REFERENCE BOOKS:

1. Schweyer H. E., Process Engineering Economics, Mc Graw Hill, 1969.

2. Max. S. Peters And Klaus D. Timmerhaus, Plant Design and Economics for Chemical Engineers, 4th Edn., Mc Graw Hill International editions, New York, 1991.

SCHOOL OF BIO AND CHEMICAL ENGINEERING

DEPARTMENT OF CHEMICAL ENGINEERING

UNIT – 2 ENGINEERING ECONOMICS FOR PROCESS ENGINEERS, INTEREST & INVESTMENT COSTS-SCH1403

UNIT 2: ENGINEERING ECONOMICS FOR PROCESS ENGINEERS, INTEREST & INVESTMENT COSTS

VALUATION CONCEPTS

The time value of money establishes that there is a preference of having money at present than a future point of time. It means

(a) That a person will have to pay in future more, for a rupee received today.

For example :

Suppose your father gave you Rs. 100 on your tenth birthday. You deposited this amount in a bank at 10% rate of interest for one year. How much future sum would you receive after one year? You would receive Rs. 110

$$\begin{aligned}\text{Future sum} &= \text{Principal} + \text{Interest} \\ &= 100 + 0.10 \times 100 \\ &= \text{Rs. } 110\end{aligned}$$

(b) A person may accept less today, for a rupee to be received in the future. Thus, the inverse of compounding process is termed as **discounting.**

TECHNIQUES OF TIME VALUE OF MONEY

There are two techniques for adjusting time value of money. They are:

1. Compounding Techniques/Future Value Techniques
2. Discounting/Present Value Techniques

The value of money at a future date with a given interest rate is called future value. Similarly, the worth of money today that is receivable or payable at a future date is called Present Value.

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Compounding Techniques/Future Value Techniques

Suppose you invest Rs. 1000 for three years in a saving account that pays 10 per cent interest per year. If you let your interest income be reinvested, your investment will grow as follows:

First year :	Principal at the beginning	1,000
	Interest for the year (1000×0.10)	100
	Principal at the end	1,100
Second year :	Principal at the beginning	1,100
	Interest for the year (1100×0.10)	110
	Principal at the end	1210
Third year :	Principal at the beginning	1210
	Interest for the year (1210×0.10)	121
	Principal at the end	1331

A generalized procedure for calculating the future value of a single amount compounded annually is as follows:

Formula: $FV_n = PV(1 + r)^n$

In this equation:

$(1 + r)^n$ is called the future value interest factor (FVIF).

where, FV_n = Future value of the initial flow n year hence

PV = Initial cash flow

r = Annual rate of Interest

n = number of years

If you deposit Rs. 55,650 in a bank which is paying a 12 per cent rate of interest on a ten-year time deposit, how much would the deposit grow at the end of ten years?

SOLUTION:

$$FV = PV(1 + r)^n$$

$$FV_n = PV(1 + r)^n \quad \text{or} \quad FV_n = PV(\text{FVIF}_{12\%, 10\ \text{yrs}})$$

$$FV_n = ₹\ 55,650\ (1.12)^{10}$$

$$= ₹\ 55,650 \times 3.106 = ₹\ 1,72,848.90$$

MULTIPLE COMPOUNDING PERIODS

- Interest can be compounded monthly, quarterly and half-yearly.

- If compounding is quarterly, annual interest rate is to be divided by 4 and the number of years is to be multiplied by 4.

- If monthly compounding is to be made, annual interest rate is to be divided by 12 and number of years is to be multiplied by 12.

$$FV_n = PV\left(1+\frac{r}{m}\right)^{m \times n}$$

DISCOUNTING OR PRESENT VALUE CONCEPT

- Present value is the exact opposite of future value.

- The present value of a future cash inflow or outflow is the amount of current cash that is of equivalent value to the decision maker.

- The process of determining present value of a future payment or receipts or a series of future payments or receipts is called discounting.

- The compound interest rate used for discounting cash flows is also called the discount rate.

SIMPLE AND COMPOUND INTEREST

In compound interest, each interest payment is reinvested to earn further interest in future periods. However, if no interest is earned on interest, the investment earns only simple interest. In such a case, the investment grows as follows:

Future value = Present value [1 + Number of years × Interest rate]

For example, if Rs. 1,000 is invested @ 12% simple interest, in 5 years

it will become

$$1{,}000\,[\,1 + 5 \times 0.12\,] = \text{Rs. } 1{,}600$$

Time Value of Money

Money has a time value because it can earn more money over time. A number of terms involving the time value of money were introduced in this chapter:

Interest is the cost of money. More specifically, it is a cost to the borrower and an earning to the lender above and beyond the initial sum borrowed or loaned.

Interest rate is a percentage periodically applied to a sum of money to determine the amount of interest to be added to that sum.

Simple interest is the practice of charging an interest rate only to an initial sum.

Compound interest is the practice of charging an interest rate to an initial sum and to any previously accumulated interest that has not been withdrawn from the initial sum. Compound interest is by far the most commonly used system in the real world.

Economic equivalence exists between individual cash flows or between patterns of cash flows that have the same value. Even though the amounts and timing of the cash flows may differ, the appropriate interest rate makes them equal.

The following compound-interest formula is perhaps the single most important equation in this text:

$F = P(1 + i)^N$.

In this formula, P is a present sum, i is the interest rate, N is the number of periods for which interest is compounded, and F is the resulting future sum. All other important interest formulas are derived from this one.

Cash flow diagrams are visual representations of cash inflows and outflows along a time line. They are particularly useful for helping us detect which of the five patterns of cash flow is represented by a particular problem.

The five patterns of cash flow are as follows:
1. Single payment: A single present or future cash flow.
2.Uniform series: A series of flows of equal amounts at regular intervals.
3. Linear gradient series: A series of flows increasing or decreasing by a fixed amount at regular intervals. Excel is one of the most convenient tools to solve this type of cash flow series.
4. Geometric gradient series: A series of flows increasing or decreasing by a fixed percentage at

regular intervals. Once again, this type of cash flow series is a good candidate for solution by Excel.
5. Uneven series: A series of flows exhibiting no overall pattern. However, patterns might be detected for portions of the series.

Cash flow patterns are significant because they allow us to develop interest formulas, which streamline the solution of equivalence problems. Table 2.10 summarizes the important interest formulas that form the foundation for all other analyses you will conduct in engineering economic analysis.

Process Engineering Economics – Equations for economic studies

S.No	Equation	Use
1.	$F = P(1+i)^n = PC_F$	Single payment at the end of n^{th} period
2.	$R = P\left(\frac{i(1+i)^n}{(1+i)^n - 1}\right) = \frac{P}{P_F}$	Uniform payment at the end of period (to pay fixed amount each year)
3.	$F = R\left(\frac{(1+i)^n - 1}{i}\right)$	Future worth at the end of n^{th} period
4.	$P = R\left(\frac{(1+i)^n - 1}{i(1+i)^n}\right) = RP_F$	Present Worth

S.No	Equation	Use
4.	$P = R\left(\frac{(1+i)^n - 1}{i(1+i)^n}\right) = RP_F$	Present Worth
5.	$R = (P-L)\left(\frac{i(1+i)^n}{(1+i)^n - 1}\right) + L \times i$	Uniform payment with salvage (*L*)
6.	$(1+i)^n = \frac{1}{1-\left(\frac{P}{R}\right)i}$	Rate of return or payment time when *L* is zero or salvage is neglected
7.	$n = \frac{-\log\left(1 - i\frac{P}{R}\right)}{\log(1+i)}$	Payment time when *L* is zero or salvage is neglected

S. No	Equation	Use
8.	$P' = \frac{R'}{i'}$	Capitalized costs (or) perpetual uniform payment *R′* to an equivalent capital cost *P′* at he present time for a given interest rate.
9.	$C_k = (C_{FC} - S_{FD}) f_k$ $\because f_k = \frac{(1+i)^n}{(1+i)^n - 1}$	Capitalized cost including cost factor.
10.	$R'' = P\left(\frac{i'}{(1+i')^n - 1}\right)$	Sinking fund deposit, *i'* – is sinking fund interest rate and *L* is zero.
11.	$P = R'''\left(\frac{(1+i')^n - 1}{i\left[(1+i')^n - 1\right] + i'}\right)$	Hoskold's formula - is rate of return, *i′* is sinking fund interest rate. Note that when *i* = *i′* equation (10) reduces to equation (4)

i = interest rate per period
i' = sinking fund interest
P = present sum of money
F = sum at future date at 'n' Periods
R = end of period payment to give P in uniform series
L = salvage at some future date
C_F = compound interest factor equal to $(1+i)^n$
P_F = present worth factor equal to $\frac{(1+i)^n - 1}{i(1+i)^n} = \frac{P}{R}$
R'' = periodic sinking fund deposit R''
R''' = the annual payment R''' to the owners each year which pays them when the studies of capital recovery for exploitation of mineral resources.
C_{FC} = fixed capital cost of equipment for a finite life of 'n' years
C_k = capitalized cost of the equipment
S_{FD} = $\frac{S}{(1+i)^n}$; salvage value or scrap value with compound interest
f_k = capitalized cost factor

What is Depreciation?

In accounting terms, depreciation is defined as the reduction of recorded cost of a fixed asset in a systematic manner until the value of the asset becomes zero or negligible.

An example of fixed assets are buildings, furniture, office equipment, machinery etc.. A land is the only exception which cannot be depreciated as the value of land appreciates with time.

Depreciation allows a portion of the cost of a fixed asset to the revenue generated by the fixed asset. This is mandatory under the matching principle as revenues are recorded with their associated expenses in the accounting period when the asset is in use. This helps in getting a complete picture of the revenue generation transaction.

An example of Depreciation – If a delivery truck is purchased a company with a cost of Rs. 100,000 and the expected usage of the truck are 5 years, the business might depreciate the asset under depreciation expense as Rs. 20,000 every year for a period of 5 years.

How to calculate depreciation in small business?

There three methods commonly used to calculate depreciation. They are:

1. Straight line method
2. Unit of production method
3. Double-declining balance method

Three main inputs are required to calculate depreciation:

1. Useful life – this is the time period over which the organisation considers the fixed asset to be productive. Beyond its useful life, the fixed asset is no longer cost-effective to continue the operation of the asset.
2. Salvage value – Post the useful life of the fixed asset, the company may consider selling it at a reduced amount. This is known as the salvage value of the asset.
3. The cost of the asset – this includes taxes, shipping, and preparation/setup expenses.

Unit of production method needs the number of units used during production. Let’s take a look at each type of Depreciation method in detail.

Types of depreciation

1) Straight-line depreciation method

This is the simplest method of all. It involves simple allocation of an even rate of depreciation every year over the useful life of the asset. The formula for straight line depreciation is:

Annual Depreciation expense = (Asset cost – Residual Value) / Useful life of the asset

Example – Suppose a manufacturing company purchases a machinery for Rs. 100,000 and the useful life of the machinery are 10 years and the residual value of the machinery is Rs. 20,000

Annual Depreciation expense = (100,000-20,000) / 10 = Rs. 8,000

Thus the company can take Rs. 8000 as the depreciation expense every year over the next ten years as shown in depreciation table below.

Year	Original cost – Residual value	Depreciation expense
1	Rs. 80000	Rs. 8000
2	Rs. 80000	Rs. 8000
3	Rs. 80000	Rs. 8000
4	Rs. 80000	Rs. 8000
5	Rs. 80000	Rs. 8000
6	Rs. 80000	Rs. 8000
7	Rs. 80000	Rs. 8000
8	Rs. 80000	Rs. 8000
9	Rs. 80000	Rs. 8000
10	Rs. 80000	Rs. 8000

2) Unit of Production method

This is a two-step process, unlike straight line method. Here, equal expense rates are assigned to each unit produced. This assignment makes the method very useful in assembly for production lines. Hence, the calculation is based on output capability of the asset rather than the number of years.

The steps are:

Step 1: Calculate per unit depreciation:

Per unit Depreciation = (Asset cost – Residual value) / Useful life in units of production

Step 2: Calculate the total depreciation of actual units produced:

Total Depreciation Expense = Per Unit Depreciation * Units Produced

Example: ABC company purchases a printing press to print flyers for Rs. 40,000 with a useful life of 1,80,000 units and residual value of Rs. 4000. It prints 4000 flyers.

Step 1: Per unit Depreciation = (40,000-4000)/180,000 = Rs. 0.2
Step 2: Total Depreciation expense = Rs. 0.2 * 4000 flyers = Rs. 800

So the total Depreciation expense is Rs. 800 which is accounted. Once the per unit depreciation is found out, it can be applied to future output runs.

3) Double declining method

This is one of the two common methods a company uses to account for the expenses of a fixed asset. This is an accelerated depreciation method. As the name suggests, it counts expense twice as much as the book value of the asset every year.

The formula is:

Depreciation = 2 * Straight line depreciation percent * book value at the beginning of the accounting period

Book value = Cost of the asset – accumulated depreciation

Accumulated depreciation is the total depreciation of the fixed asset accumulated up to a specified time.

Example: On April 1, 2012, company X purchased an equipment for Rs. 100,000. This is expected to have 5 useful life years. The salvage value is Rs. 14,000. Company X considers depreciation expense for the nearest whole month. Calculate the depreciation expenses for 2012, 2013, 2014 using a declining balance method.

Useful life = 5

Straight line depreciation percent = 1/5 = 0.2 or 20% per year

Depreciation rate = 20% * 2 = 40% per year

Depreciation for the year 2012 = Rs. 100,000 * 40% * 9/12 = Rs. 30,000

Depreciation for the year 2013 = (Rs. 100,000-Rs. 30,000) * 40% * 12/12 = Rs. 28,000

Depreciation for the year 2014 = (Rs. 100,000 – Rs. 30,000 – Rs. 28,000) * 40% * 9/12 = Rs. 16,800

Depreciation table is shown below:

Year	Book value at the beginning	Depreciation rate	Depreciation Expense	Book value at the end of the year

2012	Rs. 100,000	40%	Rs. 30,000 * (1)	Rs. 70,000
2013	Rs. 70,000	40%	Rs. 28,000 * (2)	Rs. 42,000
2014	Rs. 42,000	40%	Rs. 16,800 * (3)	Rs. 25,200
2015	Rs. 25,200	40%	Rs. 10,080 * (4)	Rs. 15,120
2016	Rs. 15,120	40%	Rs. 1,120 * (5)	Rs. 14,000

Depreciation for 2016 is Rs. 1,120 to keep the book value same as salvage value.

Rs. 15,120 – Rs. 14,000 = Rs. 1,120 (At this point the depreciation should stop).

Why should small businesses care to record depreciation?

So now we know the meaning of depreciation, the methods used to calculate them, inputs required to calculate them and also we saw examples of how to calculate them. Let’s find out as to why the small businesses should care to record depreciation.

As we already know the purpose of depreciation is to match the cost of the fixed asset over its productive life to the revenues the business earns from the asset. It is very difficult to directly link the cost of the asset to revenues, hence, the cost is usually assigned to the number of years the asset is productive.

Over the useful life of the fixed asset, the cost is moved from balance sheet to income statement. Alternatively, it is just an allocation process as per matching principle instead of a technique which determines the fair market value of the fixed asset.

Accounting entry – ***DEBIT*** *depreciation expense account and* ***CREDIT*** *accumulated depreciation account.*

If we do not use depreciation in accounting, then we have to charge all assets to expense once they are bought. This will result in huge losses in the following transaction period and in high profitability in periods when the corresponding revenue is considered without an offset expense. Hence, companies which do not use the depreciation expense in their accounts will incur front-loaded expenses and highly variable financial results.

Final Notes

Depreciation is an important part of accounting records which helps companies maintain their income statement and balance sheet properly with the right profits recorded.

CONCEPT OF DEPRECIATION

Depreciation is the process of spreading the cost of fixed asset over the different accounting periods which drive the benefit from their use. The cost of fixed assets apportioned to a given period from part of the overall cost to be matched with the revenues generated in that. So, depreciation is of great significance in the concept of income measurement. It measures the service potential of the fixed assets period.

FIXED ASSETS

They include all assets whose benefit is derived by businessman for a long period of time, usually more than one year period, Examples : Machinery, Furniture, Buildings, Leases, etc. land is affixed asset but not subject to **depreciation** because it has infinite lifetime. Assets are any property owned by a person or business. Tangible assets include money, land, buildings, investments, inventory, cars, trucks, boats, or other valuables. Intangibles such as goodwill are also considered to be assets. Capital Assets, also known as Fixed Assets, are those assets such as land, buildings, and equipment acquired to carry on the business of a company with a life exceeding one year. Fixed assets are assets that help companies reap economic benefits over a period of time. Assets such as land, building, plant and machinery are all fixed assets. The general consensus is that fixed assets cannot be liquidated easily. This is quite apparent when compared to current assets such as cash and bank account and inventories, which can be liquated or converted into cash relatively easily. It may be noted that intangible assets can also be part of this head as they benefit companies over a long period of time. Few more examples of the same would be trademarks, designs and patents.

MEANING AND DEFINITION OF DPRECIATION

Depreciation is a permanent decline in the value of an asset. The gradual decrease, both in the value and usefulness, of an asset due to its nature and usage is termed as **depreciation**. **Depreciation** is the measure of wearing out of a fixed asset. All fixed assets are expected to be less efficient as time goes on. **Depreciation** is calculated as the estimate of this measure of wearing out and is charged to the Profit & Loss account either on a monthly or annual basis. The cost of the asset less the total**depreciation** will give you the Net Book Value of the asset.

It is common experience that whenever an asset is used it reduces in value. The net result of **depreciation** is that sooner or letter, the asset becomes useless. So, it can be stated that **depreciation** is that portion of the cost of an asset which is reduced from revenues for the services of the asset in the operation of a business.

According to Spicer and Pegler "**Depreciation** is thee measure of the exhaustion of the effective life of an asset from any cause during a given period."

According to the Institute Of Chartered Accountants Of India, "**Depreciation** is a measure of the wearing out, consumption or other loss of value of a depreciable asset arising from use effluxion of time or obsolescence through technology and market changes."

According to International Accounting Standards Committee, "**Depreciation** is the allocation of the depreciable amount of an asset over its estimated useful life. **Depreciation** for the accounting period is charged to income either directly or indirectly."

The following important terms from these definitions are important:

• **Depreciable Assets**: The assets whose lifetime can be estimated and useful during two or more accounting periods in production or service activities of an organization can be called depreciable assets.

• **Useful life**: Useful life is the time during which the asset is helpful in the normal business activities of a firm. It can be less than the total life time of the asset. It can be exactly predetermined or it should be estimated on reasonable basis.

• **Depreciable Amount**: It is the cost of acquisition and installation of an asset after reducing any realizable value at the end of useful life.

• Realizable value at the end of useful life.

• **Effluxion of time**: It is the passage of time irrespective of actual use of an asset as in the case of leased assets.

• **Obsolescence**: It refers to an asset becoming out of date due to improved models or methods.

METHODS OF CALCULATING DEPRCIATION

1. Straight Line Method or Fixed Installment Method.

2. Written Down Value Method or Diminishing Balance Method.

3. Annuity Method.

4. Depreciation Fund Method.

5. Insurance Policy Method.

6. Revaluation Method.

Straightline Method or Fixed Instalment Method or Original Cost Method

Under this method, the same amount of **depreciation** is charged every year throughout the life of thee asset. The amount and rate of **depreciation** is calculated as under.

1. Amount of **depreciation** = Total cost - Scrap value / Estimated life

2. Rate of **depreciation** = Amount of **depreciation** / Original cost x 100

MERITS:

1. Simplicity: It is every simple and easy to understand.

2. Easy to calculate; It is easy to calculate the amount and rate of **depreciation**.

3. Assets can be completely written off: Under this method, the book value of the asset become zero or equal to its scarp value at the expiry of its useful life.

DEMERITS: The amount of **depreciation** is same in all the years, although the usefulness of the machine to the business is more in the initial years, although the usefulness of the machine to the business is more in the initial years than in the later years.

Written Down Value Method or Dimnishing Balance Method or Reducing Balance Method

Under this method, **depreciation** is charged at a fixed percentage each year on the reducing balance (i.e. cost less**depreciation**) goes on decreasing every year.

Merits:

1. Uniform effect on the profit and loss account of different years. The total charge (i.e.. **depreciation** plus repairs and renewals) remains almost uniform year after year, since in earlier year the amount of depreciation is more and the amount of repairs and renewals is more.

2. Recognized by the income tax authorities: This method is recognized by the income tax authorities.

3. Logical Method: It is a logical method as the **depreciation** is calculated on the diminished balance every year.

DEMERITS: It is very difficult to determine the rate by which the value of assets could be written down to Zero.

Annuity Method

The annuity method considers that the business besides loosing the original cost of the asset in terms of **depreciation** and also loses interest. On the amount used for buying the asset. This is based on the assumption that the amount invested in the asset would have earned in case the same amount would have been invested in some other form of investment. The annual amount of**depreciation** is determined with the help of annuity table.

Depreciation Fund Method or Sinking Fund Method

Under this method, funds are mad available for the replacement of asset at the end of its useful life.th depreciation remains the same year after year and is changed to profit and loss account every year through the creation of **depreciation** fund. The aggregate amount of interest and annual provision is invested every year. When the asset is completely written off or is to be replaced, the securities are sold and the amount so realized by selling securities is used to replace the old asset.

Insurance Policy Method

According to this method, an insurance policy is taken for the amount of the asset to be replaced. The amount of the policy is such that it is sufficient to replace the asset when it is worn out. A sum equal to the amount of **depreciation** is paid as premium every year. The amount goes on accumulating at a certain rate of interest and is received on maturity. The amount so received is used for the purchase of new asset, replacing the old one.

Revaluation Method

Under this method, the asset like loose tools are revalued at the end of the accounting period and the same is compared with the value of the asset at the beginning of the year. The difference is considered as **depreciation**.

Straightline Method or Fixed Instalment Method or Original Cost Method

Under this method, the same amount of **depreciation** is charged every year throughout the life of the asset .The amount and rate of **depreciation** is calculated as under.

1. Amount of **depreciation** = Total cost - Scrap Value / Estimated life

2. Rate of **depreciation** = Amount of **depreciation** / Original Cost x 100

Merits:

1. Simplicity; It is very simple and easy to understand.

2. Easy to calculate; It is easy to calculate the amount and rate of **depreciation**.

3. Assets can be completely written off; Under this method, the book value of the asset become Zero or equal to its scrap value at the expiry of its useful life.

DEMERITS:

The amount of **depreciation** is same in all the years, although the usefulness of the machine to the business is more in the initial years than in the later years.

Written Down Value Method or Dimnishing Balance Method or Reducing Balance Method

Under this method, **depreciation** is charged at a fixed percentage each year on the reducing balance (i.e., cost less**depreciation**) of asset. The amount of **depreciation** goes on decreasing every year.

MERITS:

1. Uniform effect on the profit and loss account of different years. The total charge (i.e.… **depreciation** plus repairs and renewals) remains almost uniform year after year, since in earlier year the amount of **depreciation** is more and the amount of repairs and renewals is less, Whereas in later years the amount of **depreciation** is less and the amount of repairs and renewals is more.

2. Recognized by the income tax authorities; this method is recognized by the income tax authorities.

3. Logical Method: It is a logical method as the **depreciation** is calculated on the diminished balance every year.

DEMERITS:

It is very difficult to determine the rate by which the value of asset could be written down to zero.

Depletion is an accrual accounting technique used to allocate the cost of extracting natural resources such as timber, minerals, and oil from the earth. Like depreciation and amortization, **depletion** is a non-cash expense that lowers the cost value of an asset incrementally through scheduled charges to income.

REFERENCE BOOKS:

1. Schweyer H. E., Process Engineering Economics, Mc Graw Hill, 1969.

2. Max. S. Peters And Klaus D. Timmerhaus, Plant Design and Economics for Chemical Engineers, 4th Edn., Mc Graw Hill International editions, New York, 1991.

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DEPARTMENT OF CHEMICAL ENGINEERING

UNIT – 3 COST ESTIMATION AND ANNUAL REPORTS -SCH1403

UNIT 3: COST ESTIMATION AND ANNUAL REPORTS

Cost estimation is an important part of investment appraisals. They are made for a variety of reasons.

(a) to enable feasibility studies to be carried out.

(b) to enable a manufacturing company to select from alternative investments.

(c) to provide information for planning the appropriation of capital and to enable a contractor to tender for a new project .

1. The first step in the preparation of a cost estimate both for capital investment and manufacturing is to prepare process flow sheet showing all major items of equipment including instrumentation .

The next step is to calculate the size and geometry of the piece of the equipment and to specify the materials of construction .

Then a preliminary cost estimation is made for capital investment based on the purchased cost of all the equipments shown in the flow sheet.

2. For the manufacturing cost of the product it is calculated from energy and material balances and cost of raw materials , utilities , labour and depreciation.

Working Capital Cost (C_{wci})

The working capital cost of the process includes the cost of the following items. In process industries the working capital is likely to be of the order of 10–20% of the value of total capital investment cost.

Working capital examples are :

1. Raw materials, semi-finished products and finished products.
2. Cash at bank for paying monthly operating expenses like salaries, wages etc.
3. Accounts receivable.
4. Taxes payable.
5. Inventories.

START-UP-COSTS

The start-up expenses seldom exceeds 10% of fixed capital investment cost. The duration of start-up may very from 1 month for well known processes to as much as 1 year for new ones.

PROCESS EQUIPMENT COST ESTIMATION

Particularly no literature on the cost of process equipments are available pertaining the Indian conditions. These can be broadly classified into two categories : (1) Fabricated items such as storage tanks, heat exchangers, distillation columns, reactors, evaporators, etc. (2) Proprietary items like pumps, compressors, drives etc. and special equipments like filters, conveyors etc.

Since, inflation is so much and it is not possible to predict the cost of the equipment, a cost index method is introduced.

The Rule of Six-tenths approximate costs can be obtained if the cost of a similar item of different size or capacity is known. A rule of thumb developed over the years known as the rule of six-tenths gives very satisfactory results when only an approximate cost within plus or minus 20% is required.

Cost Index

A cost index is merely number for a given year showing the cost at that time relative to a certain base year. If the cost of any past year is known, the equivalent cost at the present year can be determined.

$$\text{Cost in present year} = (\text{Cost in original}) \times \frac{\text{index value in present year}}{\text{index value in past year}}$$

Equipment Cost-size Relationship

As chemical equipment/plant increases in size and capacity its cost increases. However, there is no linear relationship between capacity and cost. The size cost relationship can be expressed as,

$$\text{Cost of equipment a} = \text{cost of equipment} \cdot \text{b} \left(\frac{\text{capacity of equipment} \cdot \text{a}}{\text{capacity of equipment} \cdot \text{b}}\right)^n$$

n = Cost capacity exponent factor

Generally, the value of the n varies from 0.6 to 1.

In the absence of available data n = 0.6 for equipments n = 0.7 for big plants. n = 0.6 was proposed by William's and it is known as **William's six-tenth's power**.

INTRODUCTION TO THE ACCOUNTING EQUATION

The financial position of a company is measured by the following items:

- Assets (what it owns)
- Liabilities (what it owes to others)
- Owner's Equity (the difference between assets and liabilities)

The accounting equation (or basic accounting equation) offers us a simple way to understand how these three amounts relate to each other.

The accounting equation for a sole proprietorship is:
Assets = Liabilities + Owner's Equity

The accounting equation for a corporation is:
Assets = Liabilities + Stockholders' Equity

Assets are a company's resources—things the company owns.

Examples of assets include cash, accounts receivable, inventory, prepaid insurance, investments, land, buildings, equipment, and goodwill.

Liabilities are a company's obligations—amounts the company owes.

Examples of liabilities include notes or loans payable, accounts payable, salaries and wages payable, interest payable, and income taxes payable (if the company is a regular corporation).

Owner's equity or *stockholders' equity* is the amount left over after liabilities are deducted from assets:

Assets – Liabilities = Owner's (or Stockholders') Equity.

Owner's or stockholders' equity also reports the amounts invested into the company by the owners plus the cumulative net income of the company that has not been withdrawn or distributed to the owners.

If a company keeps accurate records, the accounting equation will always be "in balance," meaning the left side should always equal the right side.

Assets = Liabilities + Equity

4.2 BALANCE SHEET

- The balance sheet is also known as the statement of financial position and it reflects the accounting equation.
- The balance sheet reports a company's assets, liabilities, and owner's (or stockholders') equity at a specific point in time.
- Like the accounting equation, it shows that a company's total amount of assets equals the total amount of liabilities plus owner's (or stockholders') equity.
- The balance sheet presents a company's financial position at the end of a specified date.
- Some describe the balance sheet as a "snapshot" of the company's financial position at a point (a moment or an instant) in time.
- For example, the amounts reported on a balance sheet dated December 31, 2006 reflect that instant when all the transactions *through December 31* have been recorded.

Uses of a Balance Sheet

- Because the balance sheet informs the reader of a company's financial position as of one moment in time, it allows someone—like a creditor—to see what a company *owns* as well as what it *owes* to other parties as of the date indicated in the heading.

- This is a valuable information to the banker who wants to determine whether or not a company qualifies for additional credit or loans.

- Others who would be interested in the balance sheet include current investors, potential investors, company management, suppliers, some customers, competitors, government agencies, and labor unions.

<u>Types of Balance Sheet</u>

The balance sheet is called classified if assets and liabilities are grouped into classifications, and consolidated if it contains all divisions and subsidiaries of the firm.

<u>CLASSIFIED BALANCE SHEET</u>

- Accountants usually prepare classified balance sheets.

- "Classified" means that the balance sheet accounts are presented in distinct groupings, categories, or classifications.

<u>Classifications Of Assets On The Balance Sheet</u>

<u>What are Assets?</u>

- Assets are things that the company owns.

- They are the resources of the company that have been acquired through transactions, and have future economic value that can be measured and expressed in monetary units.

- Assets also include costs paid in advance that have not yet expired, such as prepaid advertising, prepaid insurance, prepaid legal fees, and prepaid rent.

Examples of asset accounts that are reported on a company's balance sheet include:

- Cash
- Petty Cash
- Temporary Investments
- Accounts Receivable
- Inventory
- Supplies
- Prepaid Insurance
- Land
- Land Improvements
- Buildings
- Equipment
- Goodwill
- Bond Issue Costs etc.

Usually these asset accounts will have debit balances. (Assets are shown on the left hand side of a Balance Sheet).

<u>The "Asset Classifications" and their order of appearance on the balance sheet are:</u>

- Current Assets
- Investments
- Property, Plant, and Equipment
- Intangible Assets
- Other Assets

<u>Classifications Of Liabilities On The Balance Sheet</u>

<u>What are liabilities?</u>

- Liabilities are obligations of the company;

- they are amounts owed to creditors for a past transaction and they usually have the word "payable" in their account title.
- Along with owner's equity, liabilities can be thought of as a *source* of the company's assets.
- They can also be thought of as a claim *against* a company's assets.
- For example, a company's balance sheet reports assets of Rs.100,000 and Accounts Payable of Rs.40,000 and owner's equity of Rs.60,000.
- The source of the company's assets are creditors/suppliers for Rs.40,000 and the owners for Rs.60,000.
- The creditors/suppliers have a claim against the company's assets and the owner can claim what remains after the Accounts Payable have been paid.
- Liabilities also include amounts received in advance for future services. Since the amount received (recorded as the asset Cash) has not yet been earned, the company *defers* the reporting of revenues and instead reports a liability such as Unearned Revenues or Customer Deposits.

Examples of liability accounts reported on a company's balance sheet include:

- Notes Payable
- Accounts Payable
- Salaries Payable
- Wages Payable
- Interest Payable
- Other Accrued Expenses Payable
- Income Taxes Payable
- Customer Deposits
- Warranty Liability
- Lawsuits Payable
- Unearned Revenues
- Bonds Payable etc.

These liability accounts will normally have credit balances. (Liabilities are shown on the *right hand side of a Balance Sheet).*

The "liability classifications" and their order of appearance on the balance sheet are:

- Current Liabilities
- Long Term Liabilities etc.

Current vs. Long-term Liabilities

If a company has a loan payable that requires it to make monthly payments for several years, only the *principal* due in *the next twelve months* should be reported on the balance sheet as a current liability. The remaining principal amount should be reported as a long-term liability.

Classifications of Owner's Equity On The Balance Sheet

What is Equity?

- There are actually 2 types of Equity, namely owner's equity and stockholder's equity.

- Owner's Equity—along with liabilities—can be thought of as a source of the company's assets. Owner's equity is sometimes referred to as the book value of the company, because owner's equity is equal to the reported asset amounts *minus* the reported liability amounts.

- Owner's equity may also be referred to as the residual of assets minus liabilities. These references make sense if you think of the basic accounting equation:

  Assets = Liabilities + Owner's Equity

and just rearrange the terms:

Owner's Equity = Assets – Liabilities

- "Owner's Equity" are the words used on the balance sheet when the company is a sole proprietorship.

- If the company is a corporation, the words Stockholders' Equity are used instead of Owner's Equity.

- An example of an owner's equity account is Mary Smith, Capital (where Mary Smith is the owner of the sole proprietorship).

Examples of stockholders' equity accounts include:

- Common Stock
- Preferred Stock
- Paid-in Capital in Excess of Par Value
- Paid-in Capital from Treasury Stock
- Retained Earnings etc.

Both owner's equity and stockholders' equity accounts will normally have credit balances. (Equities are shown alongwith liabilities on the right hand side of a Balance Sheet).

These classifications make the balance sheet more useful.

The following sample balance sheet is a classified balance sheet.

Scott Company Balance Sheet December 31, 2007					
Assets			**Liabilities & Equity**		
Cash	$	9,700	Accounts payable	$	1,200
Supplies		1,200	Notes payable		4,000
Equipment		16,000	Total liabilities		5,200
			Owner Capital		21,700
Total assets	$	26,900	Total liabilities and equity	$	26,900

Categories of a Classified Balance Sheet	
Assets	**Liabilities and Equity**
Current assets	Current liabilities
Noncurrent assets	Noncurrent liabilities
Long-term investments	Capital
Plant assets	
Intangible assets	

Current items are those expected to come due (both collected and owed) within the longer of one year or the company's normal operating cycle.

Snowboarding Components Balance Sheet (Partial) January 31, 2008			
ASSETS			
Current assets			
Cash		$ 6,500	
Short-term investments		2,100	
Accounts receivable		4,400	
Merchandise inventory		27,500	
Prepaid expenses		2,400	
Total current assets			$ 42,900
Long-term investments			
Notes receivable		1,500	
Investments in stocks and bonds		18,000	
Land held for future expansion		48,000	
Total investments			67,500
Plant assets			
Store equipment	$ 33,200		
Less accumulated depreciation	8,000	25,200	
Buildings	1,70,000		
Less accumulated depreciation	45,000	1,25,000	
Land		73,200	
Total plant assets			2,23,400
Intangible assets			10,000
Total assets			$ 3,43,800

Current assets are expected to be sold, collected, or used within one year or the company's operating cycle.

Long-term investments are expected to be held for more than one year or the operating cycle.

Plant assets are tangible long-lived assets used to produce or sell products and services.

Intangible assets are long-term resources used to produce or sell products and services and that lack physical form.

Snowboarding Components Balance Sheet (Partial) January 31, 2008		
LIABILITIES		
Current liabilities		
Accounts payable	$ 15,300	
Wages payable	3,200	
Notes payable	3,000	
Current portion of long-term liabilities	7,500	
Total current liabilities		$ 29,000
Long-term liabilities:		
Notes payable (net of current portion)		1,50,000
Total liabilities		$1,79,000
EQUITY		
T. Hawk, Capital		1,64,800
Total liabilities and equity		$3,43,800

Current liabilities are obligations due within the longer of one year or the company's operating cycle.

Long-term liabilities are obligations **not** due within the longer of one year or the company's operating cycle.

Equity is the owner's claim on the assets.

Snowboarding Components Balance Sheet (Partial) January 31, 2008		
LIABILITIES		
Current liabilities		
Accounts payable	$ 15,300	
Wages payable	3,200	
Notes payable	3,000	
Current portion of long-term liabilities	7,500	
Total current liabilities		$ 29,000
Long-term liabilities:		
Notes payable (net of current portion)		1,50,000
Total liabilities		$1,79,000
EQUITY		
T. Hawk, Capital		1,64,800
Total liabilities and equity		$3,43,800

USEFULNESS OF A BALANCE SHEET

The balance sheet provides information for evaluating:
- Capital structure
- Rates of return
- Analyzing an enterprise's:
  - Liquidity
  - Solvency
  - Financial flexibility

LIMITATIONS OF A BALANCE SHEET

- Most assets and liabilities are stated at historical cost.
- Judgments and estimates are used in determining many of the items.
- The balance sheet does not report items that can not be objectively determined.
- It does not report information regarding off-balance sheet financing.

4.3 INCOME STATEMENT

- The income statement is the financial statement that reports a company's revenues and expenses and the resulting net income.
- While the balance sheet is concerned with *one point* in time, the income statement covers a *time interval* or *period* of time.
- The income statement will explain part of the change in the owner's or stockholders' equity during the time interval between two balance sheets.
- The income statement is sometimes referred to as :
  - Profit and loss statement (P&L),
  - Statement of operations, or
  - Statement of income.

An income statement reports on operating activities. It lists sales (revenues), costs, and expenses over a period of time. The relationship is expressed:

Net Income = Revenues – Expenses

NIKE
Income Statement (in millions)
For the Year Ended May 31, 2000

Revenues	$8,995.1
Costs and Expenses	8,416.0
Net Income	$ 579.1

Scott Company Income Statement For Month Ended December 31, 2007		
Revenues:		
Consulting revenue	$	3,000
Expenses:		
Salaries expense		800
Net income	$	2,200

Net income is the difference between Revenues and Expenses.

Thus, The income statement describes a company's revenues and expenses along with the resulting net income or loss over a period of time due to earnings activities.

Importance of Income Statement

- The income statement is important because it shows the *profitability* of a company during the time interval specified in its heading.
- The period of time that the statement covers is chosen by the business and will vary.
- For example, the heading may state:

  "For the Three Months Ended December 31, 2006" (The period of October 1 through December 31, 2006.)

  The Four Weeks Ended December 27, 2006" (The period of November 29 through December 27, 2006.)

  "The Fiscal Year Ended September 30, 2006." (The period of October 1, 2005 through September 30, 2006.)

It is to be noted that:

→ the income statement shows revenues, expenses, gains, and losses;
→ it does not show cash receipts (money you receive) nor cash disbursements (money you pay out).

People pay attention to the profitability of a company for many reasons.

- For example, if a company was not able to operate profitably—the bottom line of the income statement indicates a net loss—a banker/lender/creditor may be hesitant to extend additional credit to the company.

- On the other hand, a company that has operated profitably—the bottom line of the income statement indicates a net income—demonstrated its ability to use borrowed and invested funds in a successful manner.

A company's ability to operate profitably is important to current lenders and investors potential lenders and investors, company management, competitors, government agencies, labor unions, and others.

Format of the Income Statement

A. Revenues and Gains
   1. Revenues from primary activities
   2. Revenues or income from secondary activities
   3. Gains (e.g., gain on the sale of long-term assets, gain on lawsuits)

B. Expenses and Losses
   1. Expenses involved in primary activities
   2. Expenses from secondary activities
   3. Losses (e.g., loss on the sale of long-term assets, loss on lawsuits)

If the net amount of revenues and gains minus expenses and losses is positive, the bottom line of the profit and loss statement is labeled as net income.

If the net amount (or bottom line) is negative, there is a net loss.

A1. Revenues from primary activities

Often referred to as operating revenues or sales revenues. The primary activities of a retailer are purchasing merchandise and selling the merchandise.

The primary activities of a manufacturer are producing the products and selling them.

A2. Revenues from secondary activities

Often referred to as nonoperating revenues.
These are the amounts a business earns outside of purchasing and selling goods and services.

For example, when a retail business earns interest on some of its idle cash, or earns rent from some vacant space, these revenues result from an activity outside of buying and selling merchandise.

Both the revenues mentioned above are reported on the profit and loss statement during the period when they are earned, not when the cash is collected.

A3. Gains

Refers to the gain on the sale of long-term assets, or lawsuits result from a transaction that is outside of the primary activities of most businesses.

A gain is reported on the income statement as the net of two amounts: the proceeds received from the sale of a long-term asset minus the amount listed for that item on the company's books (book value).

A gain occurs when the proceeds are more than the book value.

Consider this example:

Assume that a clothing retailer decides to dispose of the company's car and sells it for Rs.6,000.

The Rs.6,000 received for the car will not be included with sales revenues since the account ‘Sales’ is used only for the sale of *merchandise*.

Since this retailer is not in the business of buying and selling cars, the sale of the car is outside of the retailer's primary activities.

Over the years, the cost of the car was being depreciated on the company's accounting records and as a result, the money received for the car (Rs.6,000) was greater than the net amount shown for the car on the accounting records (Rs.3,500).

This means that the company must report a *gain* equal to the amount of the difference—in this case, the gain is reported as Rs.2,500.

This gain should not be reported as sales revenues, nor should it be shown as part of the merchandiser's primary activities.

Instead, the gain will appear in a section on the income statement labeled as "nonoperating gains" or "other income".

The gain is reported in the period when the disposal occurred.

B1. Expenses involved in primary activities

These are expenses that are incurred in order to earn normal operating revenues.

e.g., wages earned by employees, employee bonuses and vacations, utilities, and sales commissions.

B2. Expenses from secondary activities

These are referred to as non-operating expenses.

For example, interest expense is a nonoperating expense because it involves the finance function of the business, rather than the primary activities of buying/producing and selling.

B3. Losses

Refers to the loss from the sale of long-term assets, or the loss on lawsuits result from a transaction that is outside of a business's primary activities.

A loss is reported as the net of two amounts: the amount listed for the item on the company's books (book value) minus the proceeds received from the sale.

A loss occurs when the proceeds are less than the book value.

Let's assume that a clothing retailer decides to dispose of the company's car.

The proceeds from the disposal are Rs.2,800.

This is *less* than the Rs.3,500 amount shown in the company's accounting records.

Since this retailer is not in the business of buying and selling cars (the sale of the car is outside of the operating activities of buying and selling clothing), the money received for the car will not be included in sales revenues, and the loss experienced on the sale of the car (Rs.700) will not be included in operating expenses.

Instead, the Rs.700 loss will appear in a section on the income statement labeled "nonoperating gains or losses" or "other income or losses".

The loss is reported in the time period when the disposal occurs.

Thus, we can understand that the income statement or profit and loss statement shows revenues, expenses, gains, and losses and

It does not show cash receipts and cash disbursements.

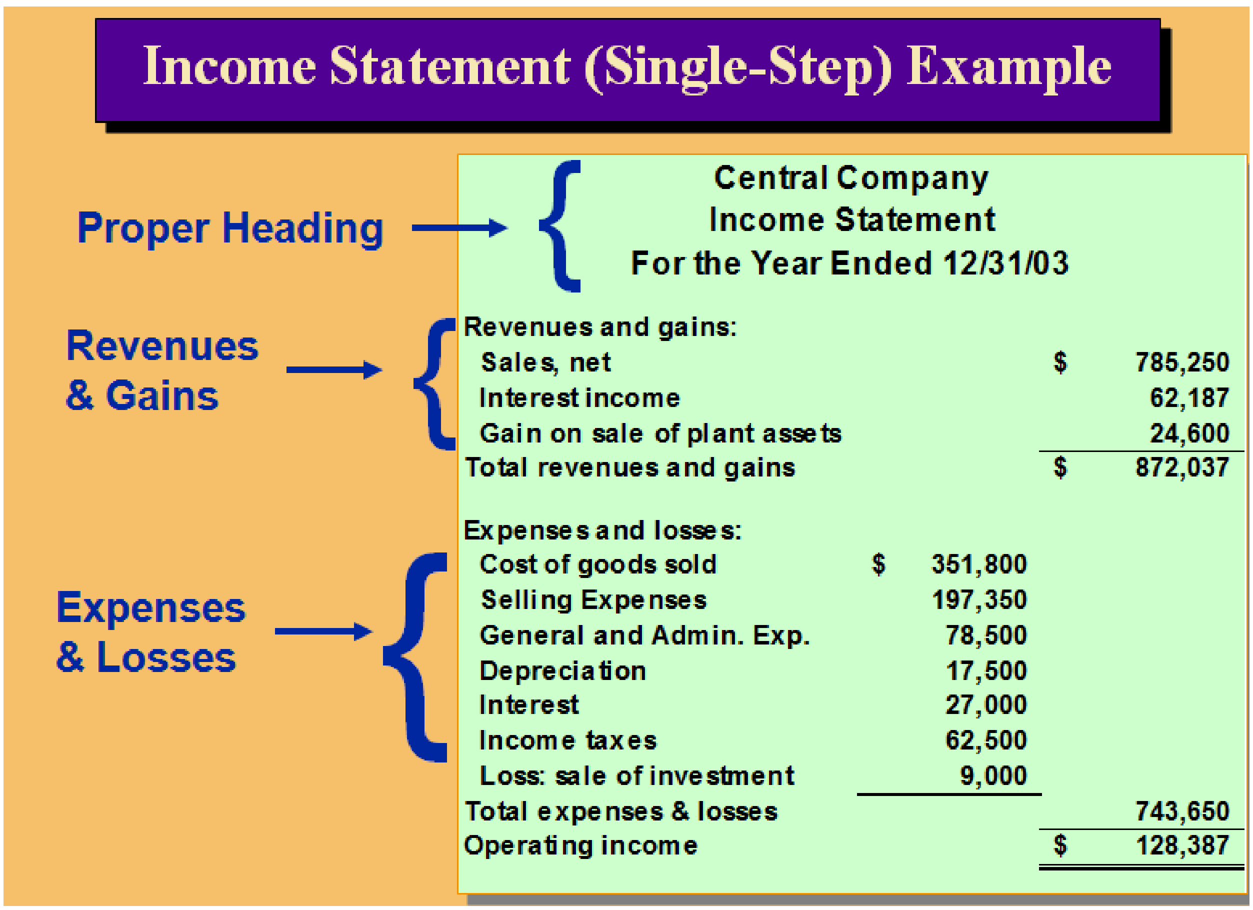
Types of Income Statement Formats

1. Single-Step
2. Multiple-Step

An income statement can be prepared in either a multiple-step or single-step format. The single-step format is simpler. The multiple-step format provides more detailed information.

The Single Step Income Statement

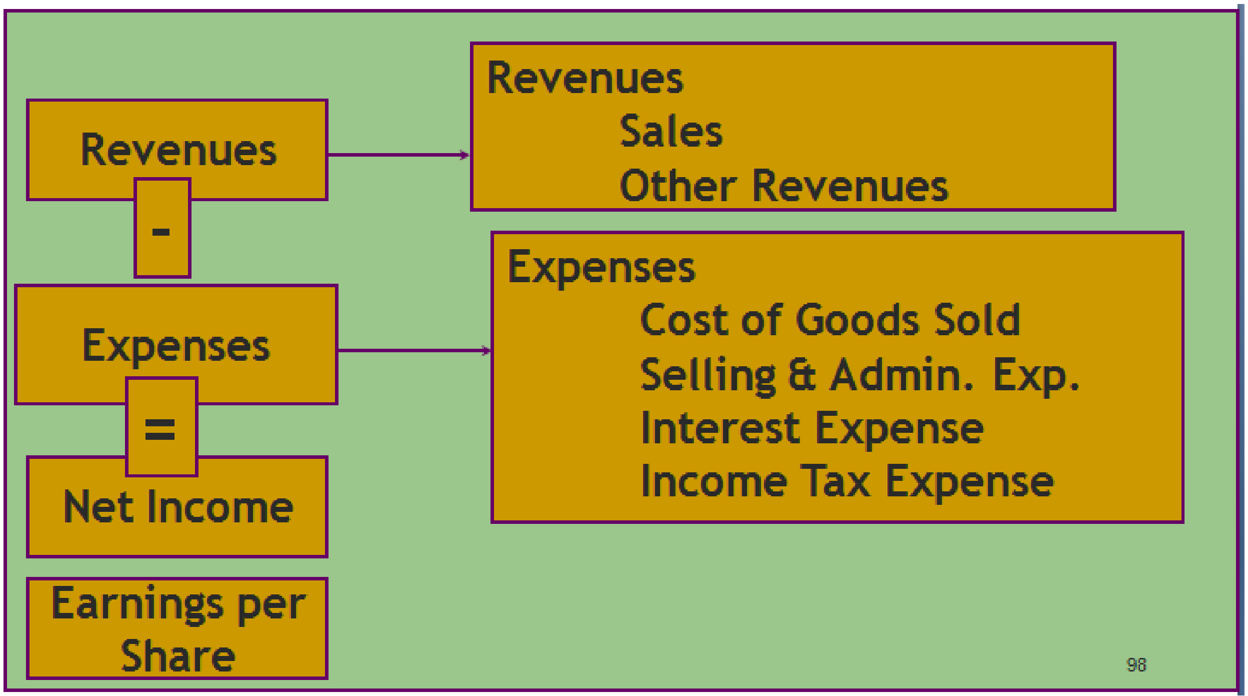
- This statement presents information in broad categories.
- Major sections are Revenues and Expenses.
- The Earnings per Share amount is shown at the bottom of the statement.
- There is no distinction between operating and non-operating activities.



Central Company
Income Statement
For the Year Ended 12/31/03

Revenues and gains:				
Sales, net			$	785,250
Interest income				62,187
Gain on sale of plant assets				24,600
Total revenues and gains			$	872,037
Expenses and losses:				
Cost of goods sold	$	351,800		
Selling Expenses		197,350		
General and Admin. Exp.		78,500		
Depreciation		17,500		
Interest		27,000		
Income taxes		62,500		
Loss: sale of investment		9,000		
Total expenses & losses				743,650
Operating income			$	128,387

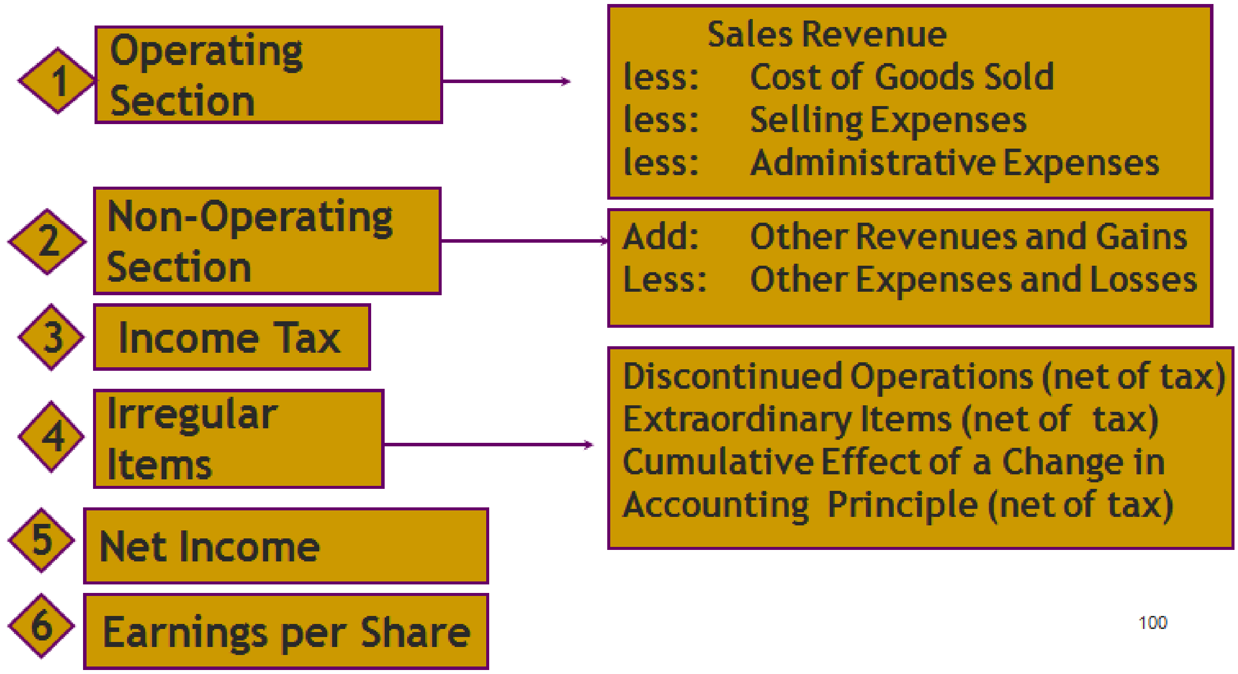
Format of a single step Income Statement



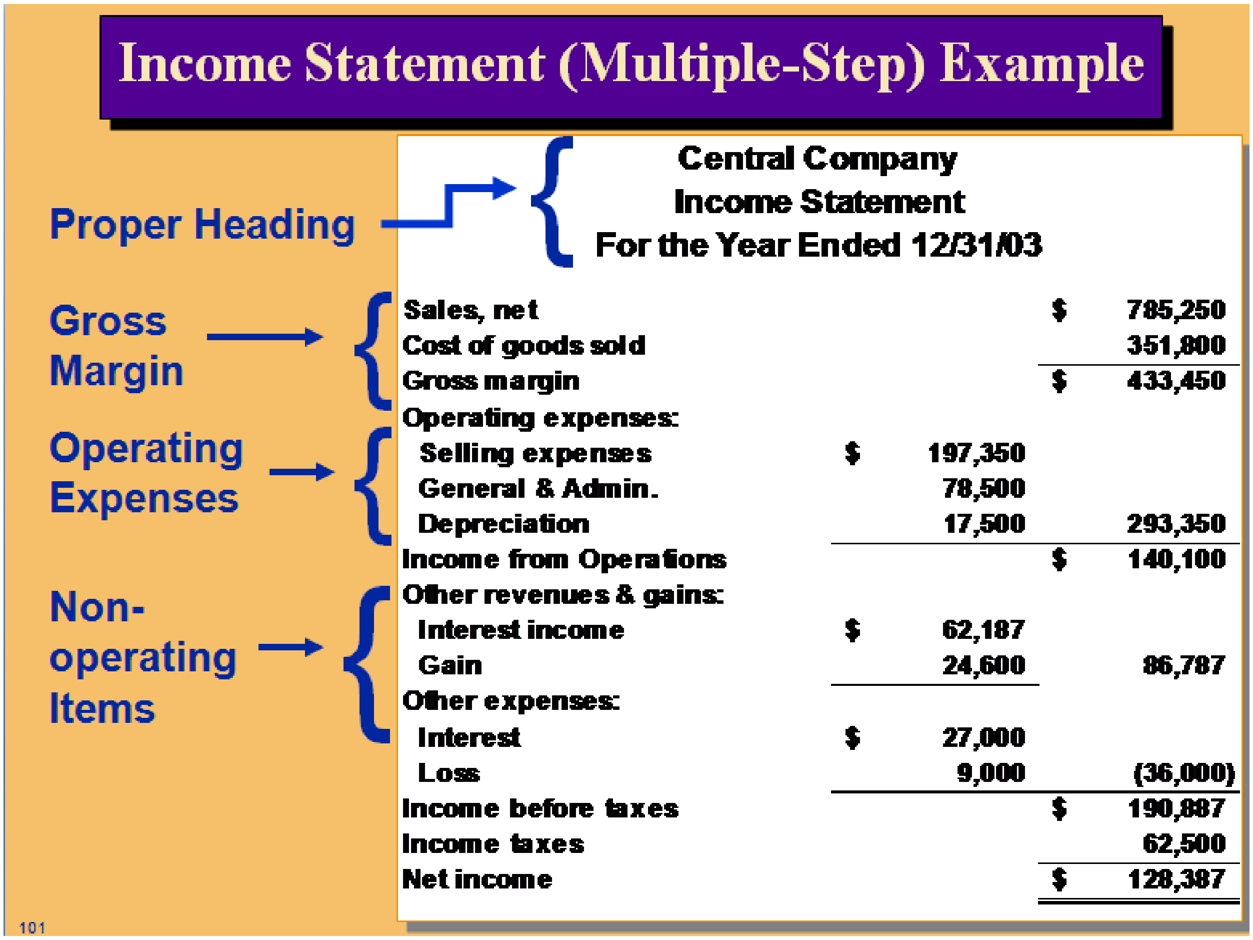
The Multiple Step Income Statement

- The presentation divides information into major sections on the statement.
- The statement distinguishes operating from non-operating activities.
- Continuing operations are shown separately from irregular items.
- The income tax effects are shown separately as well.

Format of a Multi Step Statements



Multiple-Step Income Statement Sample:



<u>**A detailed view of single-step and multiple-step income statements**</u>

- A single-step income statement format uses only one subtraction to arrive at net income.

- Net Income = (Revenues + Gains) – (Expenses + Losses)

An extremely condensed income statement in the single-step format would look like this:

Sample Products Co.
Income Statement
For the Five Months Ended May 31, 2007

Revenues & Gains	$108,000
Expenses & Losses	90,000
Net Income	$ 18,000

Single-Step Income Statement Sample

Barton Company
Income Statement
For Year Ended December 31, 2008

Net sales		$ 317,500
Cost of goods sold	$ 233,200	
Operating expenses	71,400	
Total expense	304,600	
Net income		$ 12,900

The heading of the income statement conveys critical information.
The name of the company appears first, followed by the title "Income Statement."
The third line tells the reader the time interval reported on the profit and loss statement.
Since income statements can be prepared for any period of time, it *must be made to* inform the reader of the *precise* period of time being covered.
For example, an income statement may cover any one of the following time periods: "Year Ended May 31," "Five Months Ended May 31," "Quarter Ended May 31," "Month Ended May 31, or "Five Weeks Ended May 31".

A sample income statement in the single-step format would look like this:

Sample Products Co. Income Statement For the Five Months Ended May 31, 2007	
Revenues & Gains	
Sales Revenues	$100,000
Interest Revenues	5,000
Gain on Sale of Assets	3,000
Total Revenue & Gains	108,000
Expenses & Losses	
Cost of Goods Sold	75,000
Commissions Expense	5,000
Office Supplies Expense	3,500
Office Equipment Expense	2,500
Advertising Expense	2,000
Interest Expense	500
Loss from Lawsuit	1,500
Total Expenses & Losses	90,000
Net Income	$ 18,000

MULTIPLE STEP INCOME STATEMENT

- The multiple-step income statement uses *multiple* subtractions in computing the net income shown on the bottom line.

- The multiple-step profit and loss statement segregates the operating revenues and operating expenses from the nonoperating revenues, nonoperating expenses, gains, and losses.

- The multiple-step income statement also shows the gross profit (net sales minus the cost of goods sold).

  Here is a sample income statement in the multiple-step format:

Sample Products Co.
Income Statement
For the Five Months Ended May 31, 2007

Sales		$100,000
Cost of Goods Sold		75,000
Gross Profit		25,000
Operating Expenses		
Selling Expenses		
Advertising Expense	2,000	
Commissions Expense	5,000	7,000
Administrative Expenses		
Office Supplies Expense	3,500	
Office Equipment Expense	2,500	6,000
Total Operating Expenses		13,000
Operating Income		12,000
Non-Operating or Other		
Interest Revenues		5,000
Gain on Sale of Investments		3,000
Interest Expense		(500)
Loss from Lawsuit		(1,500)
Total Non-Operating		6,000
Net Income		$ 18,000

Three benefits to using a multiple-step income statement instead of a single-step income statement:

1. The multiple-step income statement clearly states the gross profit amount.

- Many readers of financial statements monitor a company's gross margin (gross profit as a percentage of net sales).

- Readers may compare a company's gross margin to its past gross margins and to the gross margins of the industry.

2.The multiple-step income statement presents the subtotal operating income,
which indicates the profit earned from the company's primary activities of buying and selling merchandise.

3.The bottom line of a multiple-step income statement reports the net amount for all the items on the income statement.

If the net amount is positive, it is labeled as net income.
If the net amount is negative, it is labeled as net loss.

Income statements (whether single-step or multiple-step) report *nearly all* revenues, expenses, gains, and losses.

- Sometimes rare or extraordinary events will occur during the income statement's time interval along with the normally recurring events.

- It is helpful to the reader of the statement if these unique items are segregated into a special section near the bottom of either the single-step or multiple-step income statement.

- These unique or rare items are:
  1. Discontinued Operations
  2. Extraordinary Items

1. Discontinued operations

It pertains to the elimination of a significant part of a company's business, such as the sale of entire division of the company.

2. Extraordinary items

It includes things that are unusual in nature and infrequent in occurrence.
A loss due to an earthquake would certainly be extraordinary.

Note that the two unique items are shown near the bottom of the income statement.

- The notes (or footnotes) to the income statement and to the other financial statements are considered to be part of the financial statements.

  The notes inform the readers about such things as significant accounting policies, commitments made by the company, and potential liabilities and potential losses.

  The notes contain information that is critical to properly understanding and analyzing a company's financial statements.

  It is common for the notes to the financial statements of large companies to be 10-20 pages in length.

Usefulness of Income Statement

Evaluate the past performance of the enterprise.
Provide a basis for predicting future performance.
Help assess the risk or uncertainty of achieving future cash flows.

Limitations of the Income Statement

Items that cannot be measured reliably are not reported in the income statement.
Income numbers are affected by the accounting methods employed.
Income measurement involves judgment.

4.4 FINANCIAL RATIOS

Definition

Financial ratios are tools for interpreting financial statements to provide a basis for valuing securities and appraising financial and management performance.

Financial Ratios represent an attempt to standardize financial information in order to facilitate meaningful comparisons over time (time series) and between firms or firm to industry (cross section).

Uses of Financial Ratios

Financial Ratios are used as a relative measure that facilitates the evaluation of efficiency or condition of a particular aspect of a firm's operations and status

Ratio Analysis involves methods of calculating and interpreting financial ratios in order to assess a firm's performance and status

Example

Year End	(1) Current Assets/(2) Current Liab.	(1)/(2) Current Ratio
1994	Rs.550,000/Rs.500,000	1.10
1995	Rs.550,000/Rs.600,000	0.92

Groups of Financial Ratios

I. Liquidity
II. Activity
III. Debt
IV. Profitability

I. Liquidity Ratios

Liquidity refers to the solvency of the firm's overall financial position, i.e. a "liquid firm" is one that can easily meet its short-term obligations as they come due.

A second meaning includes the concept of converting an asset into cash with little or no loss in value.

Three Important Liquidity Measures

1. Net Working Capital (NWC)
   NWC = Current Assets - Current Liabilities

2. Current Ratio (CR)

$$CR = \frac{\text{Current Assets}}{\text{Current Liabilities}}$$

3. Quick (Acid-Test) Ratio (QR)

$$QR = \frac{\text{Current Assets - Inventory}}{\text{Current Liabilities}}$$

II. ***Activity Ratios:***

Activity is a more sophisticated analysis of a firm's liquidity, evaluating the speed with which certain accounts are converted into sales or cash; also measures a firm's efficiency

Five Important Activity Measures

1. Inventory Turnover (IT)
2. Average Collection Period (ACP)
3. Average Payment Period (APP)
4. Fixed Asset Turnover (FAT)
5. Total Asset Turnover (TAT)

$$IT = \frac{\text{Cost of Goods Sold}}{\text{Inventory}}$$

$$ACP = \frac{\text{Accounts Receivable}}{\text{Annual Sales}/365}$$

$$APP = \frac{\text{Accounts Payable}}{\text{Annual Purchases}/365}$$

$$FAT = \frac{\text{Sales}}{\text{Net Fixed Assets}}$$

$$TAT = \frac{\text{Sales}}{\text{Total Assets}}$$

III. ***Debt Ratios:***

Debt is a true "double-edged" sword as it allows for the generation of profits with the use of other people's (creditors) money, but creates claims on earnings with a higher priority than those of the firm's owners.

Financial Leverage is a term used to describe the magnification of risk and return resulting from the use of fixed-cost financing such as debt and preferred stock.

Measures of Debt

There are Two General Types of Debt Measures
Degree of Indebtedness
Ability to Service Debts

Four Important Debt Measures

1. Debt Ratio (DR)
2. Debt-Equity Ratio (DER)
3. Times Interest Earned Ratio (TIE)
4. Fixed Payment Coverage Ratio (FPC)

IV. ***Profitability Ratios:***

Profitability Measures assess the firm's ability to operate efficiently and are of concern to owners, creditors, and management

A Common-Size Income Statement, which expresses each income statement item as a percentage of sales, allows for easy evaluation of the firm's profitability relative to sales.

Seven Basic Profitability Measures

1. Gross Profit Margin (GPM)
2. Operating Profit Margin (OPM)
3. Net Profit Margin (NPM)
4. Return on Total Assets (ROA)
5. Return On Equity (ROE)
6. Earnings Per Share (EPS)
7. Price/Earnings (P/E) Ratio

SUMMARY OF FINANCIAL RATIOS

- Ratio analysis is used as a major tool for financial analysis :

– For a meaningful study of information contained in the financial statements
– Ascertaining the overall financial position of a Business Organization
– Ratios are calculated from the past financial statements
– Ratios could also be worked out based on the projected financial statements of the same firm

- Easiest way of evaluating the performance of a firm is by comparing past and present ratios
- Used to judge operational efficiency, financial health, solvency or soundness
- To find out the liquidity position
- Major categories of ratios
  - Liquidity ratios
  - Debt or Leverage or solvency ratios
  - Activity Ratios
  - Profitability Ratios

Thus, Ratios help to:

- Evaluate performance
- Structure analysis
- Show the connection between activities and performance

Benchmark with

- Past for the company
- Industry

Ratios adjust for size differences

Limitations of Ratio Analysis

- A firm's industry category is often difficult to identify
- Published industry averages are only guidelines
- Accounting practices differ across firms
- Sometimes difficult to interpret deviations in ratios
- Industry ratios may not be desirable targets
- Seasonality affects ratios

Text Books

1. Schweyer H. E., Process Engineering Economics, Mc Graw Hill, 1969.

2. Max. S. Peters And Klaus D. Timmerhaus, Plant Design and Economics for Chemical Engineers, 4th Edn., Mc Graw Hill International editions, New York, 1991.

SCHOOL OF BIO AND CHEMICAL ENGINEERING

DEPARTMENT OF CHEMICAL ENGINEERING

UNIT – 4 ECONOMICS OF INVESTMENT ALTERNATIVE -SCH1403

UNIT 4: ECONOMICS OF INVESTMENT ALTERNATIVE

Estimation of project profitability

Profitability is the primary goal of any business activity. If profitability is not maintained, growth and even survival is not possible over the long run. Evaluation of profitability is therefore a main function of management. Profitability evaluation techniques are as follows :

1. Rate of return on investment.
2. Payout time.
3. Discounted cash flow method.
4. Net present value method.

4.1.1 Rate of Return on Investment

The rate of return on the total capital investment is calculated on the basis of average net profit.

$$\text{Rate of return} : r = \frac{\text{Average net profit}}{\text{Total capital}} \times 100$$

$$\text{Average net profit } (A_{NP}) = \text{Gross profit } (A_{GP}) - \text{Income tax } (A_{IT})$$

$$\text{Gross profit } (A_{GP}) = \text{Annual sales} - \text{Total expenditure}$$

PROBLEM

1. A project expected to have cash flow for the five years as follows after all expenses and taxes. The initial fixed capital investment is 1000000 and the working capital investment is 15% of the fixed capital investment.

Time (Years)	Cashflow (Rs.)
0 – 1	200000
1 – 2	270000
2 – 3	330000
3 – 4	400000
1 – 5	475000

Find the rate of return using straight line depreciation.

Solution : Straight depreciation $= d = \frac{V - V_S}{n} = \frac{1000000 - 0}{5} = 200000.$

Year	Cashflow	Depreciation	Net profit (cashflow – Depreciation (200000 – 400000)
1	200000	200000	0
2	270000	200000	70000
3	330000	200000	130000
4	400000	200000	200000
5	475000	200000	275000
			Total net profit = 675000

$$\text{Average net profit} = \frac{675000}{5}$$

$$= 135000$$

$$\text{Total capital investment} = \text{fixed capital} + \text{working capital}$$

$$= 10000000 + 0.15 \times 1000000$$

$$= 1150000$$

$$\therefore \quad \text{Rate of return} = \frac{135000}{1150000} \times 100$$

$$= 11.73\%$$

4.1.2 Payout Time

Payout time is the time required to get back the original investment in the form of cashflow.

PROBLEMS

2. Find out the payout time for the part I.

Solution :

Time	Fixed capital investment	Cashflow	Leftout investment
0	1000000	–	– 1000000
1	1000000	200000	– 1000000 + 200000 = – 800000
2	800000	270000	– 800000 + 270000 = – 530000
3	530000	330000	– 530000 + 330000 = – 200000
	200000	400000	– 200000 + 400000 = 200000

The payout time is between 3 to 4 years.

3. Find the payout time for problem I, if interest is allowed on the investment at 10% a year.

Solution :

Time	Investment (fixed capital)	Interest 10%	Cashflow	Cash flow after interest	Leftout investment
0	1000000	–	–	–	– 1000000
1	1000000	100000	200000	100000	– 900000
2	900000	90000	270000	180000	– 720000
3	720000	72000	330000	258000	– 462000
4	462000	46200	400000	353800	– 462000
5	108200	10820	475000	464180	– 108200
					+ 355980

∴ The payout time is between 4 to 5 years.

4. By investing 96000 in automatic machine, number of operations are reduced. Saving in labour is estimated to be Rs. 4/hr. Find the rate of return. The salvage value after 8 years is estimated to be Rs. 16000. The unit works for 24 hrs and 300 days/year.

Solution : Data : $V = 96000,\ V_S = 16000,\ n = 8$ years, Labour rate = Rs. 4.00/hr

$$\text{No. of factory working hrs} = 300 \times 24 = 7200 \text{ hr}$$

$$\text{Saving in labour cost per year} = 7200 \times 4 = \text{Rs. } 28800$$

$$\text{Rate of return} = \frac{\text{Average net profit}}{\text{Total investment}} \times 100$$

$$= \frac{28800}{96000 - 16000} \times 100 = 36\%$$

$$\text{Rate of return} = 36\%$$

5. A mining company estimates that it can increase its sales if it procures a new machine to cut more. The installed cost of the new machine is Rs. 3000000. The extra expenditure per year is Rs. 1750000 and extra income is 75% of installed cost per year. The salvage value after 12 years is expected to be 12.5% of installed cost. What is rate of return ?

Solution : Data : Installed cost = Rs. 3000000, n = 12 years

Extra expenditure = Rs. 1750000

$$\text{Extra income} = 0.75 \times 3000000 = 2250000$$

$$\text{Net profit} = 2250000 - 1750000 = 500000 \text{ per year}$$

$$\text{Rate of return} = \frac{\text{Average net profit}}{\text{Total investment}} \times 100$$

$$\text{Salvage value} = 2000000 \times 0.125$$

$$= 375000$$

$$\therefore \quad \text{Actual investment} = 3000000 - 375000$$

$$= \text{Rs. } 2625000$$

$$\text{Rate of return} = \frac{500000}{2625000} \times 100$$

$$= 19.04\%$$

4.1.3 Discounted Cash Flow Method; Evaluating Rate of Return

In this method of evaluating profitability, time value of money is taken into account. All cash flows over the service life of the project are included and they are adjusted to the time of original investment using the compound interest procedure. A trial and error calculation is necessary to find the rate of return at which all the yearly cash flows equal the initial investments less the salvage value and working capital.

$$S = P(1+i)^n;$$

Here r is used instead of i.

$$r = \text{rate of return}$$

$$S = P(1+r)^n$$

$$\therefore \quad P = \frac{S}{(1+r)^n} \text{ where S is the cashflow.}$$

Present worth of the discounted flow = (Total capital investment)

– (Present worth of the working capital)

$$\therefore \quad P_{CF} = C_{TCI} - P_{WCI}$$

6. Find out the discounted cash flow rate of return for the problem I.

Solution : $\therefore$

$$P_{CF} = C_{TCI} - P_{WCI}$$

$$C_{TCI} = 1000000 + 0.15 \times 1000000$$

$$= \text{Rs. } 1150000$$

$$C_{WCI} = \text{Rs. } 150000$$

Present worth of working capital,

$$P_{WCI} = \frac{150000}{(1+r)^5}$$

Present worth of the cashflow =

$$P_{CF} = \frac{200000}{(1+r)^1} + \frac{270000}{(1+r)^2} + \frac{330000}{(1+r)^3} + \frac{400000}{(1+r)^4} + \frac{475000}{(1+r)^5}$$

$$\therefore \quad P_{CF} = C_{TCI} - P_{WCI}$$

$$\therefore \quad \frac{200000}{(1+r)^1} + \frac{270000}{(1+r)^2} + \frac{330000}{(1+r)^3} + \frac{400000}{(1+r)^4} + \frac{475000}{(1+r)^5} = 1150000 + \frac{150000}{(1+r)^5}.$$

Since r value is not known trial and error method should be adopted.

By trial and error method r = 0.143.

$$L.H.S. = R.H.S.$$

$$\therefore \quad r = 0.143 = 14.3\%$$

∴ Discounted cash flow rate of return = 14.3%.

4.1.4 Net Present Value Method

This method is a variation of D_{CF} method and it avoids trial and error computation. The net present value is expressed as the difference between present value of annual cash flow and the initial total capital investment.

$$N_{PV} = P_{CF} + P_{WCI} - C_{TCI}$$

7. For problem I find out the net present value and taking r = 10%.

Solution :

$$N_{PV} = \frac{200000}{(1+0.1)^1} + \frac{270000}{(1+0.1)^2} + \frac{330000}{(1+0.1)^3} + \frac{400000}{(1+0.1)^4} + \frac{475000}{(1+0.1)^5} + \frac{150000}{(1+0.1)^5} - 1150000$$

$$= 1221035 - 1056861$$

$$= \text{Rs. } 164174$$

Break Even Point

- BEP gives the idea whether a company is running under loss or profit.
- At BEP it is assumed that there is no loss or profit.
- Break even analysis revolves around BEP which means at a particular point company just breaks even without getting any profit or loss.

- BEP depends upon the costs.Variable costs (Depends on rate of production)
- Fixed cost or non variable cost (independent of rate of production)

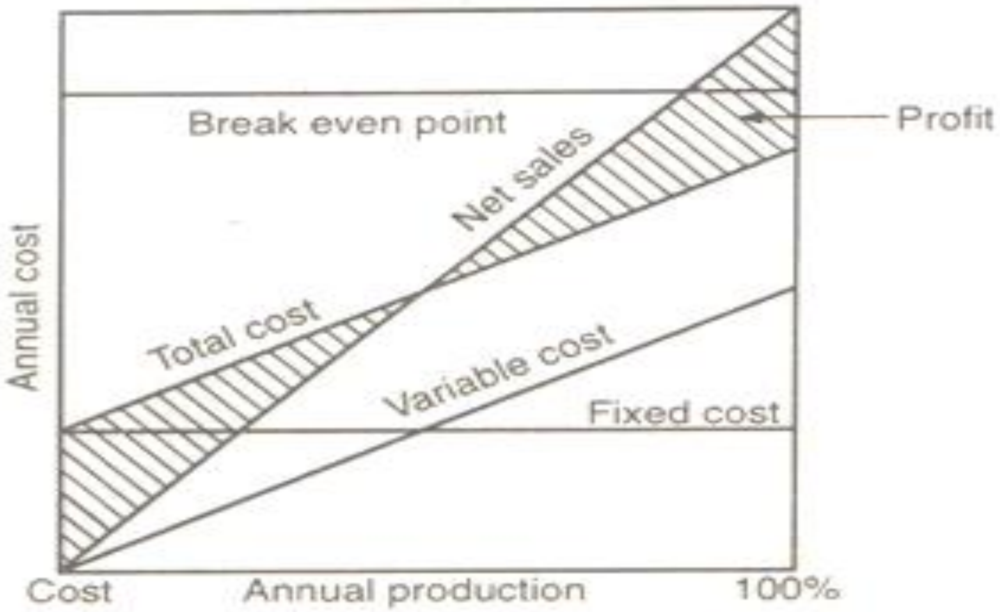


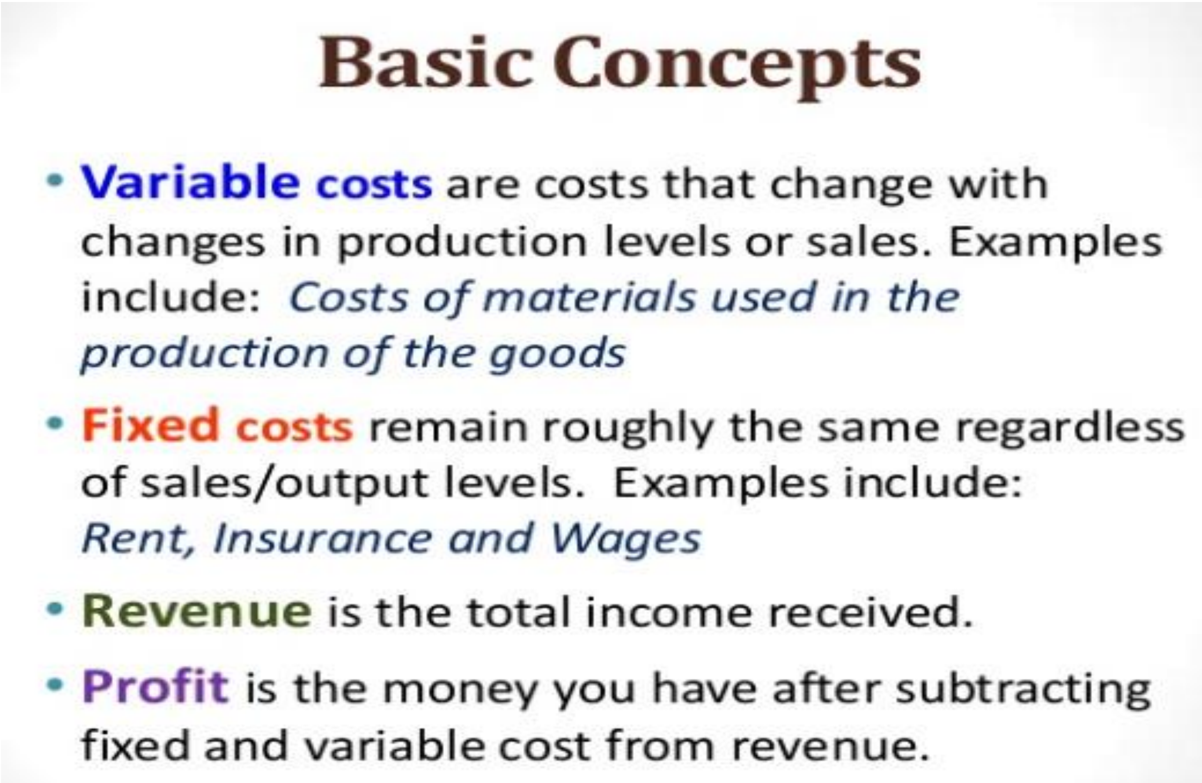
Fig. : Economic-production chart or Break-even chart

Definition

- Breakeven analysis is also known as cost-volume profit analysis
- Breakeven analysis is the study of the relationship between selling prices, sales volumes, fixed costs, variable costs and profits at various levels of activity

Cost Volume Profit analysis

- **CVP** analysis studies the relationship between expenses, revenues and net income.
- The aim is to establish what will happen to financial results if a specified level of activity or volume fluctuates.



Relation between costs and production:

Assumptions for an equation for finding break-even point if variable cost is linearly dependent on production are:

- Fixed cost is independent of production
- There is no income other than that from operations
- All units produced are sold

All units are sold at the same price per unit

REFERENCE BOOKS

1. Max. S,Peters and Klaus. D Timmerhaus., Plant Design and Economics for Chemical Engineers, 5th Edition, Mc Graw Hill International Editions, New York, 2004.
2. Schweyer. H.E.,Process Engineering Economics, 1st Edition, Mc Graw Hill, 1955.
3. Jelen F.C and Black J.H.,Cost and Optimization Engineering,3rd Edition, McGraw Hill, 1992.
4. James.R.Couper.,Process Engineering Economics, 1st Edition ,Marcel Dekker Inc, New York,2003.

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DEPARTMENT OF CHEMICAL ENGINEERING

UNIT-5 –ECONOMIC BALANCE
SCH1403

The Economic Balance

An engineering cost analysis can be used to find either a minimum total cost or a maximum benefit, such as a maximum profit for a venture. Such a cost analysis is frequently called an economic balance because it involves the balancing of economic factors to determine an optimum design or optimum operating conditions. In engineering work, correct economic analyses of both designs and operations are essential skills. An understanding of the underlying concepts of such analyses is needed for the solution of many problems and forms the basis for decisions; these can be on-the-spot or detailed investigations.

In the early days of chemical engineering, the process economics course was a course in economic balance. In recent times, the economic balance part of a process economics course has been referred to as simple optimization of process equipment. Peters and Timmerhaus [1] call this topic optimum design.

The goal is to attain the "best" situation by applying simple optimum-seeking techniques. The major challenge is to recognize the existence of an economic balance problem and then to formulate the problem for a solution. An economic balance then is a study of all costs, expenses, revenues, and savings that pertain to an operation or equipment size.

5.1 GENERAL PROCEDURE

The initial step in the development of an economic balance is to determine what variable(s) is to be optimized. Before we begin discussing the methodologies, there is terminology that needs to be defined.

The term cost refers to a one-time purchased price of capital equipment, such as a heat exchanger. If an item is a recurring "cost," it is called an expense, such as utilities or maintenance expense. Although this terminology is different from that found in some texts, at least it is consistent with the material in this text.

For the simplest case, all costs and expenses are related to an arbitrarily selected controllable variable. This variable might be the number of pounds of product manufactured, the area of a heat exchanger, the number of evaporator effects, the internal rate of return, etc. Those items in the cost analysis that increase with an increase in the controllable variable are balanced against those items that decrease as the controllable variable increases. Any costs or expenses that are constant, that is, independent of the controllable variable, do not need to be included in the analysis since they do not affect the final result of the analysis and only complicate the mathematics. Therefore, in an economic balance, the analysis is not limited to the sum of the fixed and variable expenses, although most examples are presented in this manner.

5.2 PRACTICAL CONSIDERATIONS

The various methods for determining optimum conditions described in this chapter are theoretical and they meet the required conditions for an optimum case. Often the solution may lead to a result for which industrial equipment is not available in the optimum size. Some equipment is manufactured in discrete sizes. For example, in the case of an optimum pipe size, a mathematical or graphical result may indicate that a pipe diameter of 2.67 in is optimum. If the fluid to be pumped is compatible with steel and Schedule 40 pipe is suitable, commercially available pipe sizes are $2\frac{1}{2}$ in (ID = 2.469 in) or 3 in (ID = 3.069 in) sizes. The engineer would be confronted with making a choice. The smaller diameter pipe would lead to higher pumping costs and lower pipe costs while the larger diameter pipe would have lower pumping costs but slightly higher pipe costs. Now we encounter an "engineering trade-off" that the engineer must resolve. In the author's experience, the 3 in pipe would be recommended since this allows for any potential errors in the theoretical calculations but also provides for increased production that will surely occur once the equipment is put in operation. Further, the company may have a standards program for piping such that only nominal 1, $1\frac{1}{2}$, 2, 3 in, etc. pipe will be stocked. These are practical considerations that the engineer must recognize.

Some equipment is available or can be manufactured in a continuum of sizes. In general, it is often cheaper to accept a slightly larger size rather than incur the expense of a tightly designed equipment item. For example, results of calculations indicate that a 2250 ft^2 is required for specific conditions but a fabricator has off-the-shelf exchangers of 2000 or 2500 ft^2. It is frequently cheaper to purchase the 2500 ft^2 unit rather than have a 2250 ft^2 exchanger designed and manufactured. Further, the larger unit permits more operating flexibility. An analysis of optimum conditions can only give approximate results but do serve the purpose of obtaining a minimum cost.

There are other factors that might affect an engineering recommendation, for example, the physical properties of a material. A material may be too viscous under the proposed operating conditions and a theoretical optimum may not attainable. Intangible features may also enter into the analysis like uncertain design or processing conditions or perhaps uncertain product selling price that might affect the optimization. Therefore, the economic analysis precludes the engineer from exercising extreme accuracy.

5.3 GENERAL PROCEDURE FOR FINDING OPTIMUM CONDITIONS

The first step is to determine what variable is to be optimized, and then it is necessary to determine what relationships affect the variable. Equipment designed to provide a specific duty or service should be sized so that the total annual expense, that is, the sum of the annual fixed and variable expenses, is a minimum. This ideal must be consistent with operating limitations and provide some flexibility. The essential elements of an economic balance are:

- Fixed and variable operating expenses
- An allowance for depreciation
- A term for an acceptable return on an investment

Prior to the 1960s, economic balances were performed without a term for the return on invested capital. Happel [6] identified the need to include such a term because funds for a proposed venture would have to be obtained from external sources or internally generated funds. In either case, the return term represents an expense to the corporation no matter from where the funds are obtained.

Two kinds of expenses are accounted for in an economic balance, namely, variable and fixed operating expenses.

5.3.1 Variable Operating Expenses

These expenses are recurring expenses. Table 5.1 is a list of those operating expenses that affect optimization of equipment size. Only those expenses that change with equipment size need be included in the analysis. Engineers will frequently complicate the mathematics by including variables that are of little or no consequence. A general rule is that as a first attempt, keep the analysis simple, and if more variables are thought to be required, then include them later.

In the case of equipment optimization, the major operating expenses are the utilities. Examples are

- Pipe size—electricity required to pump fluids
- Insulation thickness—the value of the condensed steam
- Multiple-effect evaporators—the cost of steam required

Other operating expenses that may be included are maintenance and waste disposal expense, and in the case of a chemical reactor, chemical raw materials may be a factor.

Table 5.2 is a guide for maintenance expenses.

TABLE 5.1 Operating Expenses in Equipment Optimization

Item	Comments

Raw materials	Generally only enters if the equipment is a reactor
Direct operating labor	Seldom affects the optimization
Supervision	Seldom affects the optimization
Maintenance	Can be a factor; usually expressed as a fraction of the fixed capital investment, (0.05 – 0.10) FCI
Plant supplies	Usually negligible
Utilities:	Usual variables
Steam	
Electricity	
Water	
Fuel	
Property taxes	Generally expressed as a fraction of the fixed capital investment, (0.02 – 0.04) FCI
Insurance	Generally expressed as a fraction of the fixed capital investment, (0.01 – 0.02) FCI

TABLE 5.2 Annual Maintenance Expense: Percentage of the Fixed Capital Investment

Type of equipment	Maintenance, %
Simple, light use	2 – 5
Average	5 – 8
Heavy or complicated	8 – 10

5.3.2 Fixed Operating Expenses

These expenses include depreciation and plant indirect expenses such as property taxes, insurance, fire protection. All these items are expressed as a fraction of the equipment cost or the fixed capital investment. The fixed capital investment represents the total money spent to purchase equipment and place it in operation. It is customary to include the return on investment on an after-tax basis using the federal rate but occasionally state and local taxes may also be included in the expression for the fixed expenses. Table 5.3 is a checklist of these items. To simplify the mathematics, annual expenses are considered to be constant, therefore; depreciation is calculated on a straight-line basis.

To estimate the total fixed capital investment, the Hand, Wroth, or Brown methods suffice for economic balances since most are of a preliminary nature.

As a general rule, variable operating expenses decrease with increasing equipment size while fixed expenses increase with increasing size, as shown in Figure 5.1.

Table 5.3 Checklist of Fixed Capital Items

Delivered equipment costs
Equipment installation
Automatic control equipment
Installation of automatic control equipment
Piping and ductwork
Insulation
Electrical equipment and installation
Auxiliary equipment
Engineering costs association with equipment installation

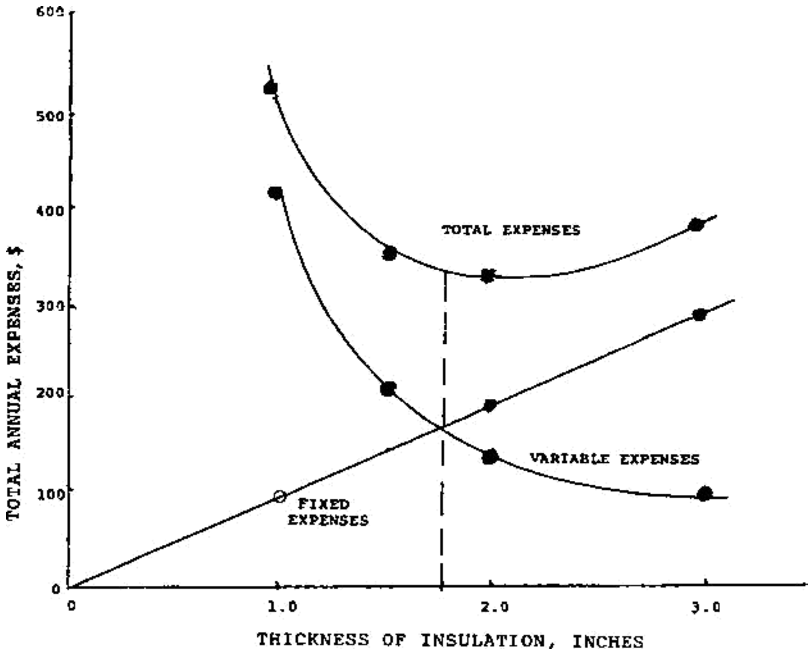

FIGURE 5.1 Optimum thickness of insulation—typical results.

5.4 PROCEDURE FOR SOLVING SINGLE-VARIABLE BALANCES

There are many instances where the optimization is based on a single variable. In that case, the procedure is simple. In Figure 13.1, the objective is to find the insulation thickness that gives the least total cost. The single variable then is the insulation thickness and variable and fixed cost relationships can be developed.

The general procedure for solving single-variable problems consist of the following steps:

1. Determine all expenses that need to be considered in the balance. These will be those expenses that vary as the size changes. For checklists, refer to Tables 5.1 – 5.3. Expenses that do not change need not be included but it is an error to exclude an expense that varies with equipment size.
2. Determine if any operating limitations exist. Some common examples are:
   - Limiting pressure drop in packed and tray towers above where flooding occurs.

- Limiting head for pipelines when flow is by gravity.
- A safety margin for reflux ratio in a distillation column above minimum reflux to ensure some tolerance because of inaccuracies in design and thermodynamic data

3. Mathematically express the expenses as a function of the variables, preferably those related to equipment size; otherwise use variables that define the operation, such as temperature, concentration, pressure. The final expression should include all pertinent expenses. The variables next need to be reduced to only those items that are significant. Frequently, only one variable is used in total expense equations e.g., pipe size for economic pipe diameter, number of effects in evaporator systems, etc.
4. Ascertain if the optimum size must be one of a number of discrete sizes that are commercially available or whether it can be any size. For example, pipe insulation as shown in Figure 5.1 can only be purchased in standard thickness. Distillation towers, heat exchangers, rotary driers, etc. may be fabricated in any size specified by the design engineer.
5. Solve the total expense equation by either an analytical or graphical method. These two methods have certain advantages and disadvantages.

5.4.1 Analytical Method

Common mathematical techniques are used to locate the optimum. For problems concerned with equipment size, the minimum size is sought; however, in cases where optimum yield is sought, the objective is to find the maximum. For the simple case in which all expenses are expressed as functions of a single variable, the total expense equation can be differentiated with respect to the single variable, the result set equal to zero and the equation solved for the optimum. Unless it is obvious from the nature of the expense curves that there is a true optimum, mathematical tests must be performed as a check.

Total annual expenses ¼ fixed expenses þ variable expenses

where the fixed expenses are depreciation and plant indirect expenses. By convention, the return on investment term is included with the fixed expenses. The variable or recurring expenses are utilities, maintenance, etc. Therefore,

$$\mathrm{TAE} = \mathrm{FE} + \mathrm{VE} \qquad \text{eq 5.1}$$

where

TAE = total annual expenses

FE = fixed expenses

VE = variable expenses

If the derivative of Eq. (5.1) is taken with respect to the controllable variable x, then

$$\frac{d(\mathrm{TAE})}{d\mathrm{x}} = \frac{d(\mathrm{FE})}{d\mathrm{x}} + \frac{d(\mathrm{VE})}{d\mathrm{x}} \qquad \text{Eq. (5.2)}$$

Equation (5.2) is set equal to zero and solved for x,

$$\frac{d(\mathrm{FE})}{d\mathrm{x}} + \frac{d(\mathrm{VE})}{d\mathrm{x}} = 0 \qquad \text{Eq. (5.3)}$$

The value of x is either a maximum or minimum, depending on the problem objective.

Advantage of method: It is a quick method.

Disadvantages of method:

1. Does not afford ready comprehension of how different cost elements vary with size.
2. Final answer does not yield standard sizes.
3. Does not indicate how sharp the maximum or minimum curve is at the optimum.
4. May result in an equation that is difficult to solve mathematically.

5.4.2 Graphical Method

For a reasonable range of sizes, the fixed and variable expenses in the total expense equation are calculated and tabulated. For piping and insulation, discrete commercial sizes are selected. The graphical method is shown in Figure 5.1. For equipment that is not fabricated in discrete sizes, the selection is dictated by the design engineer or by common engineering practice. The optimum is found by plotting the fixed expenses, variable expenses, and the total expense curves as a function of the controllable variable. From the plot, one may observe the nature of the optimum and provide a basis for judgment. If the curve has a sharp minimum, the indicated size is correct; however, if the total expense curve is relatively flat, there is some latitude in the choice. For instance, if the proposed investment is to be a minimum, the smaller equipment size is selected, whereas, if a margin for increased capacity is desirable, then a larger size might be selected provided that there is not a significant increase in the total annual expenses.

Advantages:

1. Yields an answer for available or approximate sizes that will provide the desired service at minimum cost or will provide maximum yield.
2. Produces a solution where the analytical method may be difficult or impossible to solve.
3. Indicates pictorially how the fixed, variable and total annual expenses vary with size.

Disadvantage: Takes more time to solve:

Example 5.1 is an illustration of the analytical and graphical techniques.

Example 5.1

A food company is concerned is about the conservation of energy in their baking ovens. New insulation needs to be installed and the information for this economic analysis is:

Temperature at surface of the inside oven wall	550 F
Ambient air temperature	70 F
Combined ambient air film coefficient	4 Btu/hr ft^2 F
Thermal conductivity of insulation	0.30 Btu/hr ft F
Insulation cost, installed (A board foot is 1 ft^2 of area, 1 in. thick or 144 in.^{3})	\$3.50/board ft
The value of heat	\$3.00/MM Btu
Estimated oven life	10 yr
Depreciation	7 years straight-line
Maintenance	3% FCI/yr
Insurance and property taxes	1.5% FCI/yr
Combined federal and state taxes	42%
Stream time	8700 hr/yr
Cost of capital	10%

Determine the optimum insulation thickness.

Only the expenses that appear to vary with insulation thickness will be considered:

- Installed cost of the insulation
- Cost of heat lost through the oven wall
- Maintenance on the insulation
- Depreciation

$$\text{Total fixed expenses} = \text{depreciation} + \text{return on investment}$$

$$\text{Total fixed expenses} = \frac{1}{7}\,\text{FCI} + \left[\frac{0.10}{1 - 0.42}\right]\text{FCI}$$

taxes

$$\text{Total fixed expenses} = 0.143\,\text{FCI} + 0.172\,\text{FCI} = 0.315\,\text{FCI}$$

On the basis of 100 ft^2

$$\text{FCI} = (100)(3.50)t = 350t$$

Therefore,

$$\text{Total fixed expense term} = (0.315)(350)t = 110t$$

n wall surface. Let

$$\text{Variable expenses} = \text{Cost of heat lost} + \text{maintenance} + \text{insurance} + \text{property taxes}$$

$$\text{Heat loss expense} = (Q)(8700)\left(\frac{\$3.00}{10^6}\right)$$

but

/hr

$$q = UA\Delta T = U(100)(500 - 70) = 43{,}000U$$

Btu/hr ft^2/°F

and

$$U = \frac{(1)}{1/[0.25 + (t)(0.30)/(12)]}$$

$$\text{Heat loss} = \left[\frac{(43{,}000)(8700)(\$3.00)}{10^6}\right]\left[\frac{1}{0.25 + 0.278t}\right]$$

ce, °F

$$\text{Maintenance} = 0.03\,\text{FCI} = (0.03)(350)t = 10.5t$$

$$\text{Total fixed expenses} = \text{depreciation} + \text{return on investment}$$

$$\text{Total fixed expenses} = \frac{1}{7}\,\text{FCI} + \left[\frac{0.10}{1 - 0.42}\right]\text{FCI}$$

$$\text{Total fixed expenses} = 0.143\,\text{FCI} + 0.172\,\text{FCI} = 0.315\,\text{FCI}$$

On the basis of 100 ft^2

$$\text{FCI} = (100)(3.50)t = 350t$$

Therefore,

$$\text{Total fixed expense term} = (0.315)(350)t = 110t$$

$$\text{Variable expenses} = \text{Cost of heat lost} + \text{maintenance} + \text{insurance} + \text{property taxes}$$

$$\text{Heat loss expense} = (Q)(8700)\left(\frac{\$3.00}{10^6}\right)$$

but

$$q = UA\Delta T = U(100)(500 - 70) = 43{,}000U$$

and

$$U = \frac{(1)}{1/[0.25 + (t)(0.30)/(12)]}$$

$$\text{Heat loss} = \left[\frac{(43{,}000)(8700)(\$3.00)}{10^6}\right]\left[\frac{1}{0.25 + 0.278t}\right]$$

$$\text{Maintenance} = 0.03\,\text{FCI} = (0.03)(350)t = 10.5t$$

$$\text{Insurance} + \text{property taxes} = 0.015\,\text{FCI} = 5.25t$$

$$\text{Total variable expenses} = 10.5t + 5.25t + \frac{1122}{0.25 + 0.278t}$$

$$\text{Total annual expenses} = 1100t + 10.5t + 5.25t + \frac{1122}{0.25 + 0.278t}$$

$$\text{Total annual expenses} = 125.8t + \left[\frac{1122}{0.25 + 0.278t}\right]$$

$$d(\text{TAE})/dt = 125.8 - \left[\frac{1122}{(0.25 + 0.278t)^2}\right]$$

$$t = 4.75\,\text{in}$$

This solution does not indicate how sharp the minimum is, nor does it indicate which of the nearest sizes of insulation will be more economical, 4 or 5 in thickness. This decision must be resolved by calculating the total annual expense for both sizes, viz. 4 and 5 in, or by preparing a graphical solution. Probably the 5-in insulation will be selected.

Graphical Solution:

The graphical solution is performed using the same expense equations as in the analytical solution. The terms for each expense item are calculated and presented in Table 5.4. In order to complete this solution, the fixed expenses, the variable expenses and the total annual expenses are plotted as a function of t, the thickness of the insulation. The resulting total minimum expense is found to be 4.75, as shown in Figure 5.2.

5.5 PROCEDURE WITH MORE THAN ONE CONTROLLABLE VARIABLE

In some economic analysis problems, more than one controllable variable affects the optimum cost or maximum yield. The general approach, analytical or graphical, for solving this type problem is the same; however, determining the optimum is rather tedious. This situation occurs when technical relations between design, batch size, or other economic conditions produce a basis equation such as in Eq. (5.20):

$$C_T = g(x, y) \qquad \text{Eq. (5.20)}$$

TABLE 5.4 Tabulated Results of Graphical Solution for Example 5.1

Thickness	3 in	4 in	4.75 in	5 in	6 in	7 in	8 in
Fixed expenses	$330.00	$440.00	$522.50	$550.00	$660.00	$770.00	$880.00
Variable expenses							
Heat loss	$1,035.06	$823.79	$714.42	$684.15	$584.98	$511.07	$454.42
Maintenance	31.50	42.00	49.88	52.50	63.00	73.50	84.00
Taxes & insurance	15.75	21.00	24.94	26.25	31.50	36.75	42.00
Total variable expenses	$1,082.31	$886.79	$789.24	$762.90	$679.98	$621.32	$580.42
Total annual expenses	$1,412.31	$1,326.79	$1,311.74	$1,312.90	$1,339.48	$1,391.32	$1,460.42

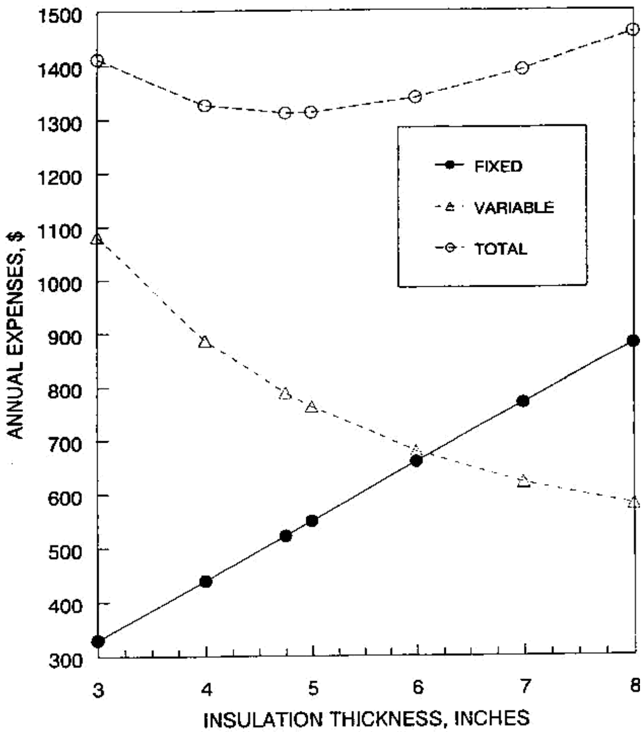

FIGURE 5.2 Optimum insulation thickness—Example 5.1.

For example, in a manufacturing process, the production capacity may vary with the speed of the equipment and its size. Since both variables are controlled by management or design personnel, perhaps the best policy is a combination of optimum speed and optimum size. The mathematical relationships for a case of two (or more) variables may be:

$$C_T = ax + \frac{b}{xy} + cy + d \qquad \text{Eq. (5.20)}$$

where

C_T =annual dollars

x; y =controllable variables

a; b; c; d = constants

The annual cost will pass through a minimum when either x or y is held constant as found by partial differentiation.

$$\frac{\partial c}{\partial x} = a - \frac{b}{yx^2}$$

and

$$\frac{\partial c_T}{\partial y} = \frac{-b}{xy^2} \qquad \text{Eq. (5.23)}$$

If c_T is plotted as the ordinate with x as the abscissa and y as the third coordinate, a curved surface results as shown in Figure 5.3. The minimum cost c_T is found by plotting Eq. (5.21) for assumed constant values of x. The line made where one constant x plane intersects the surface will give a minimum cost c_T and an optimum value. The same result may be found analytically by setting Eq. (5.23) equal to zero and solving for y at a constant assumed value of x.

5.6 INTERACTIVE SYSTEMS

Frequently more than one item of equipment influences the controllable variable(s) and the optimum solution. In this case, when solving a problem graphically, if only one item of equipment is selected, the total annual expense curve does not pass through a minimum but continues to decrease with increasing size or it may increase with increasing equipment size. If this phenomenon occurs, then more than one equipment item is affecting the optimization. The next step is to inspect the flow sheet for equipment directly upstream or down-stream from the selected item. It may be necessary to group two or more items together and treat them as a single equipment item. Such a system is said to be interactive since more than one item of equipment affects the optimum condi-tions. Example 5.3 is an illustration of such a system.

5.7 SUMMARY

This UNIT was concerned with the development of an economic balance to determine a minimum total expense or a maximum process yield. Methodologies were developed and checklists were provided for the solution of simple optimization problems. Analytical and graphical methods of solution were demonstrated for single or multiple controllable variable cases. In some instances, the analytical solution may be simpler to use but in other cases, the graphical solution is more direct and less cumbersome mathematically but may be more time consuming.

Interactive systems were introduced wherein more than one equipment item affects the controllable variable.Judgment based upon an engineer's experience is necessary in this case because there may be equipment or process limitations beyond the mathematical solution that affect the final decision.

REFERENCES

1. MS Peters, KD Timmerhaus. Plant Design and Economics for Chemical Engineers. New York: McGraw-Hill, 1991.
2. TF Edgar, DM Himmelblau. Optimization of Chemical Processes. New York: McGraw-Hill, 1988.
3. GS Beveridge, RS Schechter. Optimization Theory and Practice. New York: McGraw-Hill, 1970.
4. GV Reklaitis, A Ravindran, KM Ragsdell. Engineering Optimization. New York: Wiley, 1983.
5. RW Pike. Optimization for Engineers. New York: Van Nostrand Reinhold, 1986.
6. J Happel. Chemical Process Economics. New York: Wiley, 1958.
7. H Schweyer. Analytical Models for Managerial and Engineering Economics. New York: Reinhold, 1964.