Ministry of Higher Education and Scientific Research
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Chemical Engineering Department

Industrial Engineering & Management

For Forth Class Students
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(Chemical Processing Engineering Branch)

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Contents

INDUSTRIAL ENGINEERING & MANAGEMENT

- **Management**: - The planning, organizing, leading, and controlling of human and other resources to achieve organizational goals effectively and efficiently.
- **Managers: -** The people responsible المسؤولين for supervising the use of an organization's resources to meet its goals.
- **Resources are organizational *assets***:-
  - People ➢Skills ➢Knowledge ➢Information

Raw materials ➢Machinery ➢Financial capital

Efficiency, Effectiveness, and Performance in an Organization

- **Organizational Performance**:-A measure of how efficiently and effectively managers are using organizational resources to satisfy customers and achieve goals.
- **Efficiency :-**A measure of how well or productively resources are used to achieve a goal.
- **Effectiveness:-** A measure of the appropriateness (suitability) of the goals an organization is pursuing and the degree to which they are achieved.

Study Management

- Proper management directly impacts improvements in the well-being of a society.
- Studying management helps people to understand what management is and prepares them accomplish managerial activities in their organizations.
- Studying management opens a path to a well-paying job and a satisfying career.

Production: production can be defined as follows;

1- **Production** is a sequence of technical processes, requiring either directly or indirectly the mental and physical skill of craftsman and consists of changing the shape, size and properties of materials and ultimately converting them into more useful articles.

Production includes manufacture of goods and services, and they are four recognized factors for this procedure:

1- Natural resources including land
2- Labour.
3- Capital i.e. factory building, machinery, tools, raw materials….etc.
4- Organization.

A simple production system is shown in the following figure;

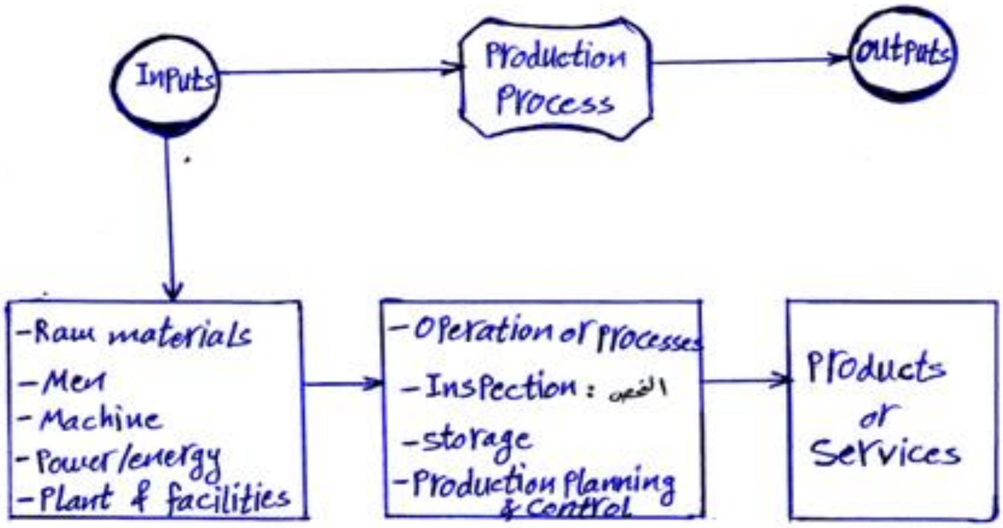


FIG-1 **Production system**

Production function: Most important task of the production management is to deal with decision making related to production processes so that the goods manufactured are according to the specifications, in the required quantity, at minimum cost as per schedule. A popular production function derived by Mr. Cobb and Mr. Douglas is as follows: $P = b.L^{\alpha}.C^{1-\alpha}$

Where p = Total output.

L = Index of employment of labour in actual manufacturing.

C = Index of fixed capital in manufacturing.

α and $1 - \alpha$ are known as elasticities of production and measured in a percentage.

Types of production : Different types of production can typically be placed under two categories:

1- Intermittent production.
2- Continuous production.

In intermittent production, machinery is used for a short duration of time for producing an item, and then changed to produce another item.

While in continuous production, set up of production is fixed and used to produce same item.

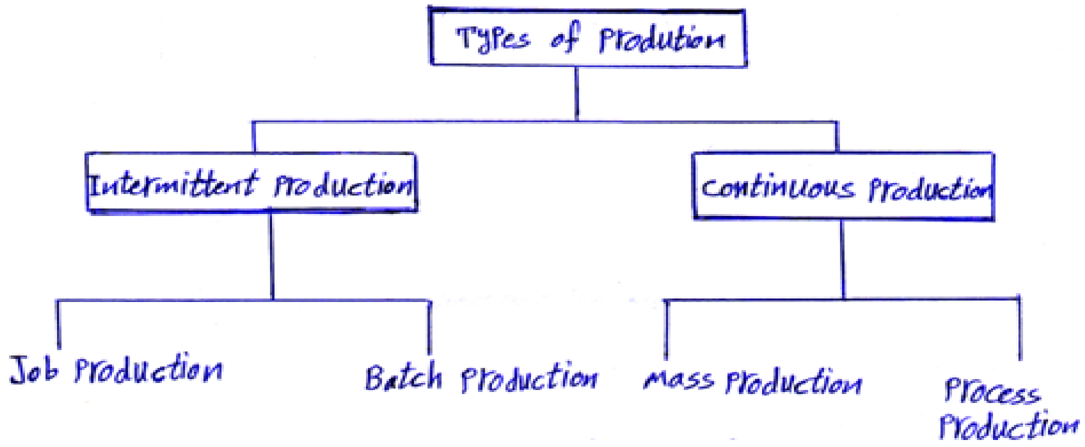


FIG-2 **<u>Types of production</u>**

<u>(a)</u>Job production :

This is the oldest method of production on a very small scale. With this method individual requirements of the consumers can met. Each job stands alone and is not likely to be repeated. This type of production has a lot of flexibility of operation and hence general purpose machines are required. Factories adopting this type of production are generally small in size. This type of production is used for things which cannot be produced on a large scale.

Advantages:

1- It is the only method which can meet the individual requirements.
2- There is no managerial problem because of very less number of workers.
3- This type of production required less money and is easy to start.
4- There is less risk of loss to the factory adopting this type of production.
5- Because of flexibility, there is no chance of failure of factory due to the reduction of demand.

Disadvantages:

1- There is no scope of commercial economy.
2- As the purchase of raw materials is in less quantity, hence cost of raw materials is slightly more.
3- For handling different type of jobs, only skilled and intelligent workers are needed, thus labour cost increases.

(b) Batch production :

This type of production is generally adopted in medium size enterprises. Batch production is a stage in between Job production and Mass production. Batch production is bigger in scale than the Job production while it is smaller than that of Mass production. Batch production required more machines than that of Job production and less machines than that of Mass production. As in this type of production, two or more types of products are manufactured in lots (i.e. batches) at regular interval, therefore this is known as Batch production. Most of the engineering concerns are adopting Batch production.

Advantages:

1- While comparing with mass production it requires less capital.
2- If demand for one product decreases then production for another may be increased, thus the risk of loss is very less.
3- Comparing with job production, it is more advantageous commercially.

Disadvantages:

1- Comparing with mass production, cost of sales and advertisement per unit is more.
2- Raw materials to be purchased are in less quantity than in mass production. Therefore, it is slightly costlier than of mass production.

(c) Mass production :

This type of production is a larger scale production and is a continuous production. In job production, factory works only when orders are received and when orders are not received for some time then for that period work may come to a standstill. But mass production is a continuous production and it does not have any non-producing time. In this method with the use of automatic machines, articles automatically move forward from one stage to the next stage of manufacturing operation. In mass production, simplification and standardization of products are made. In this type of production, different machines are assigned a definite nature of work. Throughout the run of the plant, only one type of product can be manufactured.

Advantages:

1- Mass production gives better quality and increased production.

2- Wastage is much minimum.

3- As raw materials are purchased on a large scale, higher margin of profits are available, while purchasing them.

4- Sales promotion and advertising do not prove to be costly as their expenses are spread over thousands of articles produced, hence cost per unit is low.

5- Only few skilled and rest semi-skilled workers are required hence labour cost is reduced.

Disadvantages:

1- During the period of less demand heavy losses on the invested capital may take place.

2- Because of all the machines used are one purpose machines therefore, this type of production is not changeable to other type of production.

3- Most of the workers handle only particular operation. They may get skill in their job but after sometime they feel bored with the repetition of same type of work.

4- As this type of production is on large scale, consequently it cannot fulfill individual taste. It produces things of standardized from which are demanded on a large scale.

(d)Process production :

In this type of production, the plant and its equipment and layout have been primarily designed to manufacture the desired product. Examples of such production are automobiles, chemical plants, fertilizer plants etc. Unlike other production systems, switch over to other product is very difficult and costly affair especially when special.

Industrial or production management

Production management is a branch of general management which is concerned with production activities.

Operation management can be defined as the management of the conversation process, which converts land, labour, capital, and management inputs into desired outputs of goods and services.

Scope of production management

1. ***Relating to designing of production system*:** these activities concern the production engineering, and include design of tools and jigs ; design, development and installation of equipment, and selection and optimization of the size of the firm. Selection of plant location, plant layout, materials handling systems are functions of production engineering. The problems of human factor, and research and development are also considered.
2. ***Relating to analysis and control of production operation*:** these activities include production planning, production control. Production control activities are looked after at three levels: control of inventory, control of flow of materials, and control of work -in- progress. Other controls to be looked into are quality control, cost control and labour control.

Value added process عملية القيمه المضافه

All operations add value to the object thereby enhancing its usefulness. In view of this, we can define an operation as "the process of changing inputs into outputs and thereby adding value to some entity".

Systems approach to production management

A system can be defined as an orderly arrangement of components like, men, materials, money, machine and environment that are inter-related and act and interact with one another to perform task or function in a particular environment. A system is composed of elements or sub-

systems that are related and dependent upon each other. A systems approach is a systematic and organized approach to get the task accomplished more efficiently, effectively and economically. A system can be considered as a structure of sub-system, each having the following characteristics:

- **(a)** Inputs
- **(b)** Transformation(conversation) process
- **(c)** Output
- **(d)** Feed back.

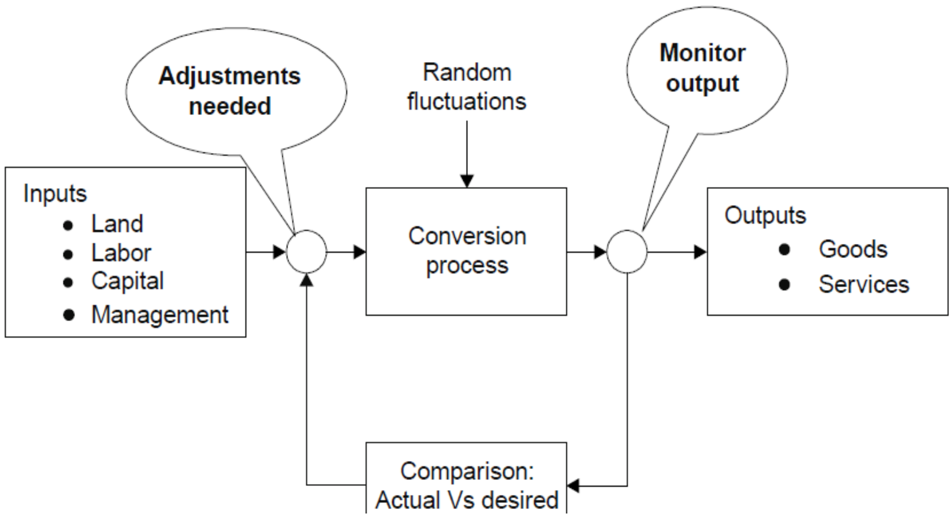


FIG-3 **Conceptual تصور خیالی model of production management**

A systems model of the organization has several sub-systems as shown in the below figure. Any business organization has finance, marketing, accounting, personnel, engineering, purchasing, and distribution systems besides operations system. All these systems are interrelated to one another in many ways.

Fig -4 A systems view of a business organization indicating its sub-systems

Production Competitiveness القدره التنافسيه in function

In order to compete in the global market, there are four dimensions of competitiveness that measure the effectiveness of the production function. These four dimensions are:

1. Cost
2. Quality
3. Dependability as a supplier الاعتماديه ك ممون
4. Flexibility

1-Cost :-Price is an important weapon used in the competitive market place. Profitability is also related to the difference between price and cost. Therefore, in order to compete on the basis of price, operations function must be capable of producing at low cost

2-Quality :-Due to Japanese concept of quality and dominance of Japanese market in consumer electronics, automobiles, steel, machine tools etc., more attention is being paid now-a-days on quality.

3- Dependability as a supplier Dependability of supply of off-the-shelf availability is considered as a strong favorable point in competitive market for an organization. Customers, sometimes,

may compromise on cost or quality in order to get on –time delivery when they need it.

4- Flexibility A firm must be flexible enough to meet customers' needs. Customers needs may be about service, change in specifications, change in delivery schedule etc.

Productivity

"*Productivity*" is nothing but the reduction in wastage of resources. The resources may be men, machines, material, power, time and building space etc.

It may also be defined as human Endeavour (Effort) to produce more and more with less and less inputs of resources as a result of which the benefits of production may be distributed more equally among maximum number of people

Difference between *Production* and *Productivity*

Sometimes, there arises confusion between production and productivity. It is, therefore, necessary to differentiate them, so that there may not be any confusion.

"Production" of any commodity or service is the volume of output irrespective of the quantity or quality of resources employed to achieve that level of output. Once we put in it element of efficiency with which the resources are employed, we enter the area of productivity

Qualities of good industrial management

A good industrial management is that which can steer through different problems and is capable of achieving its fixed targets. Some of the important qualities of the management are:

1- Collection and analysis of data. It should go on collecting the data about the products, its manufacturing including trends of sales, availability of raw materials etc.
2- Proper research. It should have properly equipped research wing.
3- Not too-rigid. Management should always be prepared to review its decisions.
4- Not too much centralization. As far as possible management should avoid over centralization.

5- Division of labour. The management should be in a position to properly divide the available man-power in such a way that there is no wastage or there is no over-lapping.
6- No wastage. Good management is expected to avoid wastage as far as possible, whether it may be human resource or material. It should see that money is spent in such a way that maximum profits are available to the industry.
7- Proper control. Good management is supposed to exercise discipline and controls over employees and over –expenditure.
8- Stress on training. Management should ensure that the employees at all the levels got refresher and in service training to keep their knowledge up to date.
9- Contacts with the employees. Employees are the life and blood of an organization. Hence management should have both formal and informal contacts with the employees.
10- Clear targets. Management must have clear and realistic planning. It must also know about its target and the way how it is to be achieved.
11- Association of employees. Management must associate with the workers while making the policy for the industry.
12- Providing incentives and initiatives. If management fails to provide incentive, initiative and adequate wages to its employees, it is bound to be miserable failure.

Functions of industrial / production management

FIG-5 Functions of industrial / production management

Major functions covered in the production management system are as follows:

A- Planning :- Planning is the main function of management. All other functions follow the planning function.

(a) Designing conversion systems.
- Operations strategy
- Forecasting
- Product and process selection
- Capacity planning
- Facility location planning
- Layout planning

(b) Scheduling conversion systems
- Scheduling systems
- Aggregate planning
- Operations scheduling

Planning

- Identifying and selecting appropriate **goals** and courses of action for an **organization**.
  - ➢ The **planning function** determines how effective and efficient the organization is and determines the **strategy** of the organization.
- Three Steps in the Planning Process:
  - ➢ Deciding which goals to pursue.
  - ➢ Deciding what courses of action to adopt.
  - ➢ Deciding how to allocate resources.
  - ➢ البت فيها أهداف تسعى لتحقيقها.
  - ➢ اتخاذ قرار بشأن ما مسارات العمل على تبني.
  - ➢ تحديد كيفية تخصيص الموارد

Advantages of planning

Following are some of the main advantages of proper planning:
-planning gives direction.
-planning helps to offset change and uncertainty.
-planning helps in economic operation.

-planning focuses attention on important activities in order to fulfill its objectivesتحقيق أهدافه .
-planning helps in control.
-planning helps in growth.

- **B- Organization:-** Organizing is an important function of management by which it combines the human power with other resources to give desired output

The process of organization is a managerial function of organizing, and Involves determination of objectives, deciding various activities, grouping of activities, assignment of responsibilities, delegation of authority, providing facilities and proper environment.

Organization is an identifiable group of people contribute their efforts towards the attainment of goals.

Characteristics of a good organization

1- Purposeful i.e. to accomplish an objective.
2- Boundaries and limitations. Limits imposed by resources and environment.
3- Interdisciplinary
4- Empirical i.e. based on real world observations and interactions.
5- Make use of information.
6- Decision oriented.
7- Feedback oriented.
8- Responsive and learning oriented.
9- Adaptive.

- **Organizational Structure**
  - A ***formal*** system of task and reporting relationships that coordinates and motivates organizational members.
  - Creating organizational structure:
    - Grouping employees into ***departments*** according to the tasks performed.
    - Laying out lines of ***authority*** and ***responsibility*** for organizational members.

C- Leading

1- Staffing

For a new enterprise, staffing function is followed by planning and organizing functions. Staffing function comprises, the activities essential to manage and keep manned the positions created by the organization structure

2- Directing is a function which includes all those activities which are designed to encourage subordinates to work effectively both in short and long run.

- Articulating a clear ***vision*** to follow, and ***energizing*** and enabling organizational members so they understand the part they play in attaining organizational goals.
    - Leadership involves using power, influence, vision, persuasion, and communication skills.
    - The outcome of leadership is highly motivated and committed organizational members.

D- Controlling

Controlling is a continuous process of measuring actual results in relation to those planned. Controlling can also be defined as that managerial activity whereby the manager compares actual performance against the planned one, fined out the deviation, and take corrective actions.

Controlling function of the management has following four main elements:

(i) Establishing standards of performance.
(ii) Measuring current performance.
(iii) Comparing performance with the established standards.
(iv) Taking corrective action, if any deviation is detected.

- Evaluating how well an organization is achieving its goals and taking action to maintain or improve performance.
    - ***Monitoring*** individuals, departments, and the organization to determine if desired performance standards have been reached.
    - Taking action to increase performance as required.

The outcome of control is the ability to measure performance accurately and to regulate the organization for efficiency and effectiveness

Types of industry

Industry is that part of the business activity which concerns itself with the production, processing or fabrication of products. The products may be consumer goods, capital goods or intermediate goods (like aluminum, copper, steel, plastic etc.) broadly the industries can be divided into four types:

1. Extractive industries. The commodities raised by such industries are produced with comparatively little assistance from man.
2. Genetic industries. These industries are engaged in reproducing تكاثرand multiplying certain species اصناف of plants and animals with the object of earning profit from their sale. For example, nurseries, cattle bearing farms, poultry farms etc.
3. Construction industries. These involve construction of buildings, roads, canals, dams, bridges etc.
4. Manufacturing industries. Generally the term industry is used to refer to manufacturing industries (which is not correct). Manufacturing industries are engaged in the conversion or transformation of raw materials or semi-finished products into finished products. These may be Analytical industries, Synthetic industries, Processing industries or Assembly –line industries. The industries are sometimes classified on the basis of size and investment, such as heavy industries or light industries.

Charts for medium and large industry:

Organization charts for medium, and large industries are given hereunder. However these can vary from organization to organization depending upon the factors.

(a) For medium industry. For a medium size industry, a sample chart for management is given at following figure. Layout given in that figure is for a medium sized concern controlled by the board of directors, who act through a managing director. Here the activities of the concern are divided into various sections namely: sales, office, works, inspection and design, with a departmental head in each.

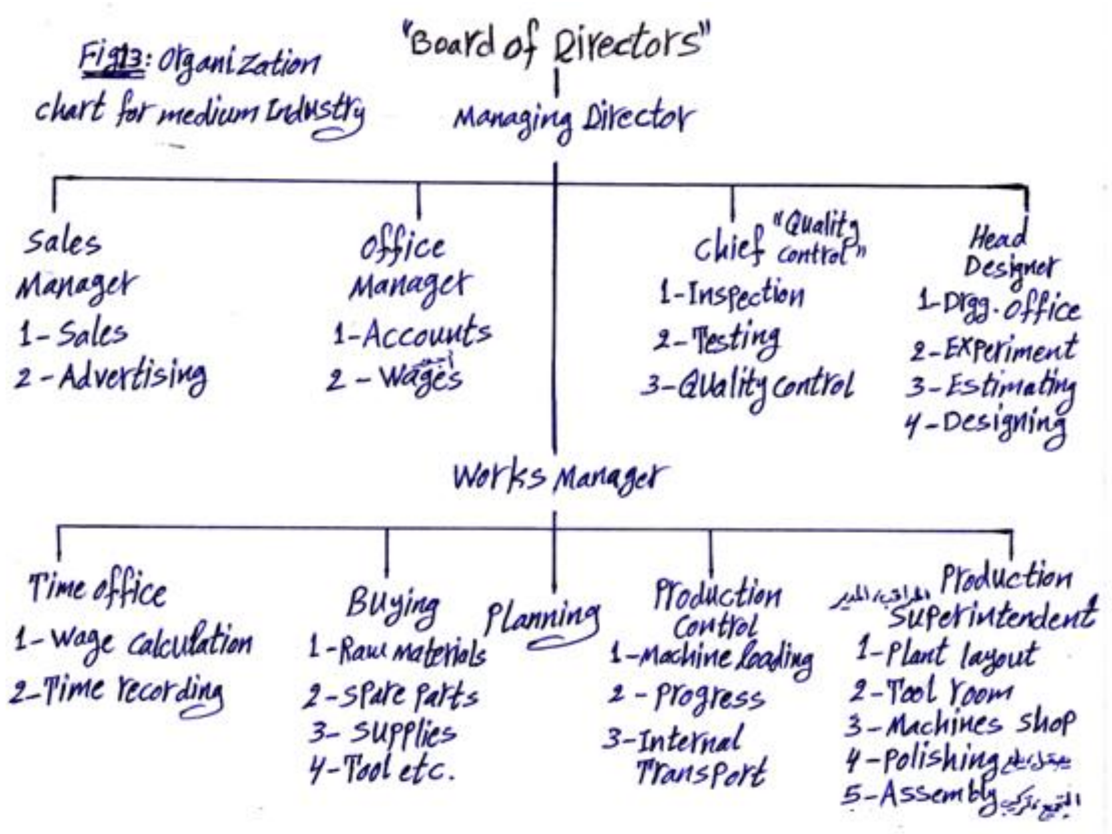


Fig : Organization chart of medium industry

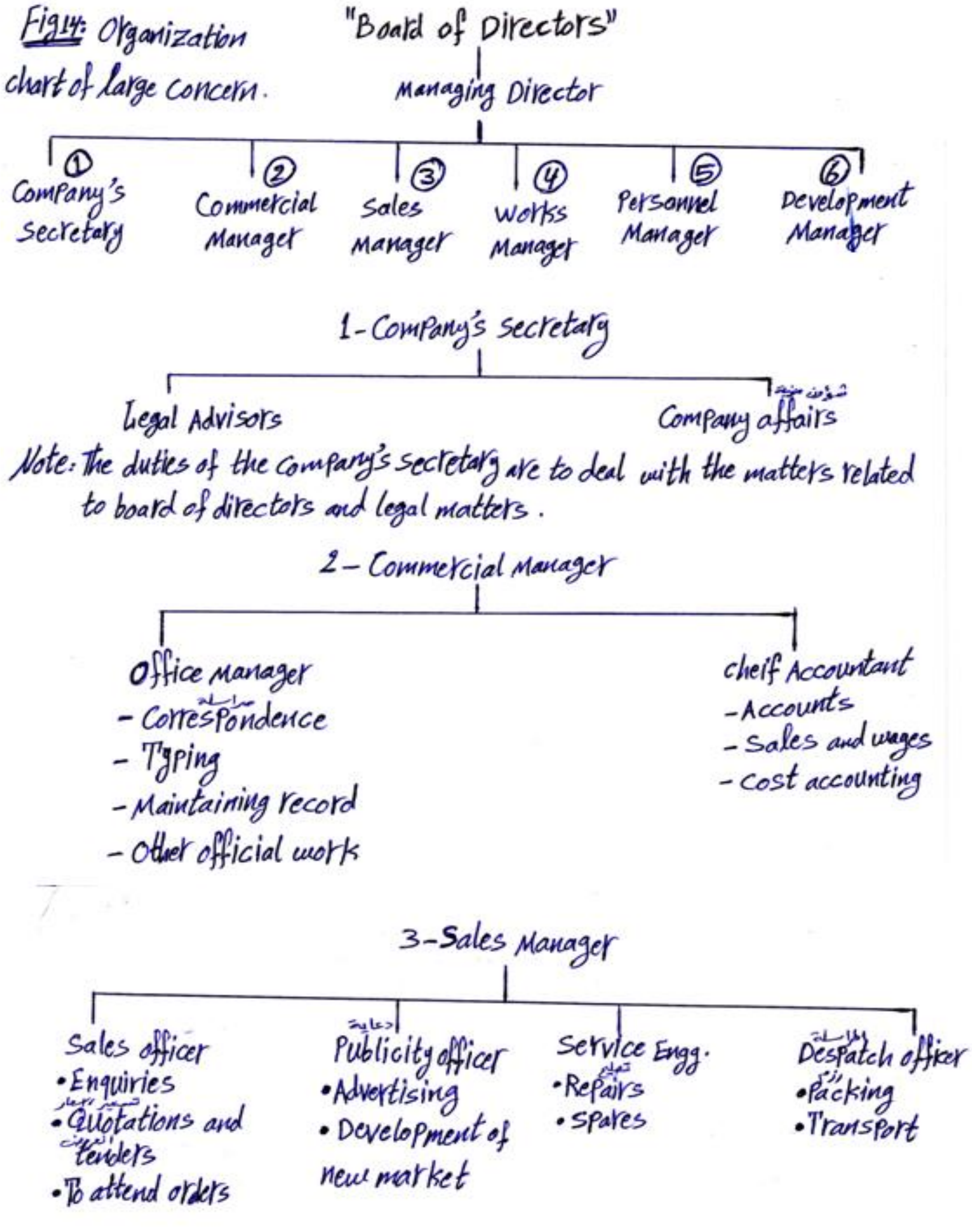
This structure is designed to permit the managing director some help from over – work of his authority while still handling control. In this manner, he is free from handling too much detail and from being brought into contact with large number of people. Main works to be done in each department are given in the chart with the designation of the head.

(a) **For large industry.** A sample organization chart for a large concern is shown in the following figure. It may have necessary alterations to meet the requirements for a particular industry.

In this chart, the activities of the concern are divided into six main sections. Each having a head who is responsible to and is in direct contact with the managing director or general manager as the case may be. Each sphere of the activity is fairly well designed and the risks of overlapping of activities are avoided. In very large organizations, there may be 2 or 3 sections under each general manager, who works under managing director. None of the chief official is required to make contact with large number of people.

This does not mean that the heads are unapproachable. What does it mean that they do not waste time asking number of persons for information

which they can get from the planned sources? The scheme is designed to make use of the skill and the time of the officials to the best advantages and to free them from handling a mass of details.



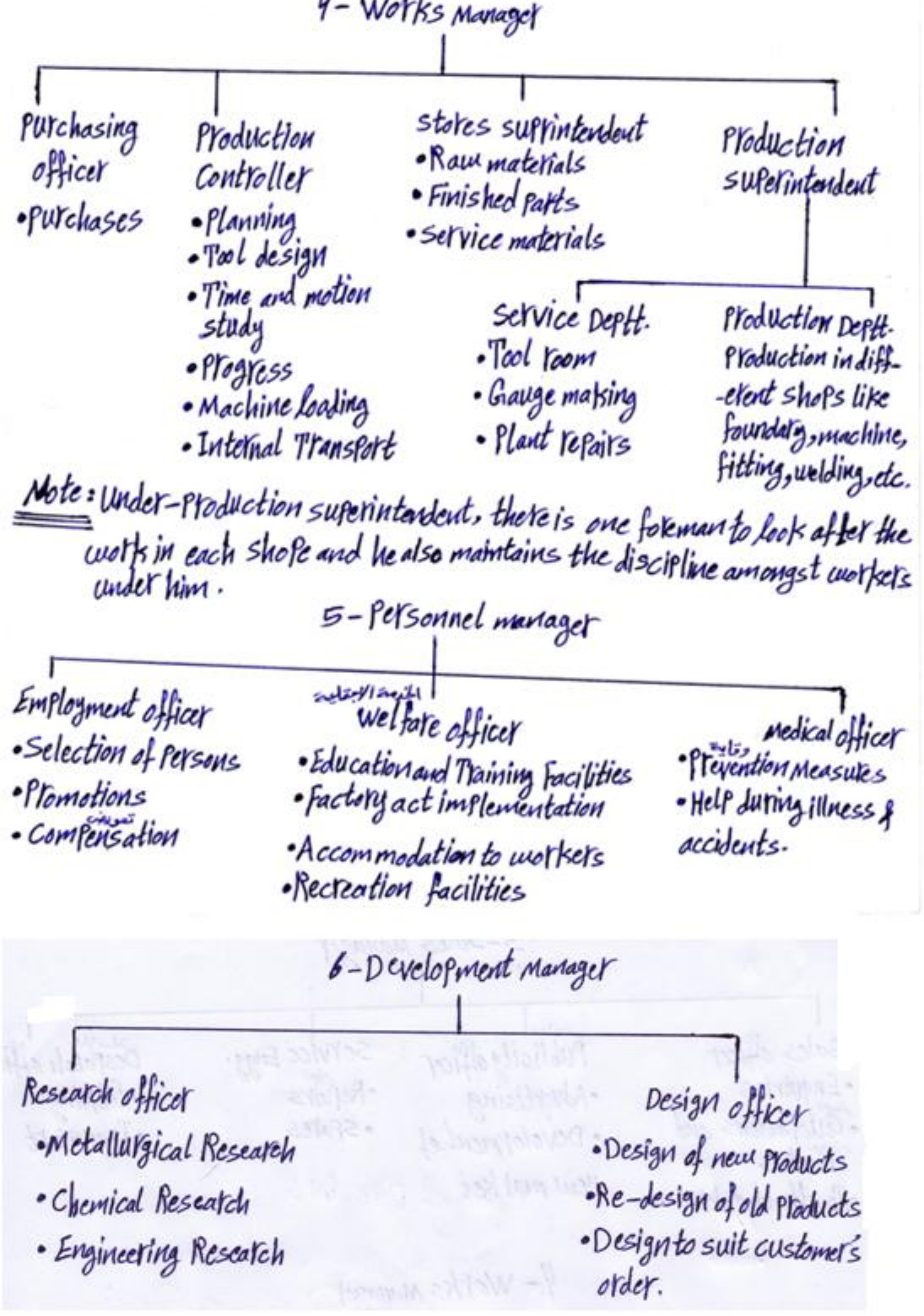


Fig 12: Organization chart of large concern

PROCESS ENGINEERING ECONOMICS

Economics is ever present in our lives because we earn money from our jobs and we spend money allocated by our personal budgets for housing, clothing, transportation, entertainment, etc. We spend money for these items based upon the perceived economic utility. Further, economics is the engine that drives industry.
Chemical engineers in the performance of their jobs will employ economics in the preparation of capital cost estimates, operating expense estimates, profitability analyses including the time value of money, feasibility studies, and to perform sensitivity and uncertainty analyses considering many alternatives. To move up the management ladder, they must have a working knowledge of balance sheets, income statements, and financial analyses of a corporate venture.

A business plan must be developed before any funds are sought for a new product or venture. The capital budgeting function may be divided into several categories depending upon the time frame involved

Strategic planning involves setting the goals, objectives, and broad business plans for a 5- to 10-year time period in the future.

. **Tactical planning involves the detailing of the strategic planning for say 2–5 years in the future.**

. **Capital budgeting involves a request, analysis, and approval of expenditures for the coming year.**

Business plans minimally consist of the following information along with a projected timetable:
. Perceived goals and objectives of the company*
A- . Market data
Projected share of the market
Market prices
Market growth
Markets the company serves
Competition, both domestic and global
Project and/or product life
. B- **Capital requirements**
Fixed capital investment
Working capital
Other capital requirements

. **C- Operating expenses**

Manufacturing expenses
Sales expenses
General overhead expenses

.D- Profitability

Profit after taxes
Cash Flow
Payout period
Rate of return
Returns on equity and assets
Economic value added

E- . Projected risk

Effect of changes in revenue
Effect of changes in direct and indirect expenses
Effect of cost of capital
Effect of potential changes in market competition

SOURCES OF FUNDS

The funding available for corporate ventures may be obtained from internal or external sources.

A- Internal Sources

The capital from internal sources is from retained earnings or from an allowance known as reserves. Internal financing is “owned” capital, and it is argued that it could be loaned or invested in other ventures to receive a given return. In determining the cost of owned capital, interest to be paid on this capital is equal to the present return on all the company’s capital

B- External Sources

There are three sources of external financing: debt, preferred stock, and common stock. These sources vary widely with respect to the cost and the risk the company assumesتفترض_ with each of these financing sources. The cheapest form of capital is the least risky. A general rule is the riskier the project, the safer should be the type of financing the capital used. A new venture with modest capital requirements could be funded by common stock. In contrast, a well-established business area may be financed by debt.

Estimation of Capital Requirements

Total capital investment includes funds required to purchase land, design, purchase, and install equipment and buildings, as well as to bring the facility into operation.

A list of these items includes:

1. Land
2. Fixed capital investment
3. Offsite capital
4. Allocated capital
5. Working capital
6. Start-up expenses
7. Other capital items (Interest on borrowed funds , Catalyst and chemicals , Patents, licenses, and royalties)

2- FIXED CAPITAL INVESTMENT

The fixed capital investment for a plant includes the manufacturing equipment, piping, ductwork, automatic control equipment, structures, insulation, painting, site preparation, and environmental control equipment, as well as engineering and contractor's costs.

2.1 Capital Cost Estimates

When a firm considers a project to manufacture a product, a capital cost estimate is prepared. An in-house engineering staff may develop the estimate, if the staff is large enough, or the estimate may be outsourced to an engineering or consulting company.

2.1.1 Classification of Estimates

There are two broad classes of cost estimates: **grass-roots** and **battery-limits** estimates. The former, also called a green-field estimate, is a descriptive term. It means the entire facility is estimated starting with site preparation and includes building and structures, processing equipment, utilities, service facilities, storage facilities, railroad yards, and docks. A battery-limits estimate is one in which there is an imaginary boundary drawn around the facility to be estimated. It is assumed that all raw materials, utilities, services, etc. are available at the boundary in the proper quantity and with the desired quality to manufacture the product in question. Only costs within this boundary are estimated—hence the name battery-limits estimate.

2.1.2 Quality of an Estimate

Capital cost estimation is more an art than a science. An estimator must use a great deal of judgment in the preparation of an estimate. As the estimator gains experience, the accuracy of the estimate improves.

2.1.3 Equipment Cost Data

The foundation of a fixed capital investment estimate is the equipment cost data. From these data, through the application of factors or percentages based upon experience, a fixed capital investment estimate may be prepared. It is essential to have reliable equipment cost data but the engineer preparing the estimate must exercise good judgment in the selection and application of the data. There are many sources of data listed in the literature, but some are old and the latest data published was in 1990. There has been no significant cost data published in the open literature since that date. It is essential for the estimator to know:

. Source of the data
. Basis for the cost data
. Date of the cost data
. Potential errors in the cost data
. Range over which the cost data apply

2.1.3.1 Data Presentation. Cost data are stated as purchased, delivered, or installed costs. Purchased cost is the price of the equipment FOB (free on board) at the manufacturer's plant. Delivered cost is the price of the equipment plus delivery charges to the purchaser's plant FOB.

Some cost data are reported as installed cost. This means the equipment item, for example, a centrifugal pump has been purchased, delivered, uncrated, and placed on a foundation in an operating department but does not include piping, electrical, insulation costs. Perhaps a more accurate term would be set-in place cost

A simple convenient method of presenting cost data is by an equation:

$$C_2 = C_1\left(\frac{S_2}{S_1}\right)^n \qquad (4.1)$$

'here

C_1 = cost for equipment capacity S_1
C_2 = cost for equipment capacity S_2
n = an exponent that varies between 0.30 and 1.20 depending on the type of equipment

Example 4.1

Problem Statement: Recently a cast iron leaf pressure filter with 100 ft2 was purchased for clarifying an inorganic liquid stream for $15,000. In a similar application, the company will need a 450 ft2 cast iron leaf pressure filter. The size exponent for this type filter is 0.6 (see Appendix D). Estimate the purchased price of the 450 ft2 unit.

Solution:

$$\text{Cost}_{450} = \text{cost}_{100}\left(\frac{\text{capacity}_{450}}{\text{capacity}_{100}}\right)^{0.6}$$

$$= \$15,000\left(\frac{450}{100}\right)^{0.6} = \$15,000(2.47) = \$37,050$$

2.1.3.2 Algorithm Format. A more convenient way to display cost-capacity data is by an algorithm.

$$C_E = 1.218\, C_B F_D F_{MC} F_P \tag{4.2}$$

where

C_E = exchanger cost
C_B = base cost of a carbon steel, floating-heads exchanger, 150 psig design pressure
F_D = design-type cost factor if different from that in C_B
F_{MC} = material of construction cost factor
F_P = design pressure cost factor

Correlations for base cost, design type factor, material of construction factor, and design pressure factor can be developed as secondary algorithms: Base cost:

$$C_B = \exp[8.821 - 0.30863\ln(A) + 0.0681(\ln A)^2] \quad (4.3)$$

where A is the heat transfer area between 150 and 12,000 ft^2

Design type, F_D:

Fixed head	$\exp[-1.1156 + 0.0906(\ln A)]$
Kettle reboiler	1.35
U tube	$\exp[-0.9816 + 0.0830(\ln A)]$

Design pressure range (psig), F_P:

100–300	$0.7771 + 0.04981(\ln A)$
300–600	$1.0305 + 0.07140(\ln A)$
600–900	$1.1400 + 0.12088(\ln A)$

Material of construction:

$$F_{MC} = g_1 + g_2(\ln A) \quad (4.4)$$

Material	g_1	g_2
Stainless steel 316	0.8603	0.23296
Stainless steel 304	0.8193	0.15984
Stainless steel 347	0.6116	0.22186
Nickel 200	1.5092	0.60859
Monel 400	1.2989	0.43377
Inconel 600	1.2040	0.50764
Incoloy 825	1.1854	0.49706
Titanium	1.5420	0.42913
Hastlelloy	0.1549	0.51774

Material

Shell/tube	f_m
cs/cs	1.0
cs/304L stainless	1.9
cs/316 stainless	2.2

Pressure

Bars	f_p
<4	1.00
4–6	1.10
6–7	1.25

2.1.4 Equipment Sizing

Before equipment costs can be obtained, it is necessary to calculate equipment sizes, specify operating temperatures and pressures as well as materials of construction. To size equipment, one must prepare material and energy balances to determine the quantities of material processed and the amount of energy transferred. With the above information, preliminary equipment sizes may be determined. In this text, it shall be assumed that a preliminary cost of equipment is to be developed.

Example 4.2

Process design of a shell-and-tube heat exchanger

Problem Statement:

An oil at a rate of 490,000 lb/hr is to be heated from 100 to 170 F with 145,000 lb/hr of kerosene at initially at 390 F from another plant unit. The oil stream enters at 20 psig and the kerosene stream at 25 psig. The physical properties are:

Oil 0.85 sp. gr.; 3.5 cP at 135 F; 0.49 sp.ht.
Kerosene 0.82 sp.gr.; 0.4 cP; 0.61 sp.ht.

Estimate the cost of an all carbon steel exchanger in late 2002. Assume a counterflow 1–2 shell-and-tube heat exchanger

.

$$\text{Energy required to heat oil stream} = (490,000)(0.49)(170 - 100\,\text{F})$$
$$= 16,807,000\ \text{Btu/hr}$$

$$\text{Exit kerosene temperature } T = 390 - \left(\frac{490{,}000}{145{,}000}\right)\left(\frac{0.49}{0.61}\right)(170 - 100\,\text{F})$$
$$= 200\,\text{F}$$

$$\text{LMTD} = \frac{220 - 100}{\ln 2.2} = \frac{120}{0.788} = 152.2\,\text{F}$$

Calculating the F factor for efficiency:

$$P = \frac{170 - 100}{390 - 100} = 0.241$$

$$R = \frac{390 - 200}{170 - 100} = 2.71$$

$$F = 0.88$$

(from Perry [5])

Since the F factor must be greater than 0.75, this exchanger is satisfactory. Then

$$\Delta T = (F)(\text{LMTD}) = (0.88)(152.2) = 133.9\,\text{F}$$

From Appendix B, a U_D of 50 Btu/hr ft^2 F is satisfactory.

$$Q = U_D A\,\Delta T = 16{,}807{,}000 = (50(A)(133.9)$$

$$A = 2510\,\text{ft}^2$$

Use the heat exchanger cost algorithm:

$$C_b = \exp\left[8.821 - 0.30863(\ln A) + 0.0681(\ln A)^2\right]$$

$$C_b = \exp\left[8.821 - 0.30863(7.83) + 0.0681(61.3)\right] = \$39{,}300$$

$$f_d = 1.0$$

$$f_m \text{ for cs/cs material} = 1.0$$

$f_p = 1.00$ (since this exchanger is operating below 4 bar).

Therefore,

$$C = f_d f_m f_p C_b = (1.0)(1.0)(1.0)(\$39{,}300) = \$39{,}300 \text{ in } 1986$$

CE Index 1986 = 318

CE Index late 2002 = 398

The cost of this heat exchanger in late 2001 is (\$39,300)(398/315) = \$49,200.

2.1.5 Cost Indexes

Cost data are presented as of a specific date. They are adjusted through the use of cost indexes that are based upon constant dollars in a base year and actual dollars in a specified year.

2.1.5.1 Marshall and Swift Cost Index (M&S). The Marshall and Swift Index, originally known as the Marshall and Stevens Index, was established in the base year, 1926, with a value of 100. The index is reported as a composite of two major components, namely, a process-industry equipment average and all industry equipment average.

2.1.5.2 Chemical Engineering Index (CE). The Chemical Engineering Index was established in the early 1960 s using a base period of 1957–1959 as 100.

2.1.5.3 Nelson–Farrar Indexes (NF). The Nelson–Farrar Indexes were originally known as the Nelson Refinery Construction Indexes

The choice of the index to use is based upon the industry in which the person works. An engineer in the petroleum or petrochemical business might find the NF Index suitable. In the chemical process industries, either the CE or the M&S are adequate.

4.2.1.7 Use of a Cost Index

A cost index as mentioned earlier is used to project a cost from a base year to another selected year. The following equation is used:

$$\text{Cost at } \theta_2 = \text{cost at } \theta_1 \left[\frac{\text{index at } \theta_2}{\text{index at } \theta_1}\right] \quad (4.5)$$

where

θ_1 = base year
θ_2 = selected year

Example 4.3

Problem Statement:

A stainless steel centrifuge cost $85,000 in 1990. What is the cost of that same centrifuge in 2001? Use the CE Index.

Solution:

$$\text{CE Index in 1990} = 357.6$$

$$\text{CE Index in 2001} = 396.8$$

$$\text{Cost in 2001} = \text{cost in 1990} \frac{\text{CE Index in 2001}}{\text{CE Index in 1990}}$$

$$\text{Cost in 2001} = \$85{,}000 \left(\frac{396.8}{357.6}\right)$$

$$\text{Cost in 2001} = \$94{,}318$$

available [2]. For example, initially a cost escalated for a 3-year period from the present might be

$$C_{esc} = (1 + f')(1 + f'')(1 + f''')(C_{present}) \quad (4.6)$$

where f', f'', f''' = inflation rates expressed as a decimal in 3 years.

Effect of Inflation and Escalation

Inflation refers to the increase in the price of good without a corresponding increase in productivity

Escalation is a more all-inclusive term used to reflect price increases due not only to inflation but also due to supply–demand factors and engineering advances. Projected escalation factors are based on past inflation rates and estimates of where these rates might be in the future.

An effective way is to estimate what the inflation rate might be 1, 2, 3, etc. years in the future and then adjust the rates later as more reliable data become available. For example, initially a cost escalated for a 3-year period from the present will discused in the next example

Example 4.4

Problem Statement:

A drier today costs $221,000. The estimated inflation rates are expected to be:

First year = 3.5%

Second year = 4.2%

Third year = 4.7%

What is the cost of that drier 3 years hence?

Solution:

$$\begin{aligned} C_{esc} &= (1+f')(1+f'')(1+f''')(C_{present}) \\ &= (1.035)(1.042)(1.047)(\$221,000) \\ &= \$249,500 \end{aligned}$$

2.2 ESTIMATION OF FIXED CAPITAL INVESTMENT

Numerous techniques are available for estimating the fixed capital investment. The methods vary from a simple single factor to a detailed method using a code of accounts that involves item-by-item costing.

2.2.1 Order-of-Magnitude Estimates

A project scope is essential before preparing an estimate irrespective of the quality of the estimate.

2.1.1.1 Turnover Ratio

This is a rapid, simple method for estimating the fixed capital investment but is one of the most inaccurate. The turnover ratio is defined as

$$\text{Turnover ratio (TOR)} = \frac{\text{annual gross sales}}{\text{fixed capital investment}}$$

TABLE 4.6 Turnover Ratios[a]

Product	TOR
Acetic acid	1.70
Acrylonitrile	1.55
Ammonia	0.65
Ammonium sulfate	3.82
Benzaldehyde	1.00
Benzene	8.25
Butadiene	1.68
Butanol	1.10
Carbon tetrachloride	1.00
Ethylene dichloride	0.51
Ethylene glycol	1.10
Ethyl ether	6.05
Methanol	1.00
Methyl chloride	2.95
Methyl isobutyl ketone	2.10
Maleic anhydride	4.82
Nitric acid	3.95
Phthalic anhydride	3.12
Polyethylene	0.40
Polypropylene	0.35
Sodium carbonate	0.39
Styrene	5.21
Sulfuric acid	0.63
Urea	2.36
Vinyl chloride	3.40

Sources: Refs. 2, 11.

Example 4.5

Problem Statement:

Estimate the fixed capital investment for a 1500 ton/day ammonia plant using the turnover ratio. The current gross selling price of ammonia is $150/ton. The plant will operate at a 95% stream time.

Solution:

$$\text{TOR} = \frac{\text{annual gross sales}}{\text{fixed capital investment}}$$

$$^{a}\text{Turnover ratio (TOR)} = \frac{\text{annual gross sales, \$}}{\text{fixed capital investment, \$}}$$

From Table 4.6, the TOR for an ammonia plant is 0.65.

$$\text{Annual gross sales} = \$150/\text{ton} \times 365 \times 0.95 \times 1500\,\text{ton/day}$$

$$= \$78{,}000{,}000$$

$$\text{FCI} = \frac{\text{annual gross sales}}{0.65} = \frac{\$78{,}000{,}000}{0.65} = \$120{,}000{,}000$$

2.2.1.2 Fixed Investment per Annual Ton of Capacity

Fixed capital investments may be calculated in an approximate manner using this method. The data for this method are often in the open literature or from information that will allow one to calculate this information. Chemical Week or Hydrocarbon Processing are potential sources.

TABLE 4.7 Fixed Investment per Annual Ton of Capacity

Product	Capacity M tons/year	Fixed investment, $/annual ton capacity
Acetaldehyde	50	400
Ammonia	350	120
Butadiene	240	150
Carbon dioxide	550	80
Ethylene oxide	200	700
Ethyl ether	40	170
Maleic anhydride	60	270
Methanol	300	120
Nitric acid	175	50
Phenol	180	275
Phthalic anhydride	185	220
Polyethylene	20	1800
Propylene	25	210
Sulfuric acid	350	90
Vinyl chloride	500	300

Sources: Refs. 2, 11.

Example 4.6 Problem Statement:
Estimate the fixed capital investment of a 75,000 ton/yr maleic anhydride plant using the data for fixed investment per annual ton capacity in Table 4.7.

Solution:

From Table 4.7 a 60,000 ton/yr plant is $270 investment per annual ton capacity. Therefore, the fixed capital investment of the plant is 75,000 ton/yr × $270 per annual ton, or $20,300,000.

Since this method is sensitive to time and the data presented in Table 4.7 was based on 1986 information, cost indexes must be applied to get a 2001 cost.

$$\text{CE Index for 1986} = 331$$
$$\text{CE Index for late 2001} = 396.8$$

Therefore, the cost in 2001 is estimated to be ($20,300,000)(396.8/331), or $24,335,000.

2.2.1.3 Seven-Tenths Rule

It has been found that cost-capacity data for process plants may be correlated using a logarithmic plot similar to the 0.6 rule. Remer and Chai have compiled exponents for a variety of processes and most are between 0.6 and 0.8.

The use of an average value 0.7 is the name of this method. Table 4.8 and Appendix E contain appropriate data. The equation is

$$\text{Cost plant } B = \text{cost plant } A \left(\frac{\text{capacity plant } B}{\text{capacity plant } A}\right)^{0.7} \tag{4.8}$$

where cost plant A is the cost of that plant with capacity A and cost plant B is the cost of that plant at capacity B.

Example 4.7

Problem Statement:

A company is considering the manufacture of ethylene oxide as an intermediate for its polymer division. The process to be used is the direct oxidation of ethylene. The company built a similar unit in 1997 that had a rated capacity of 100,000 tons annually for $66,000,000. The projected production of the new facility is to be 150,000 tons annually. Estimate the fixed capital investment in late 2001 dollars to produce the required ethylene oxide.

Solution:

$$\text{CE Index for 1997} = 386.5$$
$$\text{CE Index for late 2001} = 396.8$$

Equation (4.8) can be modified to include the cost indexes.

$$\text{Cost}_{150}(2001) = \text{cost}_{100}(1997)\left(\frac{\text{capacity } 150}{\text{capacity } 100}\right)^{0.67}\left(\frac{\text{CEI } 2001}{\text{CEI } 1997}\right)$$

$$\text{Cost}_{150}(2001) = (\$60{,}000{,}000)\left(\frac{150}{100}\right)^{0.67}\left(\frac{396.8}{386.5}\right)$$

$$\text{Cost}_{150}(2001) = (\$60{,}000{,}000)(1.31)(1.027)$$

$$= \$80{,}722{,}000, \text{ say } \$80{,}700{,}000$$

2.2.2 Study Estimates

The information needed to prepare a study estimate includes a project scope, preliminary material and energy balances, preliminary flowsheets, rough sizes of equipment, rough quantities of utilities, rough sizes of building and structures, etc. Study estimates have an accuracy of 230% to 40%.

2.2.2.1 Lang Method

Lang developed a method for obtaining quick estimates of the capital investment based upon information gathered on 14 processing plants of various sizes and types.
These factors include process equipment, instrumentation and automatic control equipment, piping, insulation, electrical, engineering costs, etc., but do not include a contingency factor. The Lang factor method has a tendency to produce high results. The factors are found in Table 4.9.

TABLE 4.9 Lang Factors

Type of plant	Factor
Solids processing	3.10
Solids–fluid processing	3.63
Fluid processing	4.74

Source: Ref. 29.

Example 4.8

Problem Statement:

A small fluid processing plant is considered for construction adjacent to a larger operating unit at a large plant site. The present delivered equipment costs are as follows:

Equipment	Delivered cost
Distillation tower	$500,000
Trays and internals for tower	435,000
Receivers	320,000
Accumulator drum	175,000
Heat exchangers	620,000
Pumps and motors	215,000
Automatic control equipment	300,000
Miscellaneous equipment	150,000

Estimate the battery-limits fixed capital investment, assuming a 15% contingency factor.

Solution:

Sum of the delivered equipment cost = $2,715,000

Because this is a fluid processing plant, the Lang factor is 4.74.

Battery–limits fixed capital investment = ($2,715,000)(4.74)(1.15)

= $14,799,000, or $14,800,000

(All calculations will be rounded to three significant figures.)

2.3 OFFSITE CAPITAL

The offsite facilities include all structures, equipment, and services that do not directly enter into the manufacture of a product. These costs are estimated separately from the fixed capital investment. They are not easy to estimate. Offsite capital would include the utilities and services of a plant. Among the utilities are:

1. Steam-generating and distribution
2. Electrical-generating and distribution
3. Fuel gas distribution
4. Water-well, city, cooling tower, and pumping stations for water distribution
5. Refrigeration
6. Plant air
7. Environmental control systems

The service facilities might include

1. Auxiliary buildings

2. Railroad spurs
3. Service roads
4. Warehouse facilities
5. Material storage—raw material as well as finished goods
6. Fire protection systems
7. Security systems

For preliminary estimates, it is suggested that offsite investment be a percentage of the processing unit's fixed capital investment.

2.4 WORKING CAPITAL

Working capital are the "working funds" necessary to conduct a day-to-day business of the firm. These funds are necessary to pay wages and salaries, purchase raw materials, supplies, etc. Although the initial input of working capital funds come from the company's financial resources, it is regenerated from the sale of products or services. Working capital is continuously liquidated and regenerated but is generally not available for another purpose, so it is regarded as an investment item.

Several methods are available for estimating an adequate amount of working capital for a proposed venture. These methods may be classified into two broad categories:

Percentage methods
Inventory method

2.4.1 Percentage Methods

These methods are adequate for order-of-magnitude, study, and preliminary methods of estimating. The working capital requirements are based upon either annual sales or capital investment.

2.4.2 Percentage of Capital Investment Methods

The ratio of working capital to total capital investment varies with different companies and different types of business. If a company manufactures and sells a product at a uniform yearly rate, then 15–25% of the total capital investment is an adequate amount of working capital.

Example 4.15

Problem Statement:

A company is considering an investment in an aldehyde facility. The engineering department has estimated that the battery-limits fixed capital investment to be \$19MM. Land allocated for the project is \$500,000 and start-up expenses to be capitalized are expected to be \$900,000. The company normally uses 15% of the total capital investment for working capital. Determine the estimated amount of working capital for this project.

Solution:

Land	\$500,000
Fixed capital investment	\$19,000,000
Start-up expenses	\$900,000
Subtotal	\$20,400,000

Since the working capital is 15% of the total capital investment, the subtotal above is 85%, providing no other capital items are added.

Therefore,

$$\text{Total capital investment} = \frac{\$20,400,000}{0.85} = \$24,000,000$$

and

$$\text{Working capital} = \$24,000,000 - \$20,400,000 = \$3,600,000$$

Checking then

$$\frac{\text{working capital}}{\text{total capital investment}} = 15\%$$

or

$$\frac{\$3,600,000}{\$24,000,000} \times 100 = 15\%$$

4.5 START-UP EXPENSES

When a process is brought on stream, there are certain one-time expenses related to this activity. From a time standpoint, a variable undefined period exists between the nominal end of construction and the production of quality product in the quantity required. This period is loosely referred to as start-up. In this period expenses are incurred for operator and maintenance employee training, temporary construction, auxiliary services, testing and adjustment of equipment, piping, and instruments, etc.

Economic evaluation of projects

As the purpose of investing money in chemical plant is to earn money, some means of comparing the economic performance of projects is needed. Before a company agrees to spend a large amount of capital on a proposed project, the management must be convinced that the project will provide a sound investment compared to other alternatives. This section introduced the principal methods used for making economic comparisons between projects.

Cash flow and cash –flow diagrams

During any project, cash initially flows out of the company to pay for the costs of engineering, equipment procurement and plant construction. Once the plant is constructed and begins operation, then the revenues from sale of product begin to flow into the company. The 'net cash flow' at any time is the difference between the earning and expenditure.

A cash–flow diagram, such as that shown in the following figure, shows the forecast cumulative net cash flow over the life of a project. The cash flows are based on the best estimates of investment, operating costs, sales volume and sales price that can be made for the project. A cash-flow diagram gives a clear picture of the resources required for a project and the timing of the earning. The diagram can be divided into the following characteristic regions:

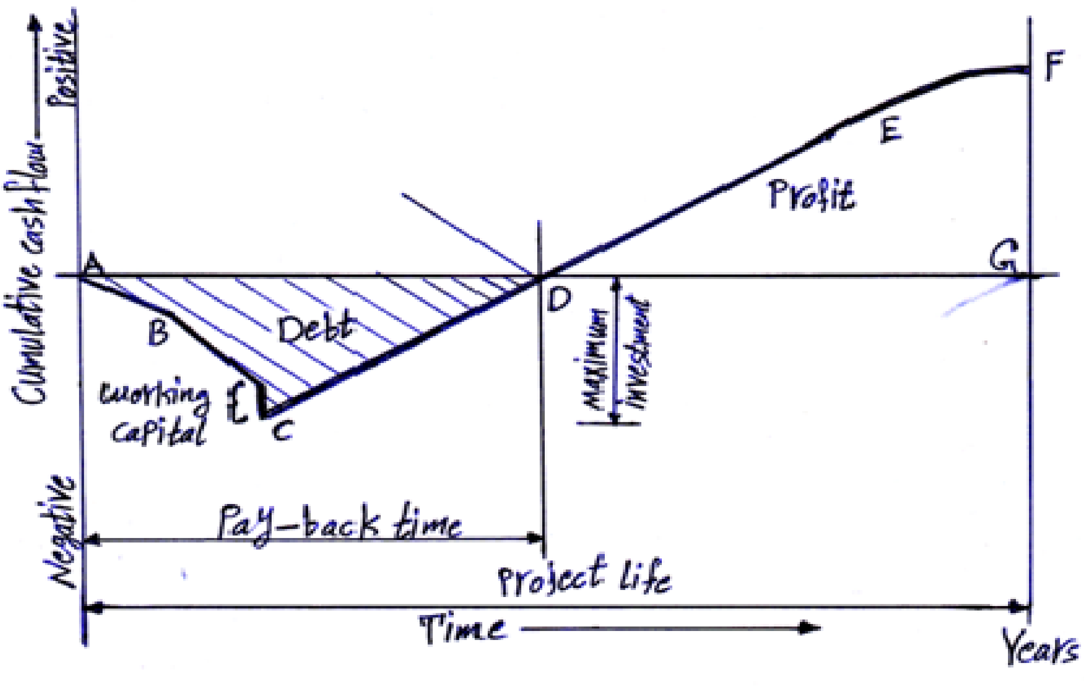


Fig 13: Project cash-flow diagram

A-B The investment required to design the plant.

B-C The heavy flow of capital to build the plant and provide funds for start-up, including working capital.

C-D The cash–flow curve turns up at C, as the process comes on stream and income is generated from sales. The net cash–flow is now positive but the cumulative amount remains negative until the investment is paid off, at point D.

Point D is known as the *break–even point* and the time to reach the break-even point is called the *pay–back time*. (In a different context, the term *break-even point* is also sometimes used for the percentage of plant capacity at which the income equals the cost of production).

D-E In this region the cumulative cash flow is positive. The project is earning a return on the investment.

E-F Toward the end of project life the rate of cash flow may tend to fall off, due to increased operating costs and falling sales volume and price due to obsolescence of the plant, and the slope of the curve changes.

The point F gives the final cumulative net cash flow at the end of the project life.

Net cash flow is a relatively simple and easily understood concept, and forms the basis for the calculation of other, more complex, measures of profitability. Taxes and the effect of depreciation are usually not considered in cash flow diagrams.

Simple methods for economic analysis

Pay-Back time

A simple method for estimating the pay–back time is to divide the total initial capital (fixed capital plus working capital) by the average annual cash flow:

$$Simple\ pay-back\ time = \frac{total\ investment}{average\ annual\ cash\ flow}$$

This is not the same pay-back time indicated by the cash-flow diagram, as it assumes that all the investment is made in year zero and revenues begin immediately. For most chemical plant projects, this is not realistic as investments are typically spread over 1 to 3 years and revenues may not reach 100% of design basis until the second year of operation. The simple pay-back time also neglects taxes and depreciation.

Return on investment

Another simple measure of economic performance is the return on investment (ROI) the ROI is defined in a similar manner to ROA and ROE:

$$ROI = \frac{net\ annual\ profit}{total\ investment} \times 100\%$$

If ROI is calculated as an average over the whole project then:

$$ROI = \frac{cumulative\ net\ profit}{plant\ life \times initial\ investment} \times 100\%$$

Calculation of the after–tax ROI is complicated if the depreciation term is less than the plant life and if an accelerated method of depreciation such as declining balance or MACRS is used. In such cases, it is just as easy to calculate one of the more meaningful economic criteria such as net present value or discounted cash-flow rate of return, described below. Because of this complication, a pre-tax ROI is often used instead:

$$pre - tax\ ROI = \frac{pre - tax\ cash\ \ flow}{total\ investment} \times 100\%$$

Note that pre-tax ROI is based on cash flow, not profit or taxable income, and therefore does not include a depreciation charge. Return on investment is also sometimes calculated for incremental modifications to a large project.

Time value of money

In project cash-flow diagram, the net cash–flow is shown at its value in the year in which it occurred. So the numbers on the ordinate show the 'future worth' of the project. The cumulative value is the 'net future worth' (NFW).

The money earned in any year can be reinvested as soon as it is available and can start to earn a return. So money earned in the early years of the project is more valuable than that earned in later years. This 'time value of money' can be allowed for by using a variation of the familiar compound interest formula. The net cash flow in each year of the project is brought to its 'present value' at the start of the project by discounting it at some chosen compound interest rate.

The future worth of an amount of money, *P*, invested at interest rate, *i*, for *n* years is:

$$Future\ worth\ in\ year\ n = P\ (1 + i)^{n}$$

Hence the present value of a future sum is:

$$present\ value\ of\ \ \ future\ sum = \frac{future\ worth\ in\ \ year\ n}{(1 + i)^{n}}$$

The interest rate used in discounting future values is known as the discount rate and is chosen to reflect the earning power of money. In most companies the discount rate is set at the cost of capital.

Discounting of future cash flows should not be confused with allowing for price inflation. Inflation is a general increase in prices and costs, usually caused by imbalances between supply and demand. Inflation raises the costs of feed, products, utilities, labour and parts, but does not affect depreciation charges, which are based on original cost. Discounting, on the other hand, is a means of comparing the value of money that is available now (and can be reinvested) with money that will become available at some time in the future. All of the economic analysis methods can be modified to allow for inflation.

In practice, most companies assume that although prices may suffer inflation, margins and hence cash flows will be relatively insensitive to inflation. Inflation can therefore be neglected for the purposes of comparing the economic performance of projects.

DEPRECIATION

"Depreciation is a decrease in value of a property over a period of time. Events that can cause a property to depreciate include wear and tear, age, deterioration, and normal obsolescence," according to the Internal Revenue Service [1].

In order for a property to be depreciated, it must meet the following requirements:

. It must be used in a business or held to produce income.

. It must be expected to have a useful life of more than 1 year.

. It must be something that wears out, decays, gets used up, becomes obsolete, and loses its value from natural causes

Depreciation reserve:- is the accumulated depreciation at a specific time.

Book value:- is the original asset investment minus the accumulated depreciation.

Service life :-is the time period during which an equipment item or asset is in service and is economically feasible.

Salvage value:- is the net amount of money obtained from the sale of a used property over and above any charges involved in the removal and sale of the property.

Scrap value:- implies that the asset has no further useful life and is sold for the value of scrap material in it.

Types of depreciation

For further understanding depreciation can be classified as under:

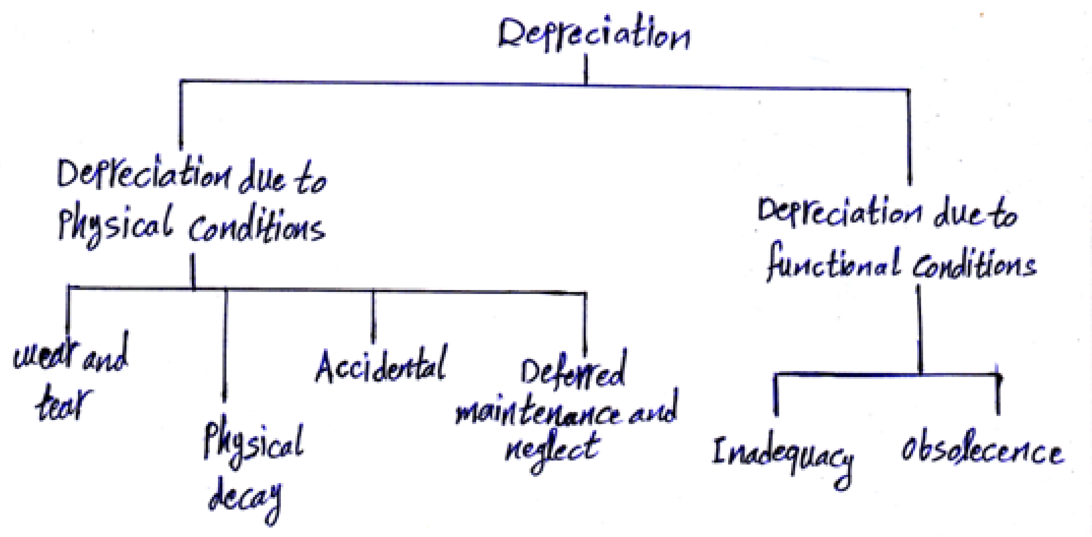


Fig: Classification of depreciation

(a) Depreciation due to wear and tear. Everybody knows that when any machinery performs work, wear and tear of certain components takes place, although sufficient precautions are taken, i.e. proper lubricating and cooling is done, which minimize wear and tear but it cannot be totally prevented. Hence the cost of replacement because of this cause is the value of depreciation due to wear and tear.

(b) Depreciation due to "physical decay". There are certain items in a factory, such as insulation of materials, furniture, electric cables, buildings, chemicals, vessels etc., which get decay, because of climatic and atmospheric effect, with the result the value of these articles goes on reducing with the lapse of time. Although every effort is made by the owner to keep them in serviceable condition even then because of climatic and atmospheric effect, there will be reduction in their costs. This reduction in cost is depreciation due to physical decay.

(c) "Accidental" depreciation. Although, the machine might have installed even few days back and sufficient care is taken to prevent accident, even then, accident may occur due to some wrong operation, or some loose component or some other cause which may result in heavy damages. The depreciation in a machine caused due to this reason is called accidental depreciation.

Now-a-days, to cover this risk, most of the owners get their equipment insured with the insurance companies. For this, owners have to pay certain premium yearly. The amount of premium depends upon the estimated cost and life of equipment.

(d) Depreciation due to "deferred maintenance and neglect". Every manufacturer supplies certain instructions for the smooth and efficient running of equipment. For example, in the case of a vehicle, a manufacturer gave the following instructions:

(i) Lubricating oil of particular grade should be used in engine.

(ii) Oil should be drained and new oil should be refilled after first 1000 km running, and then every 5000 km.

(iii) All the bolts and nuts should be re-tightened after 5000 km running.

(iv) Decarburizing after 300000 km running and so on.

(v)

If these instructions are not followed because of neglect, and proper maintenance is not done as recommended by manufacturer, then the life of the vehicle may be reduced. Depreciation in value because of this, is called depreciation due to deferred maintenance and neglect.

(e) Inadequacy. This is the form of functional depreciation. Inadequacy means reduction in efficiency of an asset. This may result even if any equipment is servicing under proper precautions and sufficient maintenance is provided, there is fall in efficiency with the lapse of time.

Secondly, suppose after 2-3 years of running, the demand of products manufactured by certain plant is increased. But the plant cannot cope with the increased demand. This needs additional money either to replace with the bigger size machinery or installation of more similar size plants. This is, known as depreciation due to inadequacy.

(f) Depreciation by obsolescence. Now-a-days because of rapid scientific advancement, there are frequent changes. If a new machine comes in the market which is more efficient because of new invention or better design than the existing one, manufacturing same type of products by the new one are much cheaper and better than the existing one, then the existing machinery has to be replaced to withstand market competition. This is called depreciation by obsolescence.

DEPRECIATION EQUATIONS

In this section, the current methods for determining annual depreciation charges are presented. The following methods will be discussed:

Straight line Declining balance

A- Straight-Line Method

In this method the cost of an asset is distributed uniformly over its expected useful life. If I is the cost of the asset, n is the expected service life, then the annual depreciation charge is I=n: If salvage value is estimated, then the annual depreciation is

B-Declining-Balance Method

The declining-balance method is also called the fixed-percentage method. It is the basis for the Modified Accelerated Cost Recovery System (MACRS) that will be presented in a later section.

QUALITY ASSURANCE

"Quality control" may be broadly defined as that "Industrial management technique by means of which products of uniform acceptable quality are manufactured". Quality control is concerned with making things right rather than discovering and rejecting those made wrong.

Factors affecting quality

In addition to men, materials, machines and manufacturing conditions, there are some other factors which affect the product quality. These are:

- Market research i.e., demands of purchasers.
- Money i.e., capability to invest.
- Management i.e., management policies for quality level.
- Production methods and product design.

Apart from these, poor packing, in –appropriate transportation and poor after –sales service are areas which can cause damage to a company's quality image. There are many cases where goods of acceptable quality before transportation were downgraded on receipt by the retailer just because they had been damaged in transportation.

Modern quality control performs an evaluation of the customer's requirements and has a part to play at every stage from goods manufactured right through sales to a customer who remains satisfied. To be more effective, quality should be everybody's business and not merely the activity of the persons in the laboratory or in the Inspection Staff.

Quality Assurance

Quality Assurance means to provide the necessary confidence to the customer as well as to top management that all concerned are carrying out their job effectively and that the product quality is as per customer's satisfaction with economy.

Responsibilities of quality assurance department

- Plan, develop and establish Quality policies.
- To assure that products of prescribed specification reaches to the customers.
- Regularly evaluate the effectiveness of the Quality programmers.
- Conduct studies and investigations related to the quality problems.
- Liaise with different department, in and outside the organization.
- Organize training programmers on quality.
- Plan and coordinate vender quality surveys and evaluate their results.
- Develop Quality assurance system and regularly evaluate its

Quality Assurance System

Quality assurance system should be developed incorporating the following aspects:

- Formulate the quality control and manufacturing procedures.
- Percentage checking be decided.
- Procedure and standards for plant performance as regards to quality be developed.
- Rejection analysis and immediate feedback system for corrective action.
- Prepare a manual for quality assurance.
- Formulate plans for quality improvement, quality motivation and quality awareness in the entire organization.

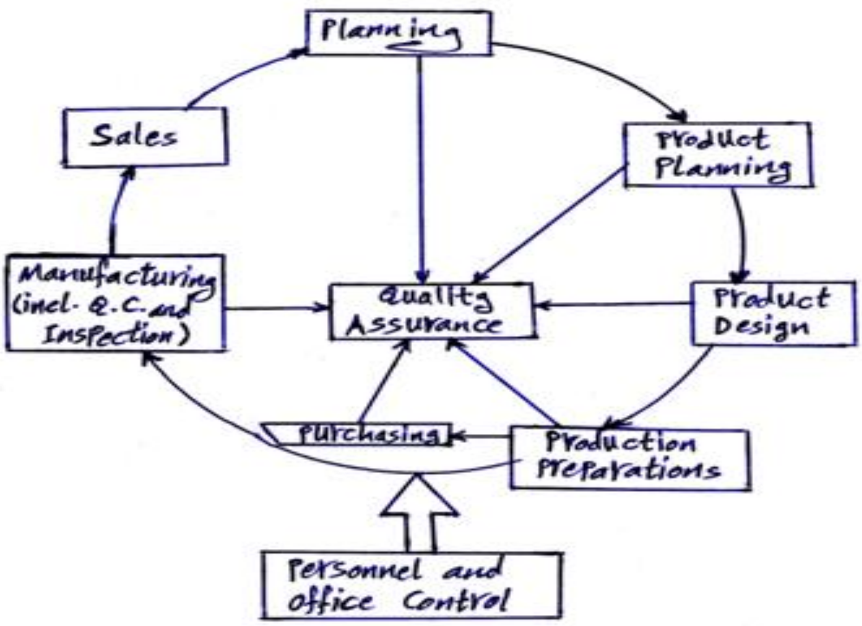


Fig 19: Concept of cross function for quality management

Economics of quality

The good economic performance is the most essential for survival and growth of any organization in the highly competitive environment. Therefore, one of the most common objectives of every organization is to attain excellence in its economic performance. The single most important factor which leads to good economic performance is the 'quality' of its products or services.

Therefore, in order to achieve economy, quality management system must contribute towards the establishment of customer- oriented quality discipline in the marketing, design, engineering, procurement, production, inspection, testing and other related servicing functions. Everybody in the organization must be involved in the production and delivery of quality product or services, consistently to meet the customer needs and satisfaction.

Quality and cost

Studies have indicated that any reduction in quality results in a reduced level of satisfaction and decrease in customer goodwill toward the producer. This will lead to reduction in return on investment in the long run. Following are the general principles of quality and cost relationship:

- **(i)** Costs of poor quality are far larger than that had been recognized.
- **(ii)** Appraisal costs are reduced by focusing on preventing errors at the source.
- **(iii)** System is established for reducing the cost rather than reducing the quality.
- **(iv)** By focusing on quality improvement overall, performance of the firm can be improved.
- **(v)** Focus of quality improvement is shifted from product attributes to operational procedure.

Quality Cost (or costs associated with quality)

Quality cost means cost of poor quality goods or services. Following are the main quality associated costs:

1. **Failure costs**

   (A) Internal failure costs:

   (i) Scrap and rework cost.

- **(ii)** Costs involved in testing, inspecting and sorting for down-gradation.
- **(iii)** Losses due to avoidable processing.
- **(iv)** Expenditure in failure analysis.

(B) External failure costs:

- **(i)** Warranty charges
- **(ii)** Redressal of complaints
- **(iii)** Loss of future sales
- **(iv)** Other expenses on return of materials, failure analysis outside the factory.

2. Appraisal/Detection costs

- **(i)** Incoming test and inspection including materials, in-process and final quality sampling.
- **(ii)** Quality audits.
- **(iii)** Equipment calibration.
- **(iv)** Evaluation of performance.
- **(v)** Evaluation of customer satisfaction.

3. Prevention costs

- **(i)** Quality planning
- **(ii)** New product review
- **(iii)** Process control
- **(iv)** Training and education
- **(v)** Process quality planning.

Quality cost control

For the purpose of reducing the cost, when internal and external failure costs are cut down, the appraisal cost and preventive cost may slightly go up. Therefore, it is necessary for optimum balance to reduce failure cost with slight increase in appraisal and preventive cost, with the aim of substantial reduction in total quality cost without compromising with the quality.

Efforts for reducing quality cost must be continuous. The cost reduction programme must be followed in following stages:

1. Identification of quality cost items,

2. Structuring of quality cost reporting, including related analysis and control, and
3. Maintenance of programme to ensure that the objectives of higher quality at lower cost.

Quality control and quality cost must be directed in such a way so as to provide the firm with major added business value.

Quality control organization

Over the years, the status of the quality control organization changed from a function merely responsible for detecting inferior or standard material to function that establishes what are termed preventive progremmes. These programmes are designed to detect quality problems in the design stage or at any point in the manufacturing process and to follow up on corrective action. Immediate responsibility for quality products is rest with the manufacturing departments.

All the activities concerning product quality are usually brought together in the organization which may be known as inspection, quality control, quality assurance department or any other similar name.

Quality control is a staff activity since it serves the line or production department by assisting them in managing quality. Since the quality control function has authority delegated by management to evaluate material produced by the manufacturing department, it should not be in a position to control or dictate to the quality activity.

The quality control organization depending upon the type of product, method of quality is sufficient enough to carry out following activities:

1. Inspection of raw material, product or processes.
2. Salvage inspection to determine rejected part and assembly disposition.
3. Records- and- reports maintenance.
4. Statistical quality control.
5. Gauges for inspection.
6. Design for quality control and inspection.
7. Quality control system maintenance and development.

Quality management system

A quality management system organizes overall activities of the company in such a way that the technical, administrative and human factors affecting the quality of products or services are under control. The quality management system guides the cooperated actions of the people, machines and information to achieve the quality objectives.

1. Activities

Activities of quality management system are:

(i) Marketing to evaluate customer needs and use requirements.

(ii) Design and engineering to translate the customer needs into product, process and material specifications.

(iii) Purchasing to select the competent vendors who can supply materials, components, sub assemblies as per specifications.

(iv) Production to ensure that product is produced under controlled conditions in conformance to standards.

(v) Quality assurance to identify appropriate test methods and exercise quality control techniques.

(vi) Shipping to ensure proper packaging, transportation and distribution of material.

(vii) Documentation to maintain system and progress documents at each stage of operation.

(viii) Product development for innovation and improvement based on customer's feed back.

(ix) Auditing to identify the non- conforming of the system and product, and follow up the corrective actions.

2. Benefits

(i) To meet the customer requirements by providing quality products or services to satisfy the customer needs.

(ii) Good reputation helps in better marketability of the company's products and services.

(iii) Confidence is created

(iv) Consistency in quality

(v) Productivity improvement

(vi) Better financial performance

(vii) Brings clarity in working

(viii) Better documentation

(ix) Better monitoring

(x) Increases export potential

(xi) Human resources development.

3. Quality function

(i) Marketing and market research

(ii) Design and product development

(iii) Procurement

(iv) Process planning and development

(v) production

(vi) inspection, testing and examination

(vii) Packaging and storage

(viii) Sales and distribution

(ix) Installation and operation

(x) Technical assistance and maintenance

(xi) Disposal after use.

4. Quality and top management

Responsibility for and commitment to quality always is belong to the highest level of management. Following action points are necessary to be adopted by top management to achieve quality objectives of the company:

(i) Define and state quality policy

(ii) Appoint a management representative

(iii) Define responsibility and authority

(iv) Establish an internal verification system

(v) Establish a quality system

(vi) Review the functioning of quality system at regular intervals.

5. Installing the quality system

(A) *Preparations*

(i) Analyses the existing status and identify what needs to be done. Prepare an action- plan.

(ii) Develop an organization structure.

(iii) Develop quality system documentation.

(iv) Prepare the material and machinery resources.

(B) *Implementation*

(i) Implement the documented quality system.

(ii) Establish internal quality audit system.

(iii) Monitor, control and stabilize the quality system.

(iv) Harmonies the practices with the standards.

Objectives of quality control

Following are the important objects of quality control:

(1) To decide about the standard of quality of a product that is easily acceptable to the customer and at the same time this standard should be economical to maintain.

(2) If quality of product is falling down during manufacturing then steps should be taken to check this deviation.

(3) To take necessary steps so that the products which are below standard should not reach to the customers.

(4) To take different measures to improve the standard of quality of product.

Functions of quality control department

Quality control department has the following important functions to perform:

(1) Only the products of uniform and standard quality are allowed to be sold.

(2) To suggest methods and ways to prevent the manufacturing difficulties.

(3) To reject the defective goods so that the products of poor quality may not reach to the customers.

(4) To find out the points where the control is breaking down and investigates the causes of it.

(5) To rectify the rejected goods, if it is possible. This procedure is known as rehabilitation of defective goods.

The cost balance

It means the problem of balancing the value of a given result against the cost of a given result. Usually, it becomes progressively more expensive as the quality specification narrows the limits. This expense increases greatly as we approach closer and closer to perfection. This is shown in the following figure. The quality control engineer has always before him the problem of demanding great precision to fulfill the requirements to which the goods will be used and yet keeping the precision within justified limits.

(Quality at level Y is the most economical. A drop to level X reduces the cost by M but reduces the value by N which is greater than M.A rise to level Z increases the value by O but increases the cost by P, which is greater than O).

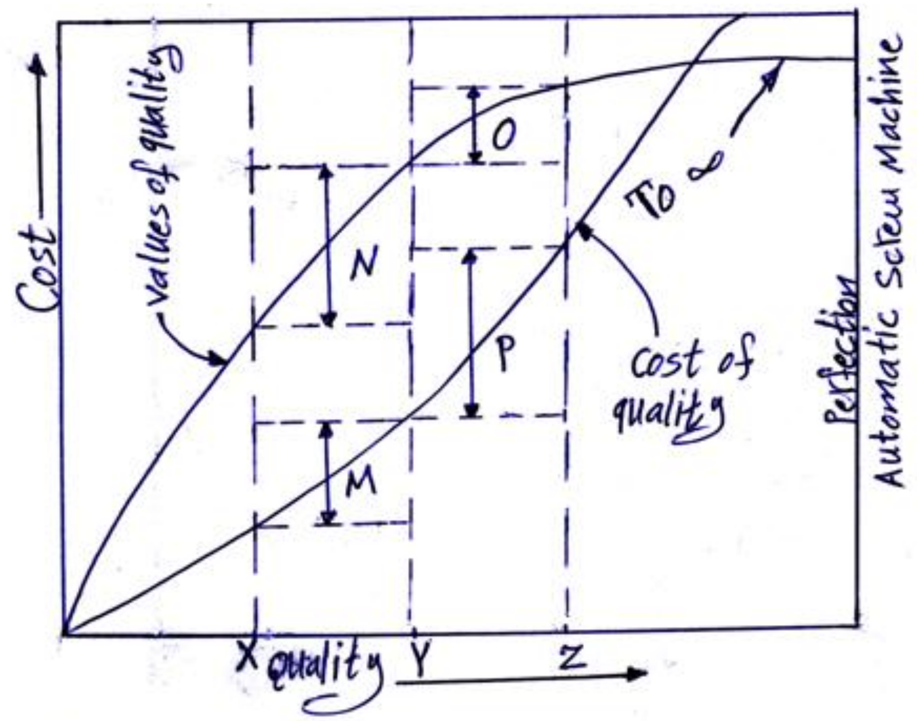


Fig 20: Relation of cost and quality

Advantages of quality control

There are many advantages by controlling the product quality. Some of them are listed below:

- Quality of product is improved which in turn increases sales.
- Rejection and rework are minimized thus reducing wastage. So the cost manufacturing reduces.
- Good quality product improves reputation.
- Inspection cost reduces to great extent.
- Uniformity in quality can be achieved.

- Improvement in manufacturer and consumer relations.
- Improvement in technical knowledge and engineering data for process development and manufacturing design.

Customer satisfaction

Quality management is focused on the requirements of the customer, who have a set of expectations and requirements that must be met to win repeat business. From quality point of view, requirements of the customers are related to the following elements:

(a) Specifications: to meet the expected requirement from the product.
(b) Conformance: whether the product meets the expectation for which he wants to purchase.
(c) Reliability: whether it can meet the requirement through out the expected life.
(d) Value (cost): whether it fulfills its value.
(e) Delivery: whether it will be available, when desired.

In order to achieve the objective of customer satisfaction, following duties should strictly be performed by every individual/ department:

1. To monitor performance and customer satisfaction levels.
2. To identify improvements necessary in the customer interface.
3. To assess and agree the customer's requirements.
4. To tailor output to the customer's demand.

Total quality management

In a total quality management concept, the word quality has a wider meaning, it means quality of output of every department and by every employee, cleanliness, orderliness, punctuality, customer service, standardization of works and continuous efforts for their improvement are also part of T.Q.M. in this, needs of the customer are constantly monitored to improve the products and processes to meet their requirement.

In total quality management programme, voluntary participation of workpeople is sought for the quality of the task.

Customer satisfaction is the most important aspect of TQM. Here customers are all those who are affected by our work. They could be external to the organization or may be inside the organization.

Total quality control

Total quality control (TQC) may be defined as," an effective system for integrating the quality development, quality maintenance and quality improvement efforts of the various groups in an organization so as to enable production and service at the most economical levels which allow for full customer satisfaction". TQC requires participation of all divisions.

Characteristics of total quality control concept

(1) Quality control is the responsibility of all the workers and all the divisions.
(2) Total quality control is a group activity and cannot be done by individuals.
(3) It calls for team work.
(4) Quality control circle activities are part of the T.Q.C.
(5) It adopts the philosophy of refusing to allow any defect.
(6) It relies on Sampling (S.Q.C.) rather than cent-percent inspection.
(7) Continuous process for improving quality of products and services.
(8) All employees are provided with proper tools and proper training to do the quality job.
(9) It clearly defines top managements permanent commitment to quality.

Integrated quality control

In affecting integrated quality control, control of quality is central, but at the same time cost control (profit control and price control), quantity control (amount of production, of sales, of stock), and control of delivery date are to be promoted. This method is based on the fundamental assumption of QC that a manufacturer must develop, produce and sell commodities that satisfy the needs of consumers. This extends the term quality to the quality of work in the offices, in the service related industries and in the banks etc.

Elements of TQM

1. Customers satisfaction
2. Employees involvement
3. Total organization involvement
4. Morale of employees
5. Quality control circles and suggestion system.
6. Higher revenue.
7. Lower cost
8. Quality control
9. Control of production.
10. Quality planning
11. Quality implementation
12. Quality improvement
13. Quality assurance system
14. Vender control and quality in procurement.
15. Customer relationship management.
16. Measurement information analysis
17. Strategic quality management.
18. Leadership
19. Quality education and training.

Ways for T.Q.M.

1. Adopt new philosophy of 'not to allow defects to occur'.
2. Create consistency of purpose for improvement.
3. Improving production and service quality, should a continuous process.
4. Cease dependence on mass inspection. Adopt statistical quality control.
5. Insist quantifiable evidence from the suppliers about the quality of their product.
6. All employees should be trained, retained and refresher courses be arranged.
7. Provide proper tools to all the employees.

8. Adopt proper communication system.
9. Encourage productivity.
10. Encourage coordination between departments
11. Permanent commitment of top management to quality.
12. Respect towards 'work' and humanity'.
13. Adopt consumer orientation and not the product orientation.
14. Objective should be, 'Quality first, and not the short term profits'.
15. Use facts and data.

I.S.O.

Introduction

ISO is the international organization for standardization. It is located in Switzerland and was establish in 1947 to develop common international standards in many areas. Its member comes from over 130 national standards bodies. ISO first published its quality standards in 1987, revised them in 1994, and then republished an updated version in 2000. Standards presently applicable are known as" ISO: 2000 standards", and facilitate international trade by providing a single set of standards that people everywhere would recognize and respect.

ISO-9000 refers to a set of standards and is the only available internationally accepted standard for quality management system in the world. It is rapidly becoming the most important quality standard and hundreds of thousands companies in over 100 countries have already adopted it. ISO-9000 is applicable to all types of organizations in manufacturing or service sectors.

It is a documentation oriented system which allows complete freedom selection and use of process and farming of operating procedures and work instructions. This is a widely recognized quality management tool and meets the quality requirements of every kind of products or services. Production of consistently good quality product or service is very important for customer Confidence Company who wants to survive and grow, have either adopted this standard or in the process of adopting it.

A properly established quality management system will help to reduce cost, improve quality, and develop confidence and a good image in the minds of customers and public. This requires consistent implementation, careful auditing and total commitment of the whole organization. ISO-9000 set of standards are" generic management system standards". This means that the same standards can be applied:

- To any organization, large or small, whatever its product;
- Including whether its" product " is actually a service;
- In any sector of activity; and

- Whether it is a business enterprise, a public administration, or a government department.

The "ISO-9000 quality management system" adopting organization fulfills:

- The customers quality requirements;
- Applicable regulatory requirements;
- Enhance customer satisfaction; and
- Achieve continual improvement of its performances

Many companies require their suppliers to adopt ISO-9000 and get registered. Registered companies find that their market opportunities have increased as it ensures a sound quality management system. Registered companies had reduction in customer complaints significant reductions in operating costs and increased demand for their product and services. Other benefits can include better working conditions, increased market share, and increased profits.

Characteristics of ISO 9000

- ISO 9000 is the only available internationally accepted standard for quality management system.
- It does not replace but complements the products standards.
- ISO 9000 is applicable to all types of industries or organization in manufacturing or service sector.
- It stands for systematic standardization and certification rather than product standardization and certification.
- ISO 9000 is a documentation oriented system which allows complete freedom on selection and use of processes and framing of operating procedures and work instructions.
- A mistake made in selection of proper product standard can never be compensated by ISO 9000 implementation.

Areas covered in ISO 9000

(1) ISO 9000 provides the guideline for selection and use of the quality standards.

(2) ISO 9001 is a quality system model for quality assurance in design/ development, production, installation and servicing. This is most exhaustive standard. The engineering organizations, where the manufacturing capabilities are based on in house designs have to work for ISO 9001 certification. Manufacturers of ***(a)*** household good like TV, refrigerator etc. ***(b)*** perishable consumer goods like tooth- paste etc. which have both servicing and design / development have to work towards ISO 9001.

(3) ISO 9002 provides a model for quality assurance only in production and installation. This does not cover areas of design / development and servicing. ISO 9002 also looks at internal quality audits. Steel plants, departmental stores, hospitals, chemical plants etc. where the designing and servicing do not constitute the key activities, may prefer ISO9002.

(4) ISO 9003 deals only with quality systems related to final inspection and testing.

(5) ISO 9004 provides guideline for quality management and quality system elements.

In addition to the ISO 9000 series, ISO 8402 deals with vocabulary used in the ISO 9000 series.

ISO -9000: 2000 set of standards

ISO-9000 currently includes three quantity standards: ISO-9000: 2000, ISO-9001: 2000 and ISO-9004: 2000. In these standards ISO-9001: 2000 presents requirements, while ISO-9000: 2000 and ISO-9004: 2000 presents guidelines. All of these are process standards (not product standards). The certificate is awarded to an organization in respect of compliance of standards ISO-9001: 2000.

Following standards currently make up the ISO 9000 family:

Standards of Guidelines	***Purpose***
ISO-9000: 2000, Quality Management System- Fundamentals and vocabulary.	For understanding the standards and defines the fundamental terms and definitions used in the ISO-9000 family
ISO -900: 2000, Quality Management Systems- Requirements	This is the requirement standard used to assess the ability to meet the

	customer and applicable regulatory requirements and thereby address customer satisfaction. It is now the only standard in the ISO-9000 family against which third-party certification can be granted.
ISO -9004: 2000, Quality Management Systems-Guidelines for performance improvements.	This guideline standard provides guidance for continual improvement of your quality management system to benefit all parties through sustained customer satisfaction.

From the above it is clear that, in order to develop a quality management system, you are required to only meet the requirements specified by ISO-9001: 2000. You can consult the ISO-9000: 2000 and ISO-9004: 2000 guidelines only when you need clarification. Your quality management system must simply meet requirements as specified in ISO-9001: 2000. When your quality system has been fully developed and implemented, you carry out an internal assessment to ensure that you have not every single ISO-9001: 2000 requirement. When you are ready, you ask an external auditor to audit the effectiveness of your quality management system. If your auditors find that you have introduced and implemented the ISO-9001: 2000 standard, they will certify that your quality system has met ISO's requirements. They will then issue an official certificate to you and will record your achievement in their registry. You can then announce to the world that the quality of your products and services is managed, controlled, and assured by a registered ISO-9001: 2000 Quality Management Systems.

ISO-9000: 2000 standards

ISO-9000: 2000 standards are based on eight quality management principles. ISO choose these principles because they can be used to improve organizational performance and achieve success. These principles can be used by senior management as a framework to guide their organization towards improved performance. The eight quality management principles as given in the ISO-9000: 2000, Quality management

systems- fundamentals and vocabulary; and in ISO-9004: 2000, Quality management systems-Guidelines for performance improvements are:

Principle 1: Focus on your customer

Organizations depend on their customers. Therefore:

1- Organizations must understand customer needs.
2- Organizations must meet customer requirements.
3- Organizations must exceed customer expectations.

Principle 2: Provide leadership

Organizations rely on leaders. Therefore:

1- Leaders must establish a unity of purpose and set the direction the organization should take.
2- Leaders must create an environmental that encourages people to achieve the organization's objectives.

Principles 3: Involvement of people

People at all levels are the essence of an organization and therefore:

1- Organizations must encourage the involvement of people at all levels.
2- Organizations must help people to develop use their abilities.

Principle 4: Use a process approach

Organizations are more efficient and effective when they use a process approach. Therefore:

1- Organizations must use a process approach to manage activities and related resources.

Principles 5: Take a system approach

Organizations are more efficient and effective when they use a systems approach. Therefore:

1- Organizations must identify inter- related processes and treat them as a system.
2- Organizations must use a systems approach to manage their inter-related processes.

Principles 6: Encourage continual improvement

Organizations are more efficient and effective when they continually try to improve. Therefore:

1- Organizations must make a permanent commitment to continually improve their overall performance.

Principles 7: Get the facts before taking a decision

Organizations perform better when their decisions are based on facts. Therefore:

1- Organizations must base decisions on the analysis of factual information and data.

Principle 8: Mutually beneficial supplier relationship

Organizations depend on their supplier help them create value. Therefore:

1- Organizations must maintain a mutually beneficial relationship with their suppliers.

ISO-9001: 2000 - Requirements

______ISO-9001: 2000 is the standard intended for quality management system assessment and registration. These apply uniformly to organizations of any size or description. ISO presents its requirements in section 4 to 8 of ISO-9001: 2000 standard. Board features of these sections and requirement thereof which have to be built in the documentation and then implemented are given hereunder:

1- **Systematic requirements**
   - **a-** Establish your quality system.
   - **b-** Documentation requirements.

2- **Management requirements**
   - **a-** Management commitment.
   - **b-** Customer focus.
   - **c-** Establish a quality policy.
   - **d-** Quality planning.
   - **e-** Control and quality system.
   - **f-** Management review.

3- **Resource requirements**
   - **a-** Provisions of resource.
   - **b-** Providing human resources.
   - **c-** Providing infrastructure.
   - **d-** Providing work environment.

4- **Realization requirements**
   - **a-** Planning of product realization.
   - **b-** Customer related processes.
   - **c-** Product design and development.
   - **d-** Control purchasing function.
   - **e-** Control production and service activities.
   - **f-** Control of monitoring and measuring devices.

5- **Remedial requirements**
   - **a-** Perform remedial processes.

b- Monitor and measure quality.

c- Control non- conforming products.

d- Analyze quality information/data.

e- Make quality improvements.

Compatibility with other management systems

This international standard (ISO 9001:2000) has been aligned with ISO 14001:1996 in order to enhance the compatibility of the two standards for the benefit of the user community.

This international standard does not include requirements specific to other management systems, such as those particular to environment management, occupational health and safety management, financial management or risk management. However, this International Standard enables an organization to align or integrate its own quality management system with related management system requirements. It is possible for an organization to adapt its existing management system(s) in order to establish a quality management system that complies with the requirements of this International Standards.

Sampling Inspection

To understand 'sampling inspection' properly, we must first discuss the two words' sampling' and' inspection'.

Sampling: A sample may be defined as the number of items or component parts drawn from a lot, batch or population. Sampling is an act of drawing samples from a batch on random basis. Since sampling depends upon statistical probability, samples must be drawn from all sides and different depths of the box containing the batch of the component parts, for inspection, so that every part has an equal chance of

being selected. The samples should be collected at regular intervals from entire production run so as to obtain a sample truly representative of the lot.

Inspection: Every manufactured item or component is expected to perform certain functions. The act of checking whether the item or component will be able to perform that function is known as inspection. The act of inspection separates defective items from non –defective ones to ensure the adequate quality of the product. It also locates defects in raw materials and flows in the processes which otherwise cause problems at final stage.

Advantages: advantages of sampling inspection as compared to 100 percent inspection are:

1- Less amount of inspection for achieving a predecided degree of certainty about the quality.
2- It is less expensive and less time consuming.
3- Since less fatigue and boredom is experienced by inspectors, their operating efficiency is high.
4- Since fewer parts are inspected, no damage to remaining pieces.
5- Fear of rejection of entire lot, pressurizes for improvement in quality.
6- It is suitable where destructive test is necessary for inspection.

<u>Basis of sampling inspection</u>

(i) Variables basis and
(ii) Attributes basis.
(i) Variable basis. In this, inspection of samples is conducted on measurement (variable) basis, i.e. on the basis of actual readings taken. Examples of variables are dimensions in mm; hardness in units; operating temperature in Fahrenheit: tensile strength in kg/cm^2 ; percentage of particular item in a chemical compound ; weight in kg of the contents of any packet, time in seconds of the blow of a fuse, life in hours of an electric bulb and so on. Variables are dealt in $\bar{X}$ (x-bar) and R Shewart control charts.
(ii) Attributes basis. In this, an inspection of samples is conducted on 'GO' and 'NOT GO' basis, i.e. determining whether or not the product in the sample conforms to the specified tolerances.

Many requirements are necessarily stated in items of attributes rather than variables. For example, the glass cover of a pressure gauge either is not cracked or is cracked. A lithographic paper either has a certain desired colour or it has not. Similarly, a spot weld in sheet metal either has not caused cracked edges of the sheets or it has. The surface finish of the top dining table presents a satisfactory appearance or it does not. Since, majority of acceptance sampling is conducted on attributes basis, therefore, acceptance tables are formed for' GO' and 'NOT GO' data.

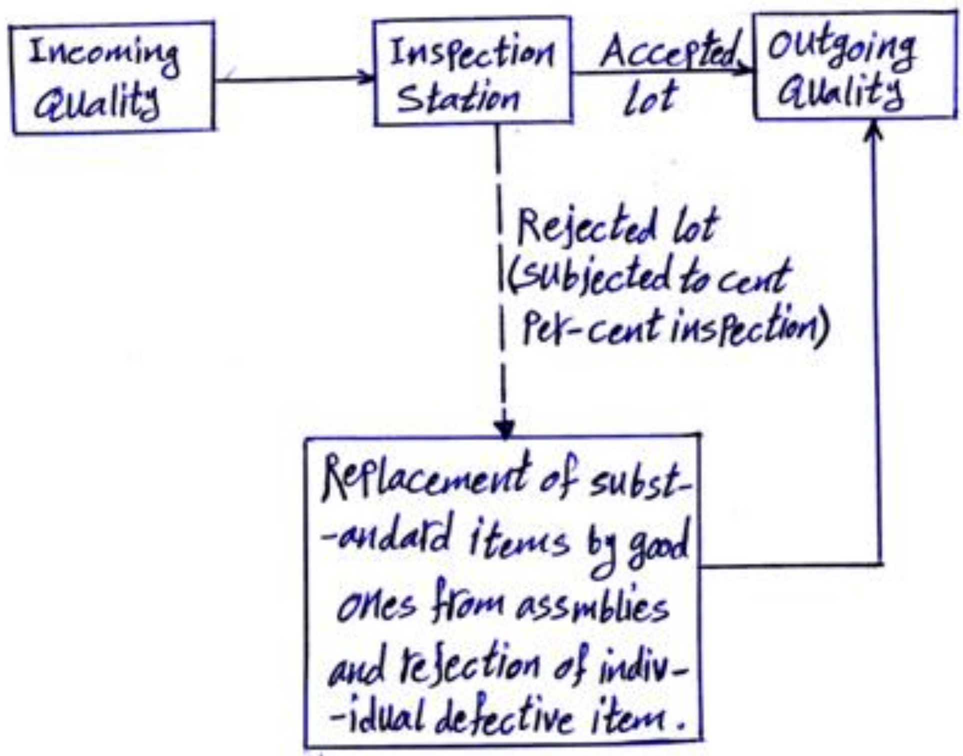


Fig 21: Dealing with lot rejected in sampling inspection

Defects classification

In sampling, the defects in a product can be classified in three categories. These defects are also known as quality characteristic of any product and are:

(a) Critical. It is that defect, which renders the use hazardous and which do not allow the poor performance of the product when in use.

(b) Major. It is defect, which could result in the failure of the product or materially affect its usability, operation or performance.

(c) Minor. It is that defect, which does not materially affect the usability, operation or performance of the product.

Procedure of sampling inspection

Following four steps are essential in setting up acceptance sampling inspection:

(1) Setting of inspection lots;

(2) Arranging for rational lots;

(3) Establishing an allowable per cent defective;

(4) Selecting a sampling plan.

(1) Setting of inspection lots.

Under sampling inspection, the lot size varies from about 300 products upto any number. Theoretically, there is no upper limit for the lot size but in practice lots should be kept small enough so that they are easy to move and do not move and do not require special handling. For lots smaller than 300, either process inspection or screening is economical and, therefore, preferable.

Another factor influencing lot size is how frequently you wish to inspect the work from one machine or process.

(2) Arranging for rational lots.

A 'rational lot' is one whose units have been produced from the same sources. As far as possible, a lot should consist of products manufactured from one batch of raw materials, one production line, known pattern, mould or die and in one and the same shift. Often it is not possible in practice to separate product strictly in this matter but it should adhere to the rule of arranging rational lots as closely as possible. If we mix up products from different sources and find a bad lot, we

cannot put out finger immediately upon the source of trouble which can be pointed out if there are rational lots.

(3) Establishing an allowable per cent defective.

In mass production, it is often not possible to continually produce hundred per cent satisfactory products. It can be assumed that certain percentage of defectives will always present on certain processes; however if the percentage does not exceed a certain limit, it is more economical to allow the defectives to go through rather than to sort out each lot. This limit is called the 'allowable per cent defective'.

But how to establish the allowable percent defective? To do this, watch the product for some time while it is under regular operation. Collect sufficient data over a period of one to two weeks to determine the percentage of defective normally occurring in the product from certain equipment or process.

(4) Selecting a sampling plan.

Now- a- days, three important plans are in use:

(a) Single sampling plan
(b) Double sampling plan
(c) Sequential or multiple sampling plan.

(a) Single sampling plan:

In inspection, defective product is one that fails to conform specifications. The most common system in this plan is to take a single sample from the lot at random. Single sample does not mean unit, it may have number of unit. The acceptance and rejection of the lot depends on the number of defective in the sample. For designing a sample plan

(b) Double sampling plan:

In the single sampling plan, if the sample size on inspection is found defective then the entire lot is rejected. To overcome this, double sampling plan is a sort of modification on single sampling plan. In this method, the lot is not rejected but again a second sample is drawn to judge the quality.

(c) Sequential sampling plan:

The third form of the sampling plan is the sequential one. In this plan- one, two, three or more samples are drawn before it is possible to reach a decision to accept or reject the lot

MAINTENANCE MANAGEMENT

Maintenance of machine means efforts directed towards the up-keep and the repair of that machine. Maintenance is responsible for the smooth and efficient working of equipment and helps in improving its productivity. It also helps in keeping the machine in a state of maximum efficiency with economy.

The following figure indicates maintenance functions performed with their input, and expected results as output. These outputs are controlled through different parameters and based on feedback of these parameters further controls can be applied till desired maintenance results are obtained.

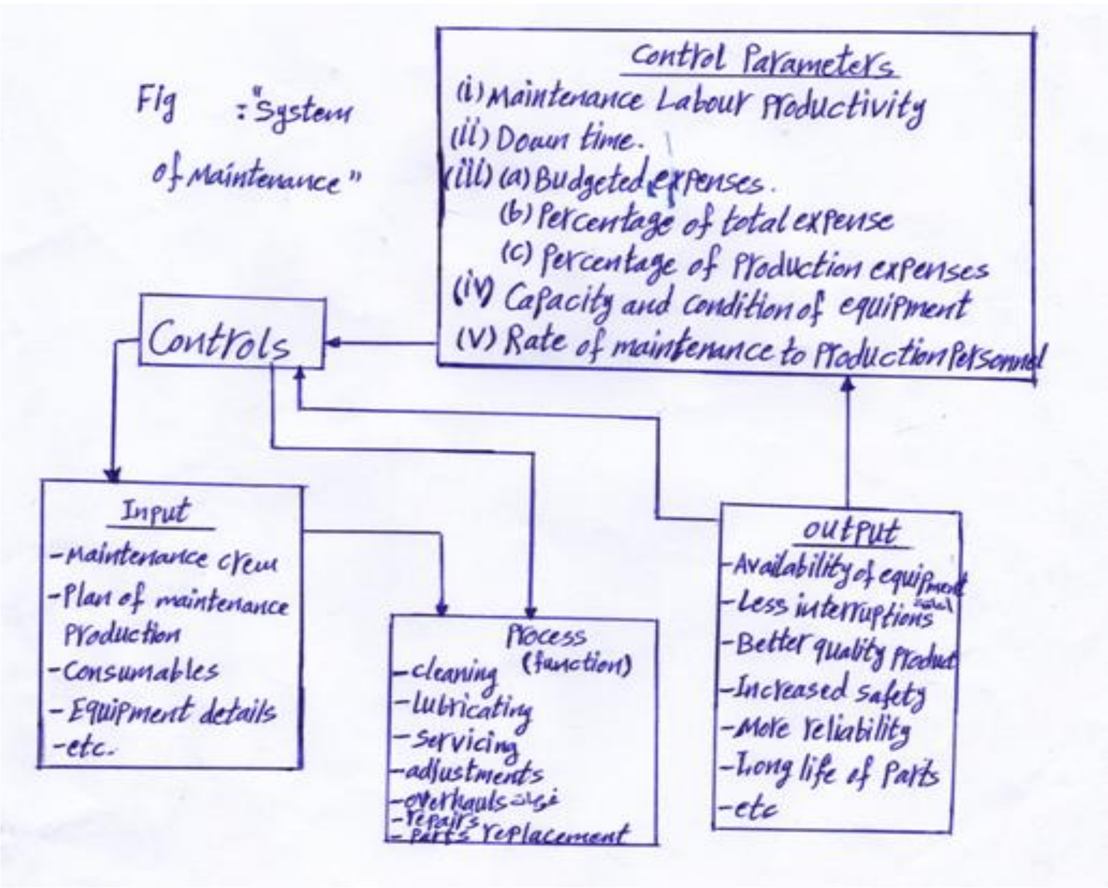


Fig 14: System of maintenance

Objectives of maintenance

The main objectives of maintenance are:

(a) To maximize the availability of plant, equipment for productive utilization.

(b) To extend the lifespan of plant/equipment by minimizing their wear and tear and deterioration.

(c) To reduce the cost of lost production due to break down.

(d) To ensure safety of personnel.

Types of maintenance

Reactive Maintenance

Reactive maintenance is basically the "run it till it breaks" maintenance mode. No actions or efforts are taken to maintain the equipment as the designer originally intended to ensure design life is reached. Studies as recent as the winter of 2000 indicate this is still the predominant mode of maintenance in the United States

The referenced study breaks down the average maintenance program as follows:

- >55% Reactive
- 31% Preventive
- 12% Predictive
- 2% Other.

Note that more than 55% of maintenance resources and activities of an average facility are still reactive

Advantages

- Low cost.
- Less staff.

Disadvantages

- Increased cost due to unplanned downtime of equipment.

•Increased labor cost, especially if overtime is needed.

•Cost involved with repair or replacement of equipment.

•Possible secondary equipment or process damage from equipment failure.

• Inefficient use of staff resources.

Preventive Maintenance

Preventive maintenance can be defined as follows: Actions performed on a time- or machine-run-based schedule that detect, preclude, or mitigate degradation of a component or system with the aim of sustaining or extending its useful life through controlling degradation to an acceptable level.

Advantages

• Cost effective in many capital intensive processes.
•Flexibility allows for the adjustment of maintenance periodicity.
• Increased component life cycle.
• Energy savings.
• Reduced equipment or process failure.
•Estimated 12% to 18% cost savings over reactive maintenance program.

Disadvantages

• Catastrophic failures still likely to occur.
• Labor intensive.
• Includes performance of unneeded maintenance.
•Potential for incidental damage to components in conducting unneeded maintenance.

Predictive Maintenance

Predictive maintenance can be defined as follows: Measurements that detect the onset of a degradation mechanism, thereby allowing casual stressors to be eliminated or controlled prior to any significant deterioration in the component physical state. Results indicate current and future functional capability.

Advantages

• Increased component operational life/availability.
• Allows for preemptive corrective actions.
• Decrease in equipment or process downtime.
• Decrease in costs for parts and labor.

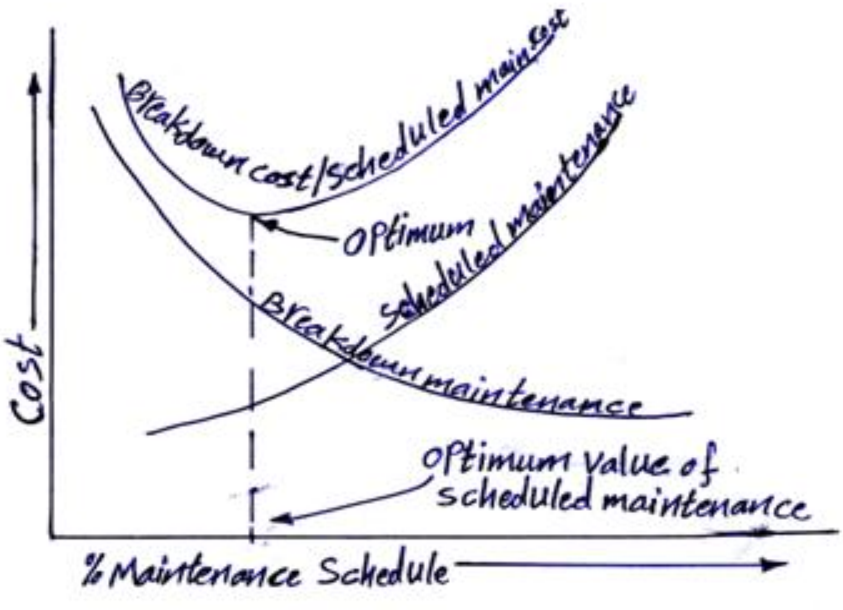
• Better product quality.
• Improved worker and environmental safety.
• Improved worker moral.
• Energy savings.
•Estimated 8% to 12% cost savings over predictive maintenance program.

Disadvantages

• Increased investment in diagnostic equipment.
• Increased investment in staff training.
• Savings potential not readily seen by management.

<u>Economic of maintenance</u>

Extent of preventive maintenance should be such that it may not become uneconomical. For this purpose, cost of breakdowns and cost of scheduled maintenance are to be studied. This cost should include expenditure of idle man, cost of idle machine, spoilage etc. it is natural that when the cost of scheduled maintenance increases, the cost breakdown decreases. But after some extent, increase in the expenditure on scheduled maintenance becomes uneconomical. For this purpose, these two costs should be plotted in graph and cumulative cost of both types of maintenance are superimposed in this graph, as shown in the following fig from_which an optimum pint can easily be determined, which gives the quantum of maintenance.



<u>Fig: Scheduled maintenance</u>

From the economic point of view, it is also necessary to decide the quantum of inspection very carefully on the basis of past experience and records analysis as explained earlier. As over-inspection costs more and results in large loss of production time while under- inspection results in more breakdowns.

Care should also be taken, while preparing maintenance programme so that as far as possible inspection and lubrication schedule should coincide, so that machine idle time and production disruption may be less. Inspection and lubrication schedules must be communicated to the production department, so that it may be able to free the machine as per programme.

Daily maintenance is done by the operators themselves. Before starting the work of their shift, cleaning, oiling and greasing should be done by the operators. For this purpose, manufacturer used to issue maintenance instructions for their machines, which should strictly be followed.

O&M Ideas for Major Equipment Types

The objectives of **O&M** are the following:

• Present general equipment descriptions and operating principles for the major equipment types.
• Discuss the key maintenance components of that equipment.
• Highlight important safety issues.
• Point out cost and efficiency issues.
• Provide recommended general O&M activities in the form of checklists.
• Where possible, provide case studies.

Boilers Maintenance

Boilers are fuel-burning appliances that produce either hot water or steam that gets circulated through piping for heating or process uses.

Types of Boilers

Fire-Tube Boilers

Fire-tube boilers rely on hot gases circulating through the boiler inside tubes that are submerged in water. These gases usually make several passes same work rough these tubes, thereby transferring their heat

through the tube walls causing the water to boil on the other side. Fire-tube boilers are generally avail-able in the range 20 through 800 boiler horsepower (bhp) and in pressures up to 150 psi.

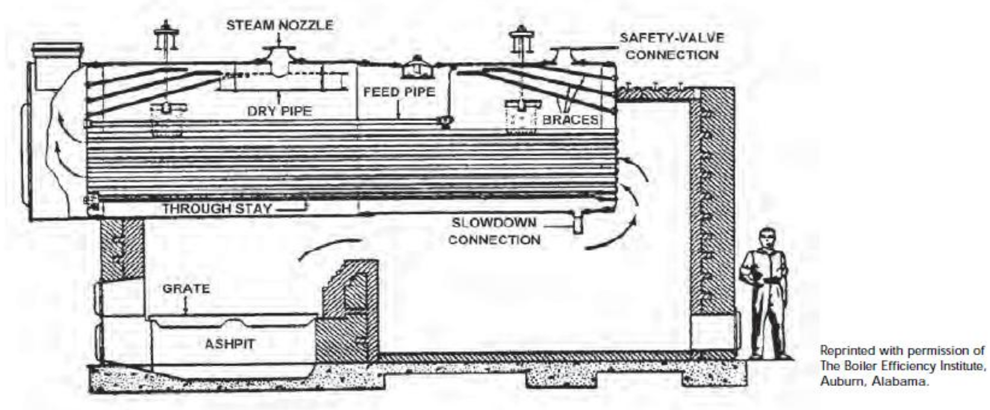


Figure 7.2.1. Horizontal return fire-tube boiler (hot gases pass through tube submerged in water).

Water-Tube Boilers

Most high-pressure and large boilers are of this type. It is important to note that the small tubes in the water-tube boiler can withstand high pressure better than the large vessels of a fire-tube boiler. In the water-tube boiler, gases flow over water-filled tubes. These water-filled tubes are in turn connected to large containers called drums.

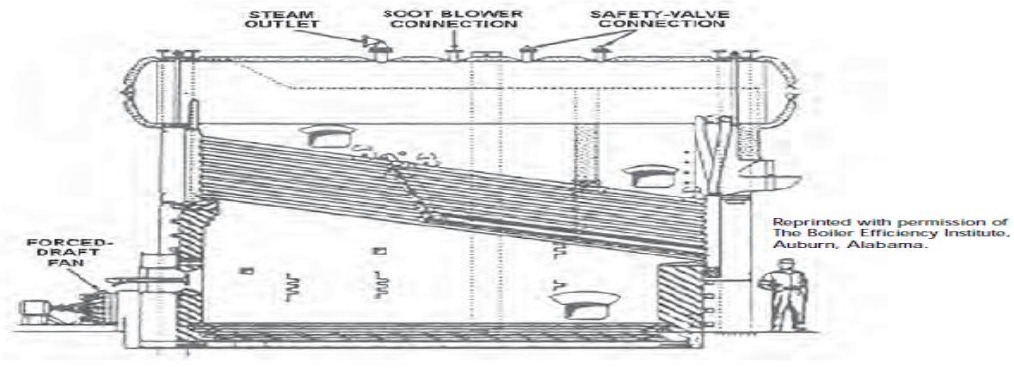


Figure 7.2.2. Longitudinal-drum water-tube boiler (water passes through tubes surrounded by hot gases).

Electric Boilers

Electric boilers are very efficient sources of hot water or steam, which are available in ratings from 5 to over 50,000 kW. They can provide sufficient heat for any HVAC requirement in applications ranging from humidification to primary heat sources.

Key Components

1-Drums – The steam drum is the single most expensive component in the boiler. Consequently, any maintenance program must address the steam drum, as well as any other drums, in the convection passes of the boiler. In general, problems in the drums are associated with corrosion

2-Headers – Boilers designed for temperatures above 900˚F (482˚C) can have superheater outlet headers that are subject to creep – the plastic deformation (strain) of the header from long-term exposure to temperature and stress. For high temperature headers, tests can include metallographic replication and ultrasonic angle beam shear wave inspections of higher stress weld locations. However, industrial boilers are more typically designed for temperatures less that 900˚F (482˚C) such that failure is not normally related to creep.

3-Tubing – By far, the greatest number of forced outages in all types of boilers are caused by tube failures. Failure mechanisms vary greatly from the long term to the short term. Superheater tubes

4-Piping -Main Steam – For lower temperature systems, the piping is subject to the same damage as noted for the boiler headers. In addition, the piping supports may experience deterioration and become damaged from excessive or cyclical system loads.

5-Feedwater – A piping system often overlooked is feedwater piping. Depending upon the operating parameters of the feedwater system, the flow rates, and the piping geometry, the pipe may be prone to corrosion or flow assisted corrosion (FAC).

6- Pilot and main burner flames
Assessmen*t*: Visually inspect pilot burner and main burner flames. -Proper pilot flame
• Blue flame.
• Inner cone engulfing thermocouple.
• Thermocouple glowing cherry red. -Improper pilot flame
• Overfired – Large flame lifting or blowing past thermocouple.
• Underfired – Small flame. Inner cone not engulfing thermocouple.
• Lack of primary air – Yellow flame tip.
• Incorrectly heated thermocouple. -Check burner flames-Main burner -Proper main burner flame

Cooling Tower maintains

A cooling tower is a specialized heat exchanger in which two fluids (air and water) are brought into direct contact with each other to affect the transfer of heat. In a “spray-filled” tower, this is accomplished by spraying a flowing mass of water into a rain-like pattern, through which an upward moving mass flow of cool air is induced by the action of a fan

Types of Cooling Towers

There are two basic types of cooling towers, direct or open and indirect or closed.

1. Direct or open cooling tower (Figure)

This type of system exposes the cooling water directly to the atmosphere. The warm cooling is sprayed over a fill in the cooling tower to increase the contact area, and air is blown through the fill. The majority of heat removed from the cooling water is due to evaporation.

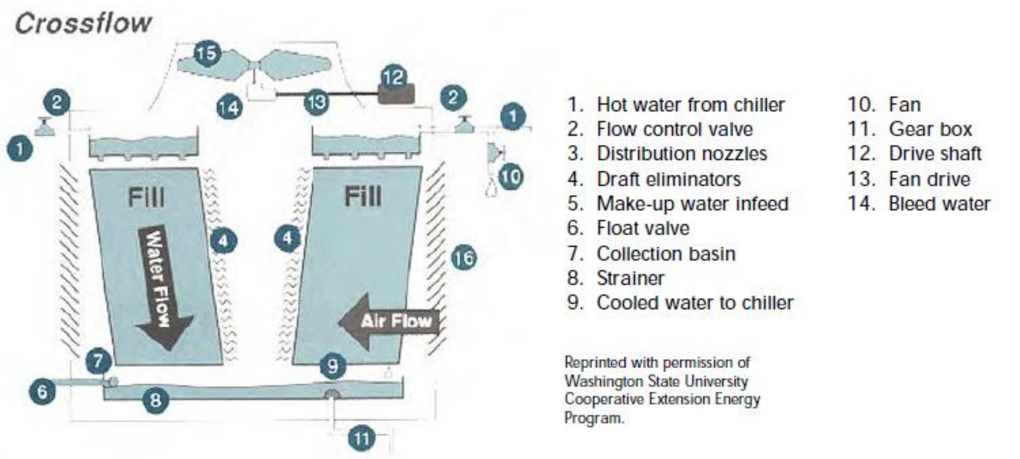


Figure 7.5.2. Direct or open cooling tower

2. Indirect or closed cooling tower

An indirect or closed cooling tower circulates the water through tubes located in the tower. In this type of tower, the cooling water does not come in contact with the outside air and represents a “closed” system.

Key Components

A cooling tower is a collection of systems that work together. Following is an overview of how these systems operate.

1-Hot water from a chilled water system is delivered to the top of the cooling tower by the condenser pump through distribution piping. The hot water is sprayed through nozzles onto the heat transfer media (fill) inside the cooling tower. Some towers feed the nozzles through pressurized piping; others use a water distribution basin and feed the nozzles through gravity.

2-A cold-water collection basin at the base of the tower gathers cool water after it has passed through the heat transfer media. The cool water is pumped back to the condenser to complete the cooling water loop.

Maintenance of Cooling Towers

Cooling tower maintenance must be an ongoing endeavor. Lapses in regular maintenance can result in system degradation, loss of efficiency, and potentially serious health issues

General Requirements for Safe and Efficient Cooling Towers Provide:

1. Safe access around the cooling tower, including all points where inspection and maintenance activities occur.
2. Fall protection around inspection and maintenance surfaces, such as the top of the cooling tower.
3. Lockout of fan motor and circulating pumps during inspection and maintenance.
4. Protection of workers from exposure to biological and chemical hazards within the cooling water system.
5. Cooling tower location must prevent cooling tower discharge air from entering the fresh air intake ducts of any building.
6. When starting the tower, inspect and remove any accumulated debris.
7. Balance waterflow following the tower manufacturer's procedure to ensure even distribution of hot water to all areas of the fill. Poorly distributed water can lead to air bypass through the fill and loss of tower performance.

8.Follow your water treating company's recommendations regarding chemical addition during startup and continued operation of the cooling system. Galvanized steel cooling towers require special passivation procedures during the first weeks of operation to prevent "white rust."

9.Before starting the fan motor, check the tightness and alignment of drive belts, tightness of mechanical hold-down bolts, oil level in gear reducer drive systems, and alignment of couplings. Rotate the fan by hand and ensure that blades clear all points of the fan shroud.

10 .The motor control system is designed to start and stop the fan to maintain return cold water temperature. The fan motor must start and stop no more frequently than four to five times per hour to prevent motor overheating.

11.Blowdown water rate from the cooling tower should be adjusted to maintain between two to four concentrations of dissolved solids.

Common Causes of Cooling Towers Poor Performance

• **Scale Deposits** – When water evaporates from the cooling tower, it leaves scale deposits on the surface of the fill from the minerals that were dissolved in the water. Scale build-up acts as a barrier to heat transfer from the water to the air. Excessive scale build-up is a sign of water treatment problems.

• **Clogged Spray Nozzles** – Algae and sediment that collect in the water basin as well as excessive solids that get into the cooling water can clog the spray nozzles. This causes uneven water distribution over the fill, resulting in uneven air flow through the fill and reduced heat transfer surface area. This problem is a sign of water treatment problems and clogged strainers.

• **Poor Air Flow** – Poor air flow through the tower reduces the amount of heat transfer from the water to the air. Poor air flow can be caused by debris at the inlets or outlets of the tower or in the fill. Other causes of poor air flow are loose fan and motor mountings, poor motor and fan alignment, poor gear box maintenance, improper fan pitch, damage to fan blades, or excessive vibration. Reduced air flow due to poor fan performance can ultimately lead to motor or fan failure.

• **Poor Pump Performance** – An indirect cooling tower uses a cooling tower pump. Proper water flow is important to achieve optimum heat

transfer. Loose connections, failing bearings, cavitation, clogged strainers, excessive vibration, and non-design operating conditions result in reduced water flow, reduced efficiency, and premature equipment failure.

Pumps

Keeping pumps operating successfully for long periods of time requires careful pump design selection, proper installation, careful operation, the ability to observe changes in performance over time, and in the event of a failure, the capacity to thoroughly investigate the cause of the failure and take measures to prevent the problem from recurring . Pumps that are properly sized and dynamically balanced, that sit o start, run, and stop carefully, and that maintenance personnel observe for the appearance of unhealthy trends which could begin acting on and causing damage to, usually never experience a catastrophic failure. n stable foundations with good shaft alignment and with proper lubrication, that operators

Safety Issues

Some important safety tips related to maintenance actions for pumps:

• **Safety apparel**

-Insulated work gloves when handling hot bearings or using bearing heater.

-Heavy work gloves when handling parts with sharp edges, especially impellers.

-Safety glasses (with side shields) for eye protection, especially in machine shop area.

-Steel-toed shoes for foot protection when handling parts, heavy tools, etc.

• **Safe operating procedures**

-Coupling guards: Never operate a pump without coupling guard properly installed.

-Flanged connections:

• Never force piping to make connection with pump.
• Insure proper size, material, and number of fasteners are installed.
• Beware of corroded fasteners.

When operating pump:

• Do not operate below minimum rated flow, or with suction/discharge valves closed.
• Do not open vent or drain valves, or remove plugs while system is pressurized.
• Pumps Maintenance safety

-Always lock out power.

-Ensure pump is isolated from system and pressure is relieved before any disassembly of pump, removal of plugs, or disconnecting piping.

-Pump and components are heavy. Failure to properly lift and support equipment could result in serious injury.

-Observe proper decontamination procedures. Know and follow company safety regulations.

-Never apply heat to remove impeller.

Maintenance of Motors

Preventative and predictive maintenance programs for motors are effective practices in manufacturing plants. These maintenance procedures involve a sequence of steps plant personnel use to pro-long motor life or foresee a motor failure. The technicians use a series of diagnostics such as motor temperature and motor vibration as key pieces of information in learning about the motors.

General Requirements for Safe and Efficiency Motor Operation

1. Motors, properly selected and installed, are capable of operating for many years with a reasonably small amount of maintenance.
2. Before servicing a motor and motor-operated equipment, disconnect the power supply from motors and accessories. Use safe working practices during servicing of the equipment.
3. Clean motor surfaces and ventilation openings periodically, preferably with a vacuum cleaner. Heavy accumulations of dust and lint will result in overheating and premature motor failure.
4. Facility managers should inventory all motors in their facilities, beginning with the largest and those with the longest run-times. This inventory enables facility managers to make informed choices about replacement either before or after motor failure. Field testing motors prior to failure enables the facility manager to properly size replacements to match the actual driven load.