CONTENTS

SYLLABUS

PRODUCTION AND OPERATION MANAGEMENT

SECTION A

1. Work Study

- Method study-Process chart, Flow process chart, Flow diagram, Man and machine chart and two handed chart.
- Work measurement—Time study, Tools and in time study, Performance rating, Allowances and use of sometime standards, time and motion study.
- Principles of human motion economy (introduction to ergonomics).

2. Plant Layout and Material Handling

- Concept of plant layout.
- Types of layout (Process, Product and Combination type); their Characteristics; Merits and demerits.
- Factors affecting plant layout.
- Work station design; Factors considered in designing a work station I.
- Introduction and functions of material handling.
- Selection of material handling equipment for different equipment.

SECTION B

3. Production Planning and Control

- Types of production : Job, batch and mass production.
- Material planning and allocation.
- Process planning and process sheet.
- Inventory control: Need and advantages of inventory control.

4. Inspection and Quality Control

- Inspection.
- Need and planning for Inspection.
- Types of inspection.
- Role of operator and inspector in inspection.
- Quality control and quality assurance.
- Meaning and need for quality control.
- Statistical quality control.
- Acceptance Sampling (Single sampling and sequential sampling plans).
- Control charts for variables and attributes, Interpretation of patterns in control charts, O.C. curves.
- Concept of TQM.
- Machine capability studies.

SECTION C

5. Standards and Codes

- National and International codes.
- ISO- 9000, concept and its evolution and implications.

6. Repair and Maintenance

- Objectives and importance of maintenance.
- Different types of maintenance.
- Nature of maintenance problem.
- Range of maintenance activities.
- Schedules of preventive maintenance.
- Advantages of preventive maintenance.

SECTION D

7. Cost Estimation

- Introduction and functions of cost estimation.
- Estimation procedure.
- Estimation of costs and ladder of costs.
- Depreciation, Methods of calculating depreciation.
- Overhead expenses and distribution of overhead expenses.
- Calculation of cost of machining and metal.

8. Value Engineering

- Concept of value engineering and techniques.

Note :

- An expert from industry may be invited to deliver the lecture.
- Industrial visit may be planned.

CHAPTER

1

INTRODUCTION TO PRODUCTION AND OPERATIONS MANAGEMENT

LEARNING OBJECTIVES

- Introduction
- Production Management (1930) and Operation Management
- Organization Structure of Production Management
- Factors of Production
- Objectives in Production and Operation Management
- Production and Operation Management Decisions
- History of Production and Operation Management
- Production Management and Industrial Engineering
- Production and Operation Management Scenario Today

1.1. INTRODUCTION

Production implies the creation of goods services to satisfy human needs. Production involves the transformation of inputs (resources) in to Goods services using physical resources.

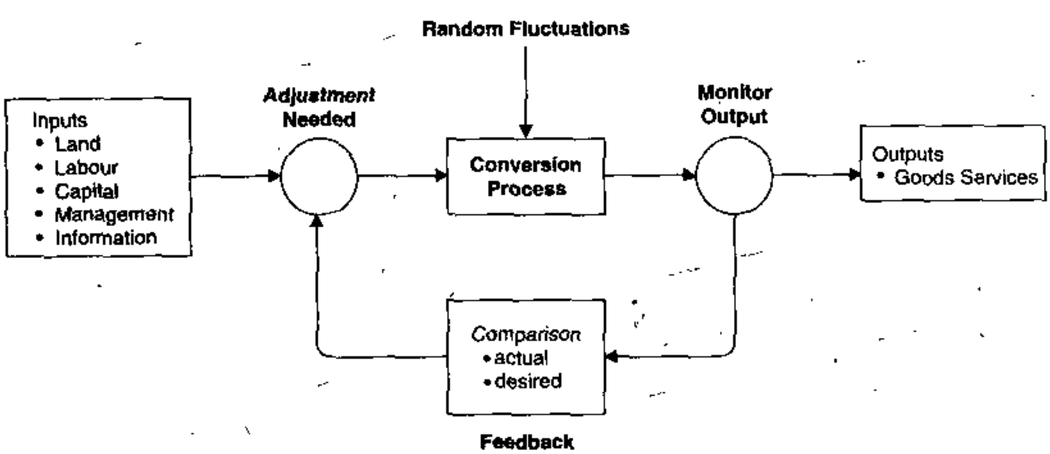


Fig. 1.1. Conceptual Model of a Production Operation System.

NOTES

Conversion is effected by using physical resources. Conversion processes are welding, forging, machining, moulding, assembling etc. Conversion process adds value to raw materials by changing its shape, size or weight.

Transformation process entails changes in form, location or time.

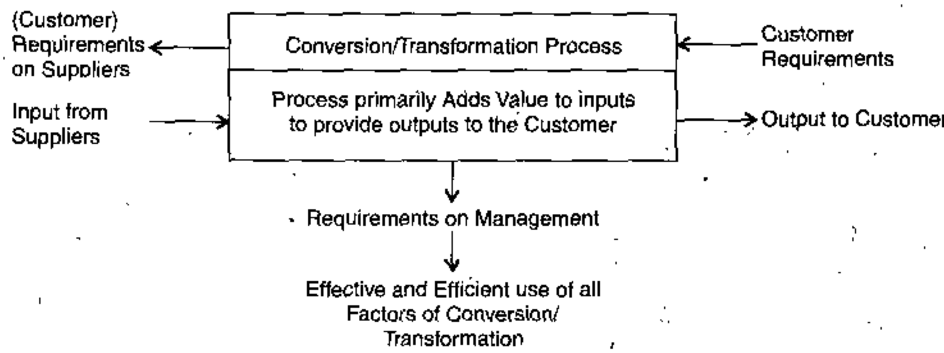


Fig. 1.2. Conversion/Transformation Process.

Inputs may be physical/non-physical.

Outputs may be physical/non-physical.

Type of utility provided to the customer form, state, possesion, place or combination thereof.

Production is the process of transforming raw materials or purchased components/semi- finished products into finished products for sale. —*Carl Heyle*

Production is the transformation of raw materials by factory methods into things wanted by society. —*Bethel, Smith and society*

For long the term production has been associated with a factory like situation where goods are produced in the physical sense.

Factory has been defined as any premises in which persons are employed for the purpose of making, altering, repairing, ornamenting, finishing, cleaning, washing, breaking, demolishing or adopting for sale of any article.

However by generating the concept of production as the process through which goods and services are created we can include both manufacturing and service organizations within the purview of production management.

The value added process. Value can be added to an entity by performing an operation function. There are four major ways :

(*i*) **Alter.** Change in the form or state of the inputs. This change may be

(*a*) *Physical*—manufacturing.

(*b*) *Sensual or psychological*—feeling of comfort, satisfaction after getting cured from an illness.

(*ii*) **Transport.** Entity may have more value if located somewhere other than where it currently is.

(*iii*) **Store.** Entity is kept in a protected environment for some period of time.

(*iv*) **Inspect.** Production is fabrication of a physical object through the use of men, material and equipment. During production and after production services if goods are inspected for defects then value increases.

Productive Use of Resources

Every organization has number of resources. For producing goods/services we use inputs and we get outputs plus some wastes. Thus

$$\text{Inputs} = \text{Outputs} + \text{Wastes}$$

or

$$\frac{\text{Inputs}}{\text{Inputs}} = \frac{\text{Outputs}}{\text{Inputs}} + \frac{\text{Wastes}}{\text{Inputs}}$$

$$= \text{Productivity} + \text{Wastivity.}$$

Productivity means Outputs/Inputss

Productivity is for every resource—material, machine, money, labour, energy, floor space, fuel, etc.

$$\text{Total Productivity} = \frac{\text{Total output}}{\text{Labour input} + \text{Capital input} + \text{Raw materials inputs} + \text{Other input factors}}$$

Productivity can be increased by following methods :

(*a*) Elimination of waste

(*b*) By using improved technology

(*c*) Better product design

(*d*) Better management efforts

(*e*) Reducing down time of maintenance

(*f*) Reduction in materials input

(*g*) Better quality of goods

(*h*) Decreasing wastvity

(*i*) Improved utilization of resources

(*j*) Reduction in working capital requirements

(*k*) Reduction in inventory level

(*l*) Improvement in skills through training

(*m*) Better leadership management.

Minimize generation of waste at the source. Develop technology which produces minimum air, water pollution. Low waste technology.

Production is the process of creating utility in products or adding the value of products.

In a manufacturing organization, production is the fabrication of a physical ob*ject through the use of men, materials and equipments.* —*R.R. Mayer*

Objectives of Production

(*a*) Optimum use of resources at optimum cost of production

(*b*) Production of the goods providing services of the desired quality.

1.2. PRODUCTION MANAGEMENT (1930) AND OPERATIONS MANAGEMENT (1970)

It is the process of planning and regulating the operations of that part of an enterprise which is responsible for actual transformation of materials into finished products. —*A.W. Field*

Production management deals with decision making related to production process so that the resulting goods are produced in accordance with the quantative specifications and demand schedule with minimum cost. —*E.S. Buffa*

NOTES

Production management is a set of general principles for production economies, facility, design, job design, schedule design, quality control, inventory control, work study and budgetary control.

Operation Management (1970)

Generally operation management is word used to describe system of producing articles and providing services. Production management is for producing articles.

Following are areas of production function :

(*i*) Engineering—Product design and development, drawings, specifications and standards

(*ii*) Production planning and control, pre-production planning—layout planning, process planning, scheduling design—Job design and assignment, production standards and work study

(*iii*) Materials management—Inventory control

(*iv*) Procurement stores, waste

(*v*) Manufacturing process control

(*vi*) Quality control

(*vii*) Distribution—marketing

(*viii*) Customer

(*ix*) Sales

(*x*) Finance—Cost control.

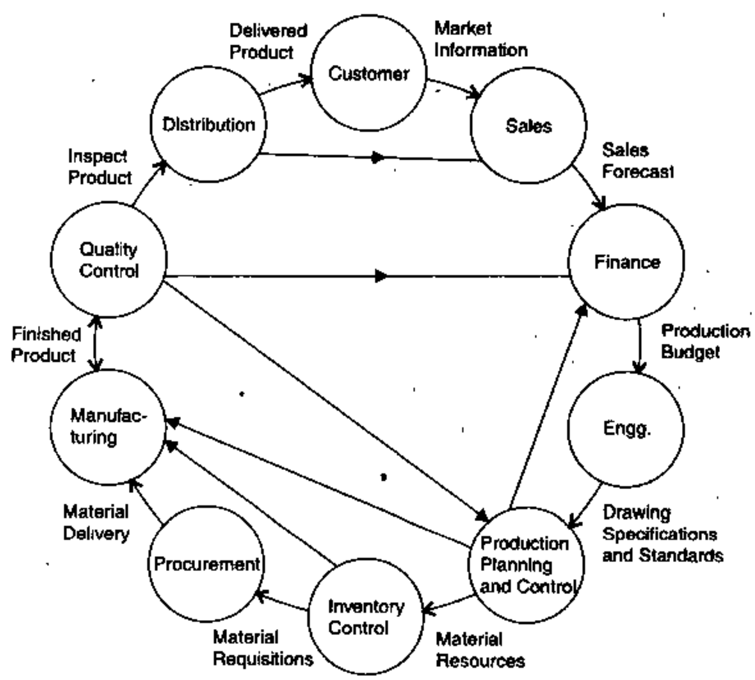


Fig. 1.3. Production Functions.

Production is concerned with the conversion of inputs into outputs using physical resources so as to provide the desired utilities of form, place, possession or state or a combination thereof to the customer while meeting the organizational objectives.

It is the process of planning, organising, directing the activities of production.

Functions/Activities of Production Management

(*a*) Specifications and procurement of input resources.

(*b*) Product design and development to determine the production process for performing the input factors into output of goods services.

(*c*) Supervision and control of transformation process for efficient production of goods services.

Importance of Production Management

Production management department makes it possible outlining the latest techniques of production of a new product, improvement in the existing product line, catching up newer techniques, improving the quality of goods services and controlling the cost of production. Following are functions of production management :

(*a*) Maintains optimum inventory level.

(*b*) Improves productivity of all inputs.

(*c*) Provides uninterrupted supply of goods services.

(*d*) Improves the profitability of the organization.

(*e*) Provides employment.

Scope of Production Management

(*i*) Designing and developing products and packages.

(*ii*) Production engineering—Manufacturing.

(*iii*) Production planning and control.

(*iv*) Inventory control procurement (purchasing), stores, waste.

(*v*) Impection, quality assurance and control.

(*vi*) Distribution.

(*vii*) Customer requirements.

(*viii*) Sales.

(*ix*) Finance.

(*x*) Repairs and maintenance.

Objectives of Production Management

These are :

(*a*) Optimum use of resources at optimal cost.

(*b*) Producing in required quantities of required quality as per schedule.

(*c*) Producing efficiently and effectively.

(*d*) Lead time should be minimum. Lead time is time between ordering and receiving article.

(*e*) Capacity utilization should be maximum.

(*f*) There should be flexibility.

(*g*) Material cost, labour cost, rework cost, maintenance cost should be minimum.

(*h*) Storage, material handling, packaging, inspection, down times should be minimum.

Decisions in Production Management are :

(*i*) Planning for operation/the conversion system.

(*ii*) Facility location planning, layout planning.

(*iii*) Product design and development.

NOTES

(*iv*) Capacity planning—delivery schedule.

(*v*) Planning the use of conversion system—forecasting, aggregate planning.

(*vi*) Production planning and control—planning and scheduling planning and control resource allocation, dispatching, expediting, project planning and scheduling.

(*vii*) Plant engineering—equipment and tool design, manufacturing techniques and process design.

(*viii*) Organizing for conversion—organizing and staffing for operation and job design.

(*ix*) Industrial engineering—work study, job and work design, structuring of operations, production/operations standards.

(*x*) Inventory management—purchasing, store keeping, recording, waste.

(*xi*) Conversion system, controlling operations, time, inventory, cost, maintenance, repairs, servicing, replacement, preventive, checking, quality control—specifications, standards, inspection and testing.

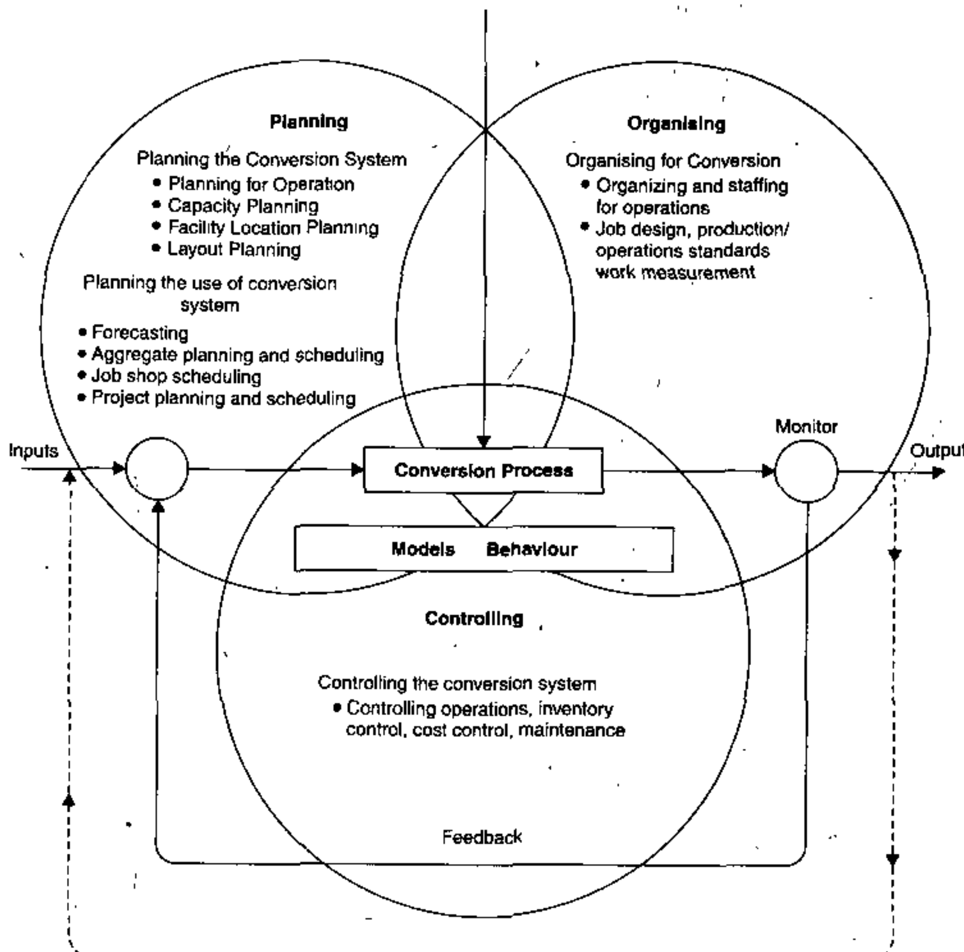


Fig. 1.4. A Framework of Planning, Organizing and Control Decisions in Production Systems.

Monitoring and Feedback Control

In every system, the actual accomplishment of objectives may not be as planned for various reasons. It is therefore very important to monitor the actual performance by measuring the actual output or some performance indicators. Basic elements of monitoring and feedback—be it control of quantity, quality, time, inventory or cost—are :

(1) Establish standards of performance or outputs

(2) Measure actual performance

(3) Compare the difference between the actual and planned

(4) Take appropriate remedial actions by changing inputs, revising plans, changing priorities, expediting the progress etc.

Design of an appropriate feedback control system is therefore vital for all production management problems. Control is complementary to planning without monitoring and control planning may not be effective. Thus planning and control are two sides of the same coin.

In the design of control systems, we should consider cost-benefit aspect of control in mind. If cost of control exceeds its benefits, it becomes counter-productive. Thus, *selective controls* must be exercised employing the exception principle or Pareto's Law. A more effective control could be self-control or cybernetic or steering control but it may be difficult to design such controls in a large and complex organization.

Need for Updating and Review of Decisions

When we plan or design our production system, the process of planning assumes certain external and internal environment on work. In a dynamic system there may be changes in the environmental parameters which make our previous decisions out of date and irrelevant. In such a situation, we need to review ; revise and update our decisions. For example we may switch over to group technology layout from existing process type layout, we may add or delete our product lines, we may revise the product design in the light of newer types of materials that have developed or on the basis of feedback from customers etc.

It is a good practice to incorporate periodic reviews and updating as a part of our system. So that our decisions are relevant to the prevailing circumstances and are *compatible with the external environment*. Thus, we should be able to revise all the previously stated decisions.

Decisions are based on time :

(*a*) **Long term/Strategic decisions.** Selection of the product. Design of the product, selection of equipments and processes, production, design of items processed, job design, site of the industry and business, facility layout, capacity planning, material handling system and storage system etc.

(*b*) **Operational/Short run decisions.** Inventory control, production control, maintenance and reliability of the systems, quality control, labour control, cost control and improvement. Replacement, work study, manpower planning and operations planning.

(*c*) ***Intermediate time decisions.*** *Product variations,* methods selection, forecasting, etc.

Review decisions.

Classification of decision areas. Technology selection and management, capacity schedule, maintenance.

1.3. ORGANIZATION STRUCTURE OF PRODUCTION MANAGEMENT

NOTES

The duties of the production manager—production planning, production control, quality control, method of analysis, plant layout and material handling, inventory control, work study, motivation, cost control.

Production Department

(*i*) Section which complies and record information
Plant, equipment, labour, stock, customer demand, standard time.

(*ii*) Section concerned with
Production plans, Inspection.

(*iii*) Section that translates plans into performance and control results.

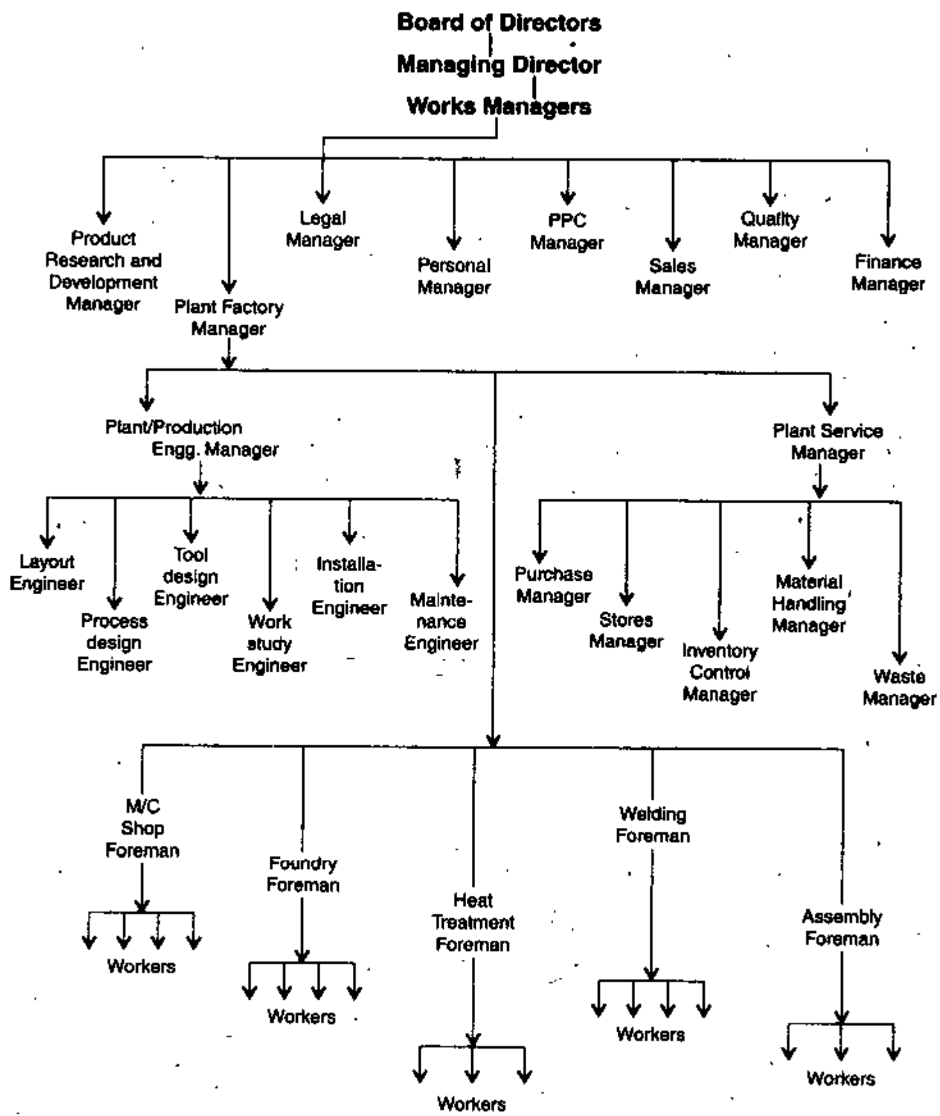


Fig. 1.5. Organization Structure of Production Management.

NOTES

Activities of Productions

(a) **Manufacturing.** Processing of the product-Foremen and workers.

(b) Ancilliary function activities supporting manufacturing of purchasing, storage, maintenance.

(c) **Advisory function activities.** Method study, quality control.

Benefits of Sound Production Department

(a) Division of activities

(b) Specialization

(c) Clear cut authority

(d) Fixation of responsibility

(e) Higher efficiency

(f) Coordination.

Role of Scientific Methods in Production Management

(i) Industrial engineering/Scientific management

(ii) Modelling—Decision making, system theory, mathematical modelling

(iii) Computers

(iv) Behaviourial Science, etc.

Criteria of Performance of Production Management

These are :

(i) Effectiveness

(ii) Customer's satisfaction

(iii) Efficiency.

1.4. FACTORS OF PRODUCTION

These are :

(i) **Land.** All natural resources on the land—water, air, forest, animals, birds, etc. are available for man.

Land is one of the source for establishing industry.

Features of land are :

(a) Land is free gift of nature

(b) Land is limited in area

(c) Land is permanent

(d) Land is of infinite variety

(e) Cost of land differ due to fertility of land, location, soil, etc.

(ii) **Manpower**

(iii) **Capital.** It is needed for land, building, plant and machinery, manpower, utilities, raw materials, technology.

(iv) **Organization/Enterprise.** Work of bringing the above factors of production together and making them work harmoniously.

1.5. OBJECTIVES IN PRODUCTION AND OPERATIONS MANAGEMENT

NOTES

In general terms, the objectives of an organisation may be to produce the goods services in required quantities and of quality as per schedule and at a **minimum cost.** Thus quantity, quality and time schedule are the objectives that determine the extent of customer satisfaction quality, cost, delivery and after sales services are criteria for customer satisfaction. If an organisation can provide for these at a minimum cost then the 'value' of goods created enhances and that is the only way to remain competitive. Thus various objectives can be grouped as—performance objectives and cost objectives.

Performance Objectives

The performance objectives may include :

(*a*) **Efficiency** or productivity as output per unit of input.

(*b*) **Effectiveness.** Where efficiency may refer to 'doing things right', effectiveness may mean 'doing the right things.'

(*c*) **Quality.** Quality is the extent to which a product satisfies the customer needs. The output has to conform to quality specifications laid down before it can be accepted.

(*d*) **Lead times.** Manufacturing lead time or throughput time is the time elapsed in the conversion process. Minimisation of idle time, delays, waiting etc. will reduce throughput time.

(*e*) **Capacity utilisation.** Percentage utilisation of manpower, machines etc.

(*f*) **Flexibility.** If the conversion process has the flexibility of producing a combination of outputs, it is possible to satisfy a variety of customer needs.

Cost Objectives

Attaining high degree of customer satisfaction on performance front must be coupled with lower cost of producing the goods. Thus cost minimisation is an important systems objective. Costs can be explicit (visible) or implicit (hidden or invisible). These could be tangible in economic terms or intangible in social cost terms—such as delayed supplies, customer complaints etc. While managing production systems we must consider both the visible and invisible, tangible and intangible costs. Some examples of these costs are :

(*a*) Explicit (visible) costs :
- Material cost
- Direct and indirect labour cost
- Scrap/rework cost
- Maintenance cost

(*b*) Implicit (invisible/hidden) costs :
- Cost of carrying inventory
- Cost of stockouts, shortages, back-logging, lost sales
- Cost of delayed deliveries
- Cost of material handling
- Cost of inspection
- Cost of grievances, dissatisfaction

- Downtime costs
- Opportunity costs

For the purpose of managerial decision-making, we should consider the total relevant systems costs including visible and invisible. A longer term cost implications rather than only short-term will help in arriving at better decisions.

1.6. PRODUCTION AND OPERATIONS MANAGEMENT DECISIONS

Production and operation management is essentially a function concerning decision-making with respect to a production system so as to render the necessary customer satisfaction at lowest cost.

There are different ways in which the production manager and functions can be grouped for the sake of discussion. For instance, all the decisions concerning the production system could be divided as :

(*a*) **Periodic decisions** which include selection, design and updating of resources, structures, systems and procedures.

(*b*) **Continual decisions** which are required in day-to-day operation and control of production systems.

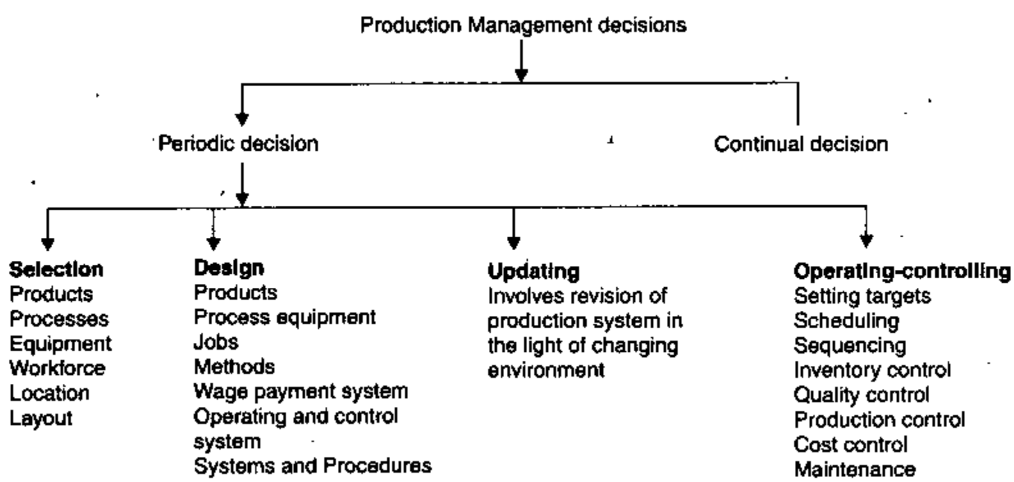


Fig. 1.6. A classification of Production Management Decisions.

Fig. 1.6 shows a listing of some of the decisions according to this scheme of functional classification. It may be seen that decisions in (*a*) above are generally strategic decisions having long-term implications while in (*b*) we have operational (short-term) decisions.

And yet another way of looking at these decisions may be :

(*i*) Planning and Design of Production Systems.

(*ii*) Operations and Control of Production Systems.

1.7. HISTORY OF PRODUCTION AND OPERATION MANAGEMENT

NOTES

The four major stages of development are the (1) Handicraft era (2) Industrial revolution (3) Scientific management era and (4) Operations research and computerized systems era. This is shown in the Fig. 1.7 which depicts some of the key individuals and events that contributed to the development of production operations over the past years.

1. Handicraft Era. Production of goods remained at a handicraft level until the industrial revolution took hold in the early 1800s.

Three note-worthy events occured within the span of few years :

(*a*) James Watt's steam engine (1764) advanced the use of mechanical power to increase productivity.

(*b*) The revolutionary war (1776) and resulting U.S. constitution (1789) encouraged capital investment and trade by protecting private property and contract rights.

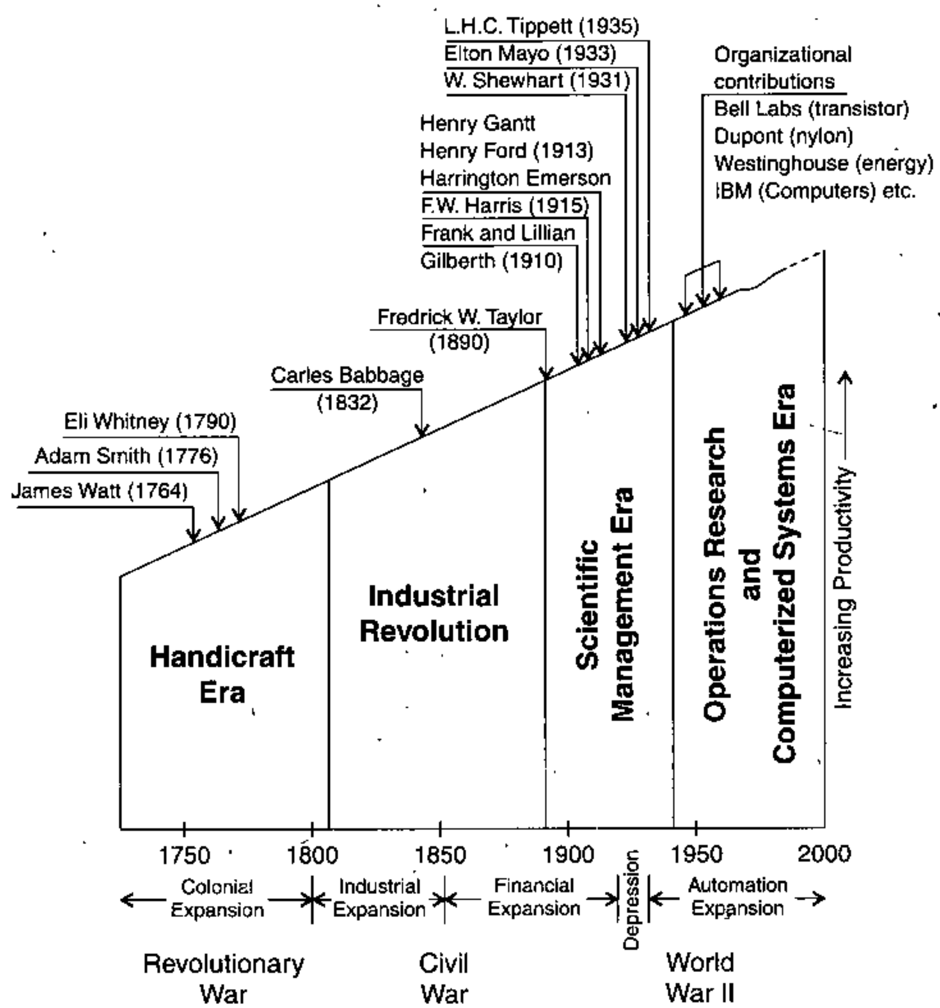


Fig. 1.7. Development of production systems.

(c) Adam Smith's Wealth of Nations (1776) publicized the advantages of the division of labour, these included skill development, time savings and the use of specialized machines.

2. Industrial Revolution. In the early 1800s the factory system began to develop, spurred on by Henry Slator's use of water and steam power in textile mills in New England and by Eli Whitney's (1790) concept of "interchangeable parts". Growth of factory system was rapid, there was no well-established craft system to suppliment and unskilled labour was available. Specialization of jobs and division of labour began to take place. **Charles Babbage** (1832) promoted an economic analysis of work and pay on the basis of skill requirements.

Starting about 1830, the railroad expansion to the West generated new demands for steel and industrial products. The railroads also placed heavy demands on capital, which businesses began to procure by selling shares of stock to "outsiders". This hastened the separation of ownership from management and marked the beginning of Professional management.

By the mid-1800s, many Northern industrialists had strong business ties to the South. They did not want a civil war, but gave President Lincoln their support when dissolution of the Union looked inevitable. As it turned out, the civil war encouraged the industrial growth. Amendments to the constitution passed as a result of the war and (ultimately) made business firms "persons" in the eyes of the law. This gave firms more constitutional rights and some firms expanded into large financial empires. The nation grew in productive capacity and the shift toward work force urbanization continued at a rapid pace.

3. Scientific Management Era. By the early 1900s the factory system was well established. Thomas Edison's first electric generating station was opened in New York city in 1882 and the U.S. soon had a over 2,000 power stations supplying electricity to factories and mills. Fredrick W. Taylor (1890) was a dissatisfied worker in one of those mills in Philaddphia. He had begun work as a labourer with the Midvale Steel Company in the late 1800s. Advancing through the ranks to foreman, master mechanic and chief engineer, he came to know and deplore the "boondoggling", loafing and general inefficiencies that existed in his company.

Taylor refused to accept such practices. Fortunately, he was advanced to a position where he could experiment with some ideas for improvement. Believing that a scientific approach to management could improve labour efficiency, he proposed the actions outlined as Taylor's philosophy became widely known through his consulting work, his testimony before a congressional committee and his book, 'Principles of Scientific Mangement' published in 1915. His "shop system" which included attention to training and instruction, specifications, standards and incentive pay systems, brought him the title *"Father of Scientific Management"*.

Taylor's collegues and followers helped the young nation become a powerful nation and mass producer of industrial goods. Frank and Lillian Gilberth (1910) developed motion economy studies, Henry Gantt (1913) instituted a charting system for scheduling production and Henry Ford (1913) inaugurated assembly-line mass production for automobiles. Others, like F.W. Harris (1915) and Walter Shewhart (1931) made analytical contributions. Elton Mayo (1933) directed attention to behavioral factors and L.H.C. Tipett (1935) contributed to work sampling activities.

By the late 1920s, the United States had became so production oriented that many firms overproduced. Prices fell and a depression ensured. President Franklin

Roosevelt championed the National Labour Relations Act, which fostered collective bargaining and helped to get the country back on its feet. This revived industrial capacity came just in time for the United States to bring World War II to a close.

NOTES

1. Collect data on each element of work and develop standardized procedures for works.
2. Scientifically select,, train and develop workers instead of letting them train themselves.
3. Strive for a spirit of cooperation between management and the workers so that high production at good pay is fostered.
4. Divide the work between management and labour so that each group does the work for which it is best suited.

Fig. 1.8. Taylor's Philosphy of Scientific Management.

4. Operations Research and Computerized Systems Era

Operations Research. Operations research involves using quantitative techniques in a systematic way to arrive at solutions to problems. During World War II, careful analysis was needed of battle problems and risk situations, such as those encountered in transporting troops across sub-marine infested waters. Researchers used mathematical equations to stimulate and analyse the effects of various warfare decision strategies. These techniques of competitive analysis were later applied to problems in the business world.

As computers became available in the 1950s, the power of operations research was multiplied. The speed and capacity of computers made them ideal for applying OR methods, such as linear programming and simulation, to complex business problems. But at first some of the scheduling and production control problems seemed even too complex for computers. Unlike the well documented accounting systems, good production control system were not already available to automate.

By the late 1960s some new but simple concepts of independent demand time phasing and material and capacity requirements planning (MRP and CRP) were introduced by Joseph Orlicky, Oliver Wight and others. These new approaches took advantage of the speed and memory capacity of computers and enabled planners to control production in a way that could never have been done manually because of the tremendous number of calculations involved. The 1970s and 1980s witnessed continued development of MRP II systems and integration of Just-in-Time (JIT) inventory concepts plus selected Japanese developments.

Today, the manufacturing sector of our economy is undergoing nothing short of an electronic revolution. It began with microprocessors which are the "chips" or processing elements, used in computers. Manufacturers are installing microprocessors and computers in virtually all types of material handling and processing equipment. The computers movement is now toward fully automated factories and service systems.

Computers. Computerized scanners can readily identify products by reading the bar codes printed on them. Automated storage and retrival systems can receive, store, select and retrive information without any human intervention. Computer-guided vehicles can deliver materials to where they are needed, when they are needed. Individual computer, controlled machines can follow programmed instructions, control their own operations and respond to directions and requests for information from larger computers. Some machines even inspect their own output—and reject it if it doesn't meet the machine's present standards.

In offices computers are equally valuable if not more so. We are all familiar with their data processing and problem solving functions. But Boeing, Chrysler and other companies employ computers for everything from product design (CAD/CAM) and purchasing to marketing and public relations. General electric company offers customers factory-modelling software that allows them to simulate a new factory design on a computer screen before their plant is constructed.

Robots. Robots are now doing much of the monotonous, dirty and possibly dangerous work that can be done by machines. In factories, they perform assembly, painting, welding and other repetitive tasks.

The simplest industrial robots are mechanical arms or fingers that are powered to follow a fixed pattern of instructions. Robots that are equipped with microprocessors are "smart", they can react to individualized and online information. An increasing number of firms are using robots to deliver customized product at volumes that were previously available only under "hard-wired" mass production automation.

Main Contributors in the Historical Development of Production Management

The first recognized attention to productions economics was paid by the great Scottish economists **Adam Smith** (1776) at the time the factory system was emerging. In 1776 he wrote "The Wealth of the Nations" in which he observed three basic economic advantages resulting from the division of labour. The book was milestone in the development of production economics, not only because Smith's observations probably accelerated the division of labour, but also because a great scholar had recognized that there existed a rational for production.

After Adam Smith, an Englishman **Charles Babbage** (1832) augmented Smith's observations and raised a number of provocative questions about production organization and economics. His thoughts were summarized in the book, "On the Economy Of Machinery and Manufactures" (1832).

Fredrick W. Taylor (1874) was undoubtedly the outstanding historical figure in the development of the production management field. Smith and Babbage both were observers and writers but Taylor was both a thinker and a doer. He was also an authoritarian with an indomitable will, a fact that caused him to be greatly criticized but at the same time, may have been the source of his great contributions.

To comprehend the extent of Taylor's accomplishments, we must understand that he was an inventor in a managerial environment of general apathy, where strong traditions existed giving the workmen a free rein to determine manufacturing methods and the right to hold their knowledge as trade secrets. In this static environment, Taylor set in motion a tidal wave of change in managerial philosophy which shook many organization from top to bottom.

Taylor's uncompromising attitude in developing and installing his ideas caused much controversy and he was strongly opposed in many quarters. In the environment in which Taylor worked, perhaps it was necessary to have a man of his hard-driving personality to change an industrial way of life.

His followers were numerous Carl Barth, Henry L. Gantt (1913), Harrington Emerson Frank and Lillian Gilberth (1915) and others worked within Taylor's general framework and philosophy. But the science of production management, in the spirit Taylor envisioned it, was very slow to evolve.

NOTES

An attempt at mathematical analysis was made in 1915 by **F.W. Harris,** who developed the first economic lot-size model for a simple solution. This was further developed by F.E. Raymond and others.

There was upsurge in the 1930s due to the work by Walter Shewhart (in 1931) who gave concept of statistical quality control and the development in 1934 of work sampling theory by L.H.C. Tippett, working in England.

1.8. PRODUCTION MANAGEMENT AND INDUSTRIAL ENGINEERING

Production management. Concepts and techniques specific to the analysis and management of production activity. How to manage (direct human efforts) in a production environment.

Industrial Engineering. Analysis, design and control of production systems. A productive system is any system that producing either a product or a service.

Industrial engineers do not operate the system which they have designed.

1.9. PRODUCTION AND OPERATION MANAGEMENT SCENARIO TODAY

1. Quality of life needs improvement.
2. Service or state utility, form utility is to be increased.
3. Variety in products and services an needs
4. **Customer.** Customer orientation Enlighted customer
5. Flexible times of working
6. Space age economics
7. Socio-techno economic scene
8. Depleting resources
9. Safety of men, machines, buildings etc. OHSAS 18001.
10. Maintenance of assets, etc.

STUDENT ACTIVITY

1. What are value adding processes ?

2. What are objectives of production ?

NOTES

SUMMARY

1. **Conversion** is effected by using physical resources. Conversion processes are welding, forging, machining, moulding, assembling etc. Conversion process adds value to raw materials by changing its shape, size or weight.
2. Production management deals with decision making related to production process so that the resulting goods are produced in accordance with the quantative specifications and demand schedule with minimum cost.
3. Production and operation management is essentially a function concerning decision-making with respect to a production system so as to render the necessary customer satisfaction at lowest cost.
4. **Industrial Engineering.** Analysis, design and control of production systems. A productive system is any system that producing either a product or a service.

TEST YOURSELF

1. Define production/conversion process. What are factors of production ?
2. Define Production.
3. Define Production Management.
4. What are functions/activities of Production Management ?
5. Write about importance of Production Management.
6. What is the scope of Production Management ?
7. What are objectives of Production Management ?
8. What are decisions in Production Management ?
9. Write about monitoring and feed back control.
10. Write about updating and review of decisions.
11. Write about organizational structure of Production Management.
12. What is the role of scientific methods in Production Management ?
13. How performance of Production Management is measure ?
14. What are the objectives of Production Management ?
15. What are the Production Management decisions ?
16. Write the history of Production Management.
17. What is relationship of Production Management and IE ?
18. Write about Production Management scenario today.
19. Identify the inputs, transformation process and outputs in the following operation system :

    Manufacture of television sets
20. Identify the main objectives relevant to the performance of the following system :

    Factory making cotton textiles.
21. Describe the framework of planning organizing and control decision in a production system.

OBJECTIVE TYPE QUESTIONS

1. Strategic (long term) Decision does not include
   (*a*) Product selection and design (*b*) Capacity planning
   (*c*) Inventory planning and control (*d*) Process selection and planning.
2. Operational level decisions deal with short term planning and control operations. Which of the followings is not true for operational short term decision
   (*a*) Maintenance and replacement
   (*b*) Production planning, schedule and control
   (*c*) Inventory planning and control
   (*d*) Facility layout and material handling.

True/False Type Questions

1. Location of a plant is an important strategic decision.
2. Mass production system is suitable for products with large variety and small volume of production.
3. Efficiency and effectiveness are synonymous terms.
4. Productivity is a ratio of output/input.
5. Feedback control is not needed if you plan your operations.

NOTES

CHAPTER

2

PLANT LAYOUT

LEARNING OBJECTIVES

- Introduction
- Types of Plant Layouts
- Plant Layout Factors

2.1. INTRODUCTION

Before establishing enterprise following should be decided :

1. Product mix
2. Capacity of plant, make or buy decision
3. Manufacturing process/technology
4. Machines required
5. Raw materials required
6. Electricity requirement
7. Material handling system
8. Plant services requirements
9. Manpower requirement
10. Plant location
11. Water requirement
12. Business organization—Individual Partnership Pvt. Ltd. Co. Public Ltd. Co. Cooperative Society.

Facilities planning is also known under other name as plant layout.

Plant layout means the disposition of the various facilities (equipment, material, manpower etc.) and services of the plant within the area of site selected previously. Plant layout begins with the design of the factory building and goes up to location and movement of a work task. All the facilities like equipments, raw materials, machinery, tools, fixtures, workers etc. are given a proper place.

Plant Layout is important because

(*i*) Between 20 to 50% of the total operating expenses are attributed to material handling. Effective facilities can reduce these costs by at least 10 to 30%.

(*ii*) Good plant layout provides easy access to equipment maintenance and repair, thus reducing downtime and maintenance costs.

(iii) Changes in level of demand, design of product(s) and in technology often result in layout adjustments that can be achieved only with *flexibility in the existing configuration.*

(iv) The plant layout design must assume every employee safe, healthy and comfortable working environment.

NOTES

Characteristics of good plant layout

(i) Improved material handling, material control and good house keeping.

(ii) Effective utilization of people, equipment, space and energy.

(iii) Minimise capital investment.

(iv) Be flexible.

(v) Promote ease of maintenance.

(vi) Provide employee safety and job satisfaction.

A poor layout results

(i) Continuous losses in terms of higher efforts for material handling.

(ii) More scrap and revenue.

(iii) Poor space utilization.

Layout problem occurs

(i) Change in product design

(ii) Introduction of new product

(iii) Obsolescence of facilities

(iv) Change in demand

(v) Market changes

(vi) Competitive cost reduction

(vii) Frequent accidents

(viii) Adoption to new safety standards

(ix) Decision to build a new plant.

According to nature of plant layout problem

(i) New facility planning

(ii) Relocating an existing facility.

Plant layout is related to a number of aspects of production management.

Or

In other words

One of the prime source of cost reduction *opportunity* is a well planned plant layout, *which means* an effective arrangement of work areas in which goods can be economically produced.

Principles of plant layout. The plant layout should be designed in such a way that the manufacturing process can be carried out in the most efficient manner. As a guideline the following *factors need to be considered* while designing a plant layout :

(i) Arrangement of machines, equipments and work areas should be such that the material is caused to move smoothly along in as straight a line as possible.

(ii) Elimination of all possible delays on account of waiting or in movement.

(iii) Plan the flow in the manner that the work passing through an area can be easily identified with little possibility of getting mixed up with other parts.

NOTES

(iv) Maintain quality of work by planning for the maintenance of conditions that are conductive to quality.

(v) Optimum utilisation of cubic space should be made. There shall be minimum spacing between machines after allowance for movement of men and materials has been made.

(vi) Provide for safe working conditions.

(vii) Allow for flexibility, specially where the products are likely to change frequently.

(viii) Reducing investment in equipment by proper arrangement of machines and departments in such a way that the quality of equipment required is optimum.

2.2. TYPES OF PLANT LAYOUTS

Following are types of plant layout

(i) Process layout

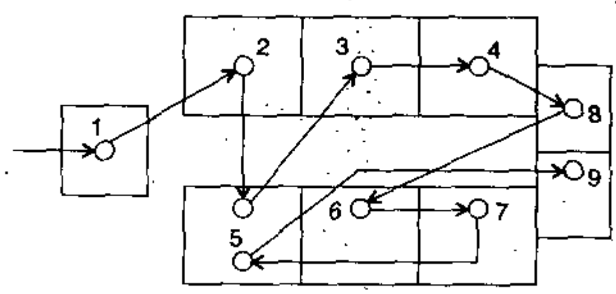
(ii) Product layout

(iii) Fixed position layout

(iv) Combination product and process and fixed position layout

(v) Group layout.

(1) **Process or Functional Layout.** The relative location of the sections/departments may be such us to suit normal sequence of operations in the manufacturing process. A systematic diagram of this type of layout is shown in Fig. 2.1.



1. Store room	2. Turning section	3. Milling section
4. Drilling section	5. Surface grinding section	6. Boring section
7. Planning section	8. Stock room	9. Inspection section

Fig. 2.1. Process layout diagram.

Layout is a per process not for a particular product used for intermittent type production. Movement of product is a per its manufacturing requirement.

The main advantages of process layout are :

(i) The capital investment on production equipment is considerably less because facilities need not be duplicated.

(ii) Variety of products can be produced without incurring additional costs.

(iii) Effective supervision is possible since the facilities are organised on functional basis.

(iv) Job satisfaction for workers and supervisors is generally higher because the work is of varied nature and more challenging.

(v) Machine failures do not seriously affect production schedules.

(vi) A small maintenance team can look after the maintenance work.

The main disadvantage of process layout are :

(i) Material handling costs are generally high, because the production job often have to move longer distances and might back-track also.

(ii) The floor area per unit of product produced will be more.

(iii) The machine labour need to have higher skills since a large variety of jobs are likely to be taken.

(iv) Large number of inspection staff will be required because of a higher inspection work load caused by the larger variety of products.

(v) For each product material planning is to be done. In process inventories will be higher because, usually the economic batch quantities might be high.

(vi) Production planning and control will be quite complicated, requiring more paper work and control systems.

Application. This type of layout is suitable when

(i) The company is producing small quantities that need few days or weeks to produce several different products (jobbing work).

(ii) The production capacity is limited and there is need to load different kinds of equipment to their full or near full capacity.

(iii) Average number of operations on products are not too many and the handling costs are small.

(2) **Product or Line Layout.** If an arrangement in which production machines are laid out in a way that suits the flow of the product in one line without back tracking. The machines are arranged as per the sequence of operations required for producing are product.

Suppose for a particular product the sequence of operation require feeding of raw material to three different lines x, y, z and the machines are arranged as shown in Fig. 2.2. Line x represents the main line the raw material is processed on machines A, B and C then it is assembled to the part processed on machines D and E on line y,

NOTES

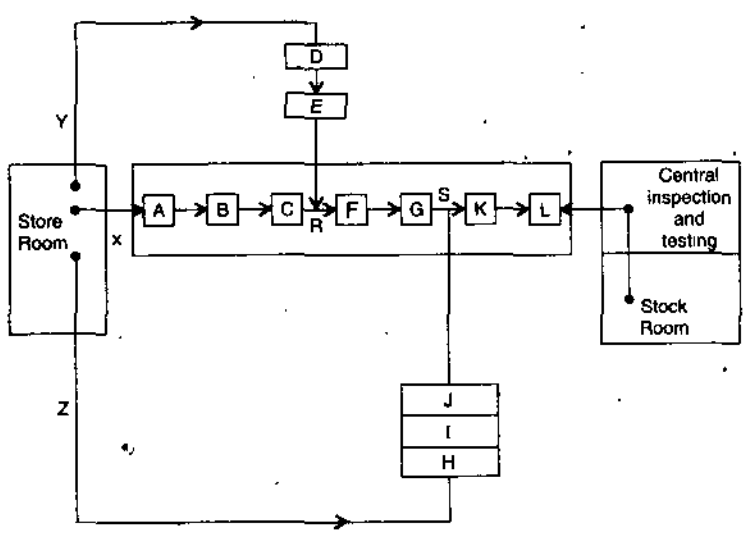


Fig. 2.2. Product layout.

NOTES

which is further processed on machines F and G. A second sub-assembly processed from line Z on m/cs H, I, J joins the main part at S and subsequently processed on K and L from where it is sent to central inspection and testing and finally to finished goods store. A schematic diagram is shown in Fig. 2.2.

At each of the work stations the member and type of machines would depend upon the production rate and the extent of line balancing required.

Advantages

(*i*) Since the distance to be travelled by material is small, material handling costs are less.

(*ii*) The floor area per unit of output is less because not much working space and aisle spaces are required.

(*iii*) Less inspection is needed because of routine operations.

(*iv*) The in-process inventory can be kept small.

(*v*) Production control is simple as the line integrates different production stages and allows least number of planning and control operations.

Disadvantages

(*i*) Investment on production equipments would be high.

(*ii*) Flexibility is limited, since production line set up, for a particular product cannot be used for other product.

(*iii*) Supervision is difficult, since production line set up, it calls for knowledge of a variety of processes.

(*iv*) Breakdown of one m/c or the absence of an operator in the line will affect the production severely.

(*v*) Because of routine operations, job satisfaction will be low.

Application. This type of layout is suitable when

(*i*) The life of the product is long enough to justify the expenditure. Reasonably stable product demand.

(*ii*) The production volume is large enough to give a good equipment utilisation.

(*iii*) The supply of materials and men of requisite skill is not difficult.

(*iv*) Standardization of product is possible.

(3) **Project or Fixed Position Layout.** This is generally used for manufacturing ships, huge aircrafts etc., where it is economical to move machines, tools and men on to the job rather than moving the job.

Advantages

(*i*) Very little material handling.

(*ii*) Continuity of operation is ensured.

(*iii*) Capital investment is minimum.

(*iv*) Close supervision is possible.

Disadvantages

(*i*) Highly skilled workers are required.

(*ii*) Setting up machines and tools take large time.

(*iii*) Work is to be carried out sometimes in confined spaces.

NOTES

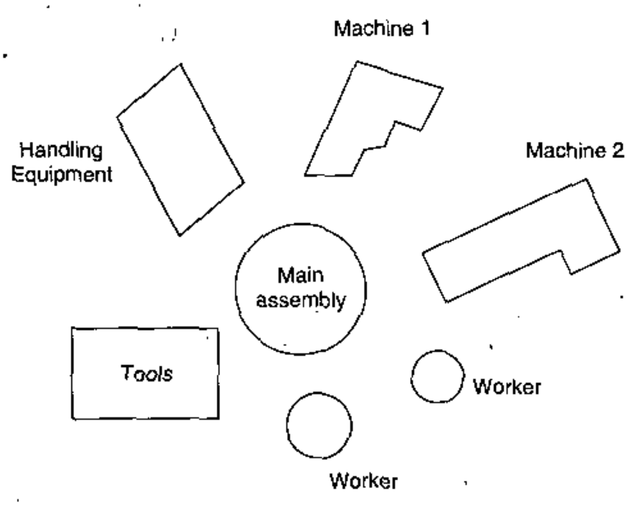


Fig. 2.3. Fixed position layout.

(4) **Combination Layout.** Because of the obvious advantages and limitations of each of the above methods a combination of any two or all of them is finding more and more application is the present-day.

Break-even Point Analysis of Basic Types of Layouts

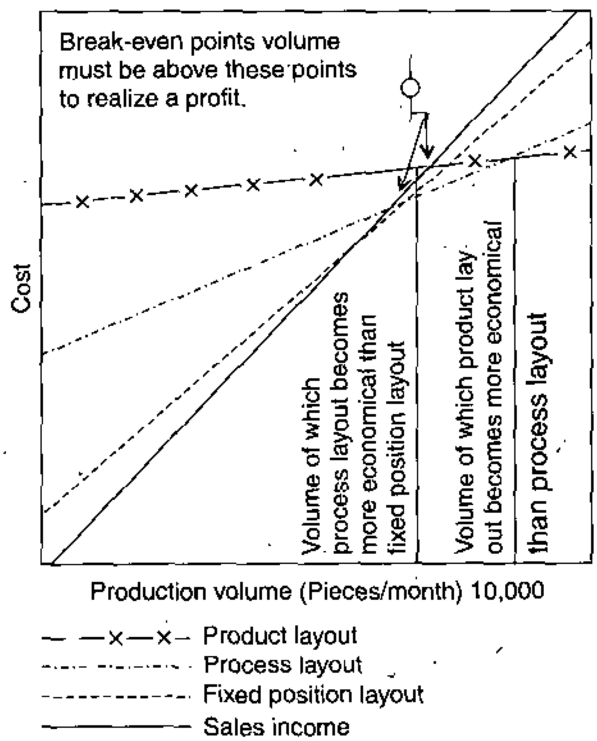


Fig. 2.4

(5) **Cellular or Group Layout.** It is a special type of functional layout in which the facilities are clubbed together into cells. This is suitable for systems designed to use the concepts, principles and approaches of 'group technology'. Such a layout offers the advantages of mass production with high degree of flexibility. We can employ high

degree of automation even if the number of products are more with flexible requirements. In such a system the facilities are grouped into cells which are able to perform similar type of functions for a group of products. A typical cellular layout is shown in Fig. 2.5.

NOTES

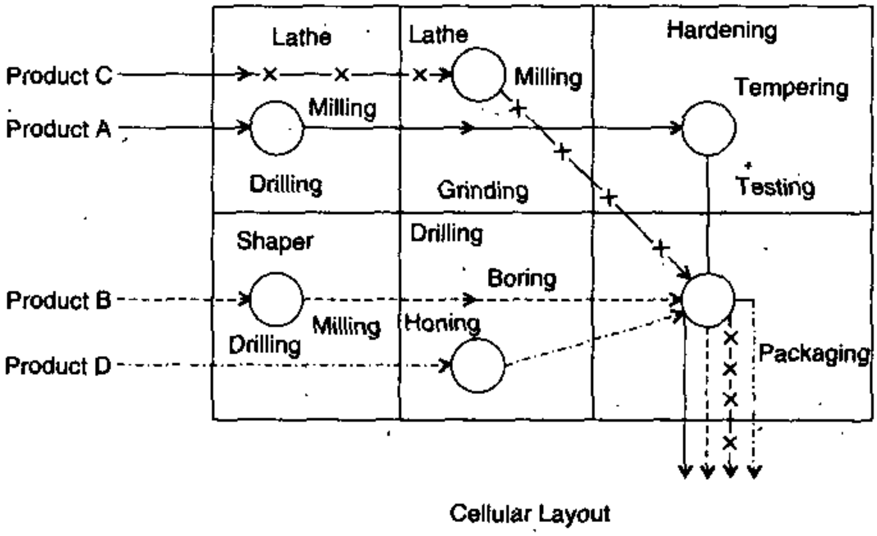


Fig. 2.5

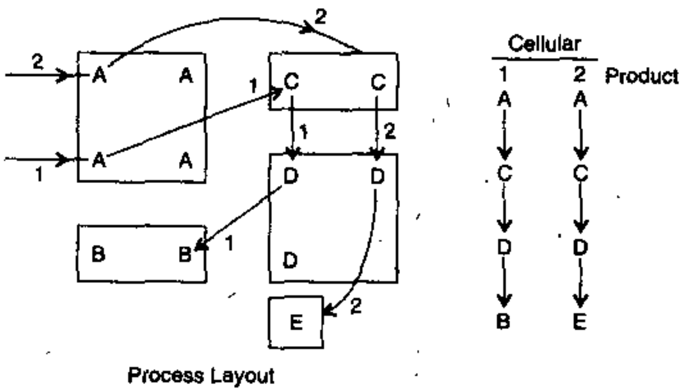


Fig. 2.6. Comparison of process layout and cellular layout

2.3. PLANT LAYOUT FACTORS

The design of any layout is governed by a number of factors and the best layout is the one that optimises all the factors. As discussed by Muther (1955) the factors influencing any layout are categorised into the following eight groups :

(i) *The material factor :* Includes design, variety, quantity, the necessary operations, and their sequence.

(ii) *The man factor :* Includes direct workers, supervision and service help, safety and manpower utilisation.

(iii) *The machinery factor :* Includes the process, producing equipment and tools and their utilisation.

(iv) *The movement factor :* Includes inter and intradepartmental transport and handling at the various operations, storages and inspections, the materials handling equipments.

(v) *The waiting factor :* Includes permanent and temporary storages and delays and their locations.

(vi) *The service factors :* Include service relating to employee facilities such as parking lot, locker rooms, toilets, waiting rooms etc. service relating to materials in terms of quality, production control, scheduling, despatching, waste control ; and service relating to machinery such as maintenance.

(vii) *The building factor :* Includes outside and inside building features and utility distribution and equipment.

(viii) *The change factor :* Includes versatility, flexibility and expansion.

Each of the above mentioned factors comprise a number of features and the layout engineer must review these in the light of his problem.

NOTES

STUDENT ACTIVITY

1. Give example of organization that have predominting
   - Product layout
   - Process layout
   - Fixed Position layout.

2. Consider a layout decision which has been made in your organization at work. How was the decision made ? What were the important factors ?

NOTES

SUMMARY

1. Plant layout means the disposition of the various facilities (equipment, material, *manpower etc.*) and *services* of the plant within the area of site selected previously. Plant layout begins with the design of the factory building and goes up to location and movement of a work task. All the facilities like equipments, raw materials, machinery, tools, fixtures, workers etc. are given a proper place.
2. The plant layout should be designed in such a way that the manufacturing process can be carried out in the most efficient manner.

TEST YOURSELF

1. What is Plant Layout ?
2. Why plant layout is important ?
3. What are characteristic of good plant layout ?
4. What are principles of plant layout ?
5. Write about process layout.
6. Write about product layout.
7. Write about fixed position layout.
8. Write about combination type layout.
9. Write about group layout.
10. Which type of plant layout would you suggest of the following and why (*a*) A car manufacturing unit (*b*) steel plant.
11. Critically evaluate the process adopted in to manufacture the product in your organization.

YES/NO TYPE QUESTIONS

1. Product layout produces only are type of product.
2. Functional layout is more suited for low volume of production Batch production.
3. In fixed position layout machine (s) and workers etc are kept in a fixed position and the assembly or fabrication of a product is carried out.

NOTES

CHAPTER

3

WORK STATION DESIGN

LEARNING OBJECTIVES

- Introduction
- Work System Design Involves
- Job Analysis is to Define a Job in Terms of Tasks, Behaviours, Education Skills, Relationship and Responsibility
- Job Design
- Job Satisfaction
- Behaviourial Approaches to Job Design
- Job Rotation
- Job Enlargement
- Job Enrichment (1970)
- Socio-technical Systems Approach to Job Design

3.1. INTRODUCTION

Work Station Design means

Proper equipment, tools-location and positioning

Proper hand or elbow height relative to tasks

Proper reach distance

Proper seating facility

Proper seat height for focal length

Proper environment lighting

Adequate space for materials

Proper input data for job

The process of defining tasks and jobs to achieve both organizational and employees goal.

3.2. WORK SYSTEM DESIGN INVOLVES

(*i*) Job design.

(ii) Work measurement.

(iii) Worker compensation.

Product design determines the type of activities the worker will be involved with.

NOTES

Facilities planning decision affect work design *e.g.*, process layout requires broader job content to product layout.

Every one works. Tools, techniques and methods are used for production of finished goods, producing goods is work.

A work system brings together technical competence in the form of people and equipments to achieve the organizational objectives.

Work system design is concerned with the study and design of work system in any type of organization.

Work system design is for

(i) Increasing productivity—work study is one of the technique.

(ii) Developing manpower effectiveness.

People abilities and talents are integral part of work system design.

Work System Design Assumptions

(i) Increasing productivity and developing manpower effectiveness are the objectives for studying work system.

(ii) Work systems can be encountered in three conditions design, betterment and improvement.

(iii) All aspects of the work system are to be considered in work design.

(iv) People, their abilities and talents are integeral part of work design. This results from the recognition that people at all levels can rarely understand many of events, the most involved techniques and situations.

3.3. JOB ANALYSIS IS TO DEFINE A JOB IN TERMS OF TASKS, BEHAVIOURS, EDUCATION, SKILLS, RELATIONSHIP AND RESPONSIBILITY

Job. A job is a type of position within the organization.

A job family is a group of two or more jobs that either call for similar work characteristics or contain parallel work tasks as determined by **Job analysis.**

A **job description** is a written statement of what the job holder does ? How it is done ? And why it is done ?

Job specification states the minimum acceptable qualifications that the incumbent must possess to perform the job successfully.

The time a person puts into a job represents about 35 percent of his or her working hours.

The job characteristics model

— **Skill variety.** Enables workers derive satisfaction from using a number of different kinds of skill levels.

— **Task variety.** A task is a distinct work activity carried out for a distinct purpose—Typing, preparing a lecture, unloading a mail truck. To much variety leads to inefficiency, too less variety leads to freedom.

NOTES

— **Task significance.** The degree to which the job has a substantial impact on the lives or work of other people.

— **Task Autonomy.** The degree to which the job provides substantial freedom, interdependence and discretion to the individual in scheduling the work and in determining the procedures to be used in carrying it out. Enables to exercise same control over work means informing employee about their performance.

— **Feedback.**

Job satisfaction. Refers to an employees general attitude towards his job.

Job depth. The extent to which an individual can control his or her work.

Job scope. The number of different operations a particular job requires and the frequency with which the job cycle must be repeated.

Job evaluation. It is the technique for rating the job.

Job Analysis. Is a formal process used to determine the type of task which people can do satisfactorily as well as its frequency and duration.

Job analysis is carried out with the help of questionnaire which includes questions related to various elements like equipments materials. Job task characteristics, work station environment, health, comfort, suggestions and comments. The users are asked to fill up the questionneir then their opinions are analyse and according job design process is carried out.

Job designers usually attempt to minimize the amount of physical human effort.

3.4. JOB DESIGN

The design of the job should start with the tasks to be accomplished. The design is usually broad enough to accommodate people's work and desires.

Job design is the consciously planned structuring of work effort performed by an individual or a team of person.

Job design is concerned with specifying the contents and methods of job.

Job design consists of three activities :

(*a*) Specifying individual work tasks.

(*b*) Specifying the method of performing the work task.

(*c*) Combining work task in to jobs for assignment to individuals.

Goods job design is a means of reducing job stresses. It involves knowledge committment and time on the part of management and users.

It must answer the job related questions ? Who is to perform the work ? When the work is to be done ? Why the job is necessary and how should the work be accomplished ?

Objective of job design is to develop a work system which is productive and efficient, is to develop work assignments that must the requirements of the organisation and technology and at the same time also satisfy the personal and individual requirement of the job holder.

Job design is carried out to satisfy the user needs using job task analysis.

When we speak of the design of jobs, we are thinking of two broad area ; Job content and work methods. Given the job content, the **work method** design is meant to develop the optimal combination of all variables of the job. However, if we accept a given job content and then try to arrive at some optimal combination of the remaining variables, we run the risk of sub optimization, because *job content is also a major* determinant of effectiveness.

In other situations, the process, the machine, the physical layout, time require*ments, and traditions are likely to play a dominant* role in determining job content. Each resulting job or operation can be analyzed from the several view points in order to produce an optimally designed job. But how would this optimal design compare with other basic alternatives of job content ? If we were to consider as a part of the problem, all possible alternatives of job content, there would be a baffling number. Unfortunately, there is very little information available to guide us here. The result, in practise, is that such considerations as the machines, layouts, production quotas, and machine and conveyor pacing often dictate job content.

Job has been broken down to the point where the worker finds little satisfaction in performing his tasks. In recent years there has been a reaction against excessive job breakdown ; *a few investigators found* that combinations of operations to create jobs of greater scope, recaptured the worker's interest ; increases in productivity, quality level, etc., were reported. A new term, job enlargement, appeared.

The ultimate answer lies in research attempt to isolate the factors that determine an optimal combination of tasks to make up jobs. This effort has been called 'job design'.

What is involved in the design of jobs ?

Conceptually the design of jobs can be divided into determination of job content *and the job determination* of the actual methods of execution. There is very little in the way of guides or principles to help us to determine optimal job content. In general, job content is not consciously designed but *is result of limitations of project designs,* machine designs, layouts, production quotas, and pacing effects and of the design to make skill requirements, uniforms with in jobs. Within these limitations, the scope of jobs is determined on the one hand by a desire to gain the advantage inherent in division of labour and, on the other hand, by a desire to design jobs that meet worker satisfaction needs. Whether an organization *tends toward finally divided jobs* or enlarged jobs depends on its managerial philosophy, traditions, and degree of investment committed in existing systems.

The design of job methods has received much attention since the time of Taylor. Since which optimize productivity and other measures of effectiveness for a given set of conditions. These data pertain *to control of the work environment,* physiological measures of body strength and sizing, psychological factor related to the various sensory inputs to the human operator, principles of arrangement and flow of work, and fatigue and work schedules. The data are applied with in a framework of physical and economic limitations.

Physical limitations may *relate to existing products, machines,* and layouts. Economic limitations refer both to the economic resources of the organization and to the justificable expenditures on a given product ; the letter depend to a great extent on the volume and market stability of products. Thus the design of work methods for a high-volume automotive part, such as a spark plug, will justify expenditure of funds for machines, *jigs, figures and other special tools.* On the other hand, job design to produce a novelty toy. Which may cease to exist in six months, might be quite crude. Thus, a given job design is likely to be a temporary thing which may change with gross changes in the volume and market stability of the part or product.

NOTES

Job Design—Job Satisfaction and Worker Response. As business and industrial growth has developed more and more large scale units, and as mechanization and technology have progressed, the fractionation of jobs has accelerated. The specialization principles seemed to fit perfectly the rationale of a highly organised industrial machine in which each copy had a specialized function which is performed repetitively with precision and reliability. In its most advanced state, it was difficult to tell which links in the giant machine were mechanized and which were human. As a matter of fact, the machine designer looked at the overall problem as one of simply employing machine links (mechanical and human) in the most economical way. The mechanical link was applied when it was most economical and vice versa. The economic principal is not the issue, because few people would deny its basic validity. The error was in assuming that the mechanical and human links were equivalent and that the total problem was one of machine design.

Job satisfaction is a criterion for job design which does not apply to machine design, humans have psychology and sociology ; machines do not.

Human can **participate** in the effective development of job design and methods. Beyond that, if we look at the capabilities of man compared to existing machines. We see that man's great strength is not in the repetitive, mechanical activities at all, but rather in situations requiring improvisation, reasoning, and judgement. From a human point of view, we have misusing man's capabilities. In the current era of highly organized and expansive labour, it is becoming obvious that we may also be misusing man's capabilities from on economic point of view.

Job design

- Quality control as part of worker's job
- Cross-training workers to perform multi skilled jobs
- Employee involvement and team approach to designing and organizing work
- Use of extensive telecommunications information networks to expand the nature of work
- Use of temporary workers
- Automation of heavy manual labour

Organizational committment to providing meaningful and rewarding jobs for all employees.

- Behaviour considerations in job design
  - Specialization of labour (Pros and cons)
  - Job enrichment
  - Sciotechnical systems
  - Work activities
    - — Task variety
    - — Skill variety
    - — Feedback
    - — Task identity
    - — Task autonomy
- Physical considerations
  - Work methods
    - — Worker at fixed workplaces

— Worker interacting with equipment
— Worker interacting with other workers
- Graphics and diagramming
  — Process charting
  — Worker-machine interaction chart
  — Activity chart
  — Time-study observation
- Work measurement and standards
  — Schedule work and allocate capacity
  — Motivate the workforce and measure their performance
- Bid for new works/contracts
- Provide benchmarks for improvement

NOTES

- Work measurement techniques
  - Time study
    — Normal time
    — Standard time
    — Elemental standard-time data
    — Predetermined motion-time data systems
  - Work sampling
    — Ratio delay
    — Performance measurement
    — Time standards
      — Methods for gathering data
        — Identify activities
        — Estimate time of activity
        — State desired accuracy
        — Determine specific time
        — Recompute required sample size
- Financial incentive plans
  — Basic systems
  — Individual and small group plans
  — Organisation-wide plans
- Learning curves
  - Individual learning
  - Organizational learning
  - Plotting learning curves
  - Guidelines for learning
    — Individual performance
      1. Selection of workers
      2. Training
      3. Motivation
      4. Work specialization

NOTES

5. Do one or very few jobs at a time
6. Use proper equipment that supports performance
7. Quick and easy access for help
8. Allow workers to help redesign their tasks.

Job design techniques

(A) Traditional engineering techniques
- (*a*) Job specialization
- (*b*) Working environment

(B) Behavioural approach to job design
- (*a*) Job rotation
- (*b*) Job enlargement
- (*c*) Job enrichment
- (*d*) Systems
- (*e*) Specialisation of labour
- (*f*) Work activities.

(A) (a) Worker Specialisation. Specialisation of worker is the two-edged sword of job design. On the one hand it has made possible high speed and low cost production, and has therefore increased our standard of living. On the other hand, extreme specialisation could lead to adverse effects on the worker, like boredom etc.

Advantages of specialisation to management are the following :

(*i*) Rapid training of the workforce.
(*ii*) Ease in recruiting new workers.
(*iii*) High output due to simple and repetitive work.
(*iv*) Low wages due to ease of substitutability of worker.
(*v*) Close control over work flow and work loads. As for labour, there is little responsibility for output, little mental effort is required and little education is required to obtain work.

During the scientific management era of F.W. Taylor, management tried to increase productivity through **job specialisation**. The rationale for job specialisation is that workers who need fewer skills, can be more easily trained and lower wages can be offered for such specialised and repetitive jobs. The advantages and disadvantages associated with job specialisation are listed below :

Advantages

For Workers	*For Management*
1. Less responsibility	1. Lower wages
2. Little mental effort required	2. Simplified training
3. Low skill required	3. Higher Productivity

Disadvantages

For Workers	*For Management*
1. Boring and monotonous jobs	1. Difficult to motivate
2. Little control over work	2. Worker dissatisfaction leading to absenteeism, turnover and quality problems
3. Limited scope for advancement	

A (b) Working Environment. Vibration is also an important factor in **job design.** Vibration can come from various sources like *machines, tools, vehicles, human activity*. Corrective action for vibration include use of shock absorbers, padding, *cushioning, rubber mounting.*

NOTES

Design Factors. For good design, the designer ought to start out with the operator by laying out the areas for vision, for controls, for sitting, for leg room etc. by taking note of standard anthropometric data of men and women, as the case may be. Job design should consider whether the job is to be done standing or sitting or in both the ways. You would probably observe that people leave their work places after regular intervals in order to obtain a change of posture. It is not very surprising to note that workers find it necessary to stand up from time to time probably because the seats provided are probably too uncomfortable to be sat upon for more than a limited period.

It is the requirement of good seating that the person while sitting should be able to maintain a good posture which will not cause of any particular group of muscles. The use of a well designed and positioned back rest may relieve the back muscles of a good deal of postural strain. Moreover, the seat should not press unduly on the tissues of buttocks. The pressure will restrict the blood flow which may cause pressure on the nerve trunk which runs on the underside of the high and will cause discomfort which could also sometimes cause the need 'to go sleep' and induce numbness. A well designed seat should therefore bear the weight of the body in a good posture on the hips and not on the thighs. The elements of good seating will depend on the length, width and shape of the seat ; material of which the seat is made ; the shape and height of the backrest and the height of the seat above the floor. When high chairs are used at work benches, there will have to be some type of footrest which should preferable be a flat surface rather than a bar which causes fatigue by forcing the operator to keep the foot in a fixed position. Sometimes it may be useful to provide some standing supports or 'rump rests. In contrast to the work situations, seats which will be used for relaxation can be somewhat lower than office and factory chairs.

However, when benches are laid out for work or when office equipments positioned, the general principles of motion economy as laid down by Gilbreth should be taken as a guideline. It is now being realised that reducing movements too much could cause local muscular fatigue which will not be present if the actions are spread over more muscles in the body. Accurate positioning of manipulative movements should be made near the body and controls which need fine adjustment should be placed close to and opposite the hand which will operate them.

In case of controls, information should preferably be given to the operators in a binary form of 'yes-no' type. Alternative lights like green-red can be used. Where quantitative information has to be given, digital presentation should be used in preference to the reading of graduated scales. Important control panel instruments should have preferably a combination of auditory (sound) and a visual warning signal scheme. Care should be taken to see that visual warning should be quite evident and not misleading. Lights or blinkers that are 30° from the centre of vision will be noticed more slowly than lights that are centrally located.

Organisation Factors. The problem of when to give a 'break' or 'rest pause' to an operator has been engaging the attention of researchers for many years. Researchers have arrived at a reasonable estimate for the calorie expenditure of an 'average

NOTES

man' employed in different types of occupation. It has been estimated that the light work clerks expend about 2,800 K. cal per day. If heavier work is undertaken the daily expenditure will rise. Work physiologists seems to agree that over a period time, the calorie output of a normal men in good health should not exceed 4,800 K cal/day.

Jobs have following five interrelated components :

(*a*) Work content—The assigned tasks which grow from the needs of the technical process.

(*b*) Method content—Manner in which tasks are to be performed.

(*c*) Structure content—The organizational setting in which the assigned tasks are carried out.

(*d*) Personal content—The physical and psychological requirements placed upon the employee by various aspects of the job.

(*e*) Reward content

3.5. JOB SATISFACTION

Job satisfaction is the favourableness or unfavourableness with which employees view their work.

Job satisfaction results when job characteristics and the wants of employees are in agreement.

There is a correlation between job satisfaction and life satisfaction at home and in community—Relationship may be positive or negative.

Various factors related to job satisfaction are

(*a*) **Characteristics of the individual**—Personal variables

(*i*) individual differences—Ability to adjust oneself to unpleasant circumstances

(*ii*) Age

(*iii*) Educational level and intelligence

(*iv*) Sex

(*v*) Relative status of individual within social and economic group with which he identifies himself.

(*b*) **Characteristics of the Job**

Environmental factors

(*i*) Occupational level—Responsibility, fatigue

(*ii*) Job contents

(*iii*) Considerate leadership—Relation with supervisor

(*iv*) Pay and promotional opportunities—Excitement, Recognition

(*v*) Social interaction and working in a group

(*vi*) Security of the job

(*vii*) Intrinsic aspects of the job

(*viii*) Working condition—hours of work

(*ix*) Relation with co-workers, freedom from close supervision, freedom to live where you like, vacations, opportunity for self expression, competition, Religion, communication.

NOTES

Advantages of job satisfaction study

(*a*) Indication of general level of satisfaction

(*b*) Communication

(*c*) Improved attitudes

(*d*) Determines training needs

(*e*) Benefits to unions.

Job satisfaction and turnover. *Low job satisfaction increases* the turnover.

Job satisfaction and absenteeism. Employee who have low job satisfaction tend to remain absent off and as from their job.

Job satisfaction and community conditions. *Usually employees compare* their community conditions with their job conditions. If job conditions are better than that of community conditions, job satisfaction is higher.

Types of Job satisfaction surveys. According to the forms of questions asked :

(*a*) **Objective surveys.** Objective type questions :

These are easy to administer and analyse statistically.

Answers are written by management. Employees have to select one answer which they feel correct as per their thinking. It is not a true expression of their feelings.

(*b*) **Descriptive surveys.** Questions are set by the management, employees give answer in detail.

The descriptive survey may be written or oral-applying interview techniques.

Management comes to know the feelings of employees in detail.

It is a time consuming, expensive.

(*a*) **Projective surveys.** The projective techniques present an abstraction that is *incomplete and meaningless. The employee project those* abstraction into completeness by describing what it means for them. This technique projects new and creative thinking.

Using Job satisfaction information. *The real goal is to encourage* behavioural changes.

In using job satisfaction information long term approach is important.

Sharing information with managers and employees from start to end is essential.

Theories of Job Satisfaction

(*a*) Herz berg's Motivation hygiene theory.

(*b*) Need fulfilment theory—A person is satisfied if he gets what he wants.

(*c*) The social reference—group Theory.

The groups to which the individual looks for guidence—reference groups, they define the way in which he should look at the world and evaluate various phenomena in the environment. If a job meets the interests, desires and requirements of a person's reference group, he will like it.

NOTES

What do workers want from their Jobs ? 1 = Highest	
Good Working conditions	9
Feeling in on things	2
Tactful disciplining	10
Full appreciation for work done	1
Management loyalty to workers	8
Good wages	5
Promotion and growth	7
Sympathetic understanding of personal problems	3
Job security	4
Interesting work	6

For creating job satisfaction following things are to be done :

(a) Attending and solving problems.
(b) Satisfactory future.
(c) Testing the worker's ability and progress.
(d) Respect for creative suggestions.
(e) Co-ordial analysis or evaluation of the work.
(f) Increase in wages.
(g) Praise for good performance.
(h) Promotion according to ability.
(i) Proper quantum of work.
(j) Equal wages for equal work.
(k) Freedom to seek help involving problem.
(l) Absence of unnecessary intervention and criticism.
(m) Satisfactory hours of work.
(n) Availability of leaves and rest.

3.6. BEHAVIOURIAL APPROACHES TO JOB DESIGN

An effective job design is one which a person *can do*, one that a *person wants to do*, and one whose output is valuable to the organisation.

There are two basic schools of thought in job design ; efficiency school and behavioral school.

Efficiency school emphasizes on traditional engineering approaches to job design such as job specialisation, methods study etc. Most of the specialised jobs are found to be boring, monotonous and less satisfying, thereby leading to problems like absenteeism, turn over and rejects. This has been highlighted by behavioural aspects which point out that most workers do not like specialised jobs. They feel that specialised jobs are not interesting and they want more control over these jobs. This has led to attempts to make jobs interesting and meaningful through approaches like Job Rotation, Job Enlargement, Job Enrichment, Socio-technical systems.

NOTES

3.7. JOB ROTATION

Involves assigning different kinds of jobs to workers in turn. For example a clerk can be assigned jobs in recruitment, accounts, establishment, academic sections on a rotating basis.

The another way to approach jobs that cannot be designed or automated to eliminate undesirable features is to move or rotate employees into the job for a short period of time and then *move them out again*. This Job Rotation technique seems to be working well in a large number of situations that seem to defy job enrichment and/or enlargement.

However, *one very important fact overlooked* by designers is the person/operator who performs the job. If the ultimate beneficiary, the person/operator could be involved in a participatory design procedure, there would be greater success in implementing any changes that need to be done in the organisation.

3.8. JOB ENLARGEMENT

It refers to enlarging the range of tasks in a job to make it more broad based.

Job enlargement focuses an enlarging jobs by increasing tasks and responsibility.

It involves expression of the scope and width of the job by *means of a horizontal* loading of certain closely related operation.

Assigning additional work of same skill and responsibility. One survey of walker and Guest attempted to correlate degree of job interest *with the number of operations* performed. Jobs of broader scope tend interest and satisfaction to the worker.

Advantages

1. Better product quality. Company records showed a substantial *reduction in* losses from defects and scraps. This was due to several factors but was substantially attributate by management to "greater responsibilities taken by the individual operator *for quality of his work*".
2. Less idle time both for machines and operators. It has been found that the operators could set up and check himself with greater economy in time than could *set up men and inspectors. The cost of* setting up and inspection was reduced by 5 percent.
3. Management felt that job enlargement had "enriched the job for the worker". It had *introduced interest, variety,* and a feeling of responsibility.

3.9. JOB ENRICHMENT (1970)

Job must be developed as such so as to provide the person concerned a job providing opportunities for achievements, recognition, responsibility, advancement.

Job enrichment is procedure of redesigning work content *to make the job more* meaningful and enjoyable by involving employees in planning, organising and controlling their work.

Many employees prefer a low level of required *competency high security* and relative independence to the increased responsibility and growth. Job enrichment

NOTES

involves giving the worker work of higher skill and responsibility. Individual jobs can be enriched :

(a) By growing tasks into natural work units.

(b) Combine several tasks in to one job.

(c) Establish direct relationships with the customer.

(d) Vertical job loading, increasing individuals responsibility for planning, doing and controlling.

(e) Work team jobs can be envised.

(f) Group have to complete task to perform.

Making job enrichment effective

(a) Organizations need a better understanding of what people want.

(b) Management has to show that how workers will be benefited.

(c) People like to be involved, to be consulted and to be given an opportunity to offer suggestions.

(d) People like to feel that their managers are truely concerned with their welfare.

Enriching the job of a person. It involves

(a) Eliminating unmotivating tasks from the job.

(b) Horizontal stretching—job should give the responsibility for a particular problem concerning his speciality.

(c) Vertical loading—adding something to the job giving more challenge.

Job enrichment

— job enrichment designing job in such a way that include greater work content, require a higher level of knowledge and skill, give the worker more autonomy and responsibility for planning, organizing, motivating, directing, and controlling his own performance, and provide opportunity for personal and meaningful work experience.

— deliberate upgrading of responsibility, scope achievement and challenge in work.

— based on the assumption that each individual abilities and capacities are different and they should be allowed to improve or sharpen or enrich their facilities to the extent of potentionalities they possesses.

Approach to job enrichment

(a) No single technique can be employed for all jobs at all levels for job enrichment.

(b) The employees will cooperate sincerely if they are convinced that they are going to be benefited.

(c) The results of job enrichment should be communicated to employees.

(d) Employees should be consulted before taking any decision.

(e) Management should provide welfare opportunities to employees.

Criticism of job enrichment

(i) A large number of workers are satisfied from their job contents and they want no change in job contents.

(ii) Job enrichment is limited to unskilled and semiskilled workers.

Problems of job enrichment

(*a*) Tendency of top management and specialists to apply their own scale of values of challenge and accomplishment to other people's personalities.

(*b*) Tendency of the management to impose job enrichment on workers.

(*c*) Management should get union support for implementing.

NOTES

By products of job enrichment efforts are—

(*a*) Either the elimination of a layer of supervision of a reconcipualization of the role of the supervisor.

(*b*) Organization development activities inherenatly incorporate some job enrichment features since the process clearly includes some additional subordinate planning and controlling, particularly in group situations. Doing aspects of jobs may become narrower or more routine.

Job enrichment Principles

(*i*) Form natural work units based on training/experience of workers.

(*ii*) Combine tasks—Encourage development of several skills.

(*iii*) Establish client relationships.

(*iv*) Increase employees autonomy—Give workers more responsibility and control.

(*v*) Open feedback channels.

A job may be enriched by

(*a*) Giving workers more freedom in deciding about such things as work methods, sequence, pace, acceptance/rejection of materials.

(*b*) Encouraging participation of subordinates and interaction between workers.

(*c*) Giving workers a feeling of personal responsibility for their tasks.

(*d*) Taking steps to make sure that workers can see how their tasks contribute to a finished product and the welfare of organization.

(*e*) Giving people feedback on their job performance, before their supervisors get it.

(*f*) Involving workers in the analysis and change of physical aspects of work environment such as plant layout, temperature, sighting, noise, dust, ventilation, cleaniness, colour of walls and roofs, window openings, doors etc.

Advantages of Job Enrichment. Followings are the advantages of job enrichment :

(*i*) It makes the work interesting.

(*ii*) It decreases the rates of absenteeism and labour turnover.

(*iii*) It helps in motivation through opportunities for growth and advancement.

(*iv*) It makes easy task reinforcement and increases the skill of workers.

(*v*) Workers get higher job satisfaction.

(*vi*) The enterprise gains through improvement of output both quantitatively and qualitatively and higher satisfaction of the workers.

Limitations of Job Enrichment. The limitations of job enrichment are as follows :

(*i*) Technology may not permit the enrichment of all jobs. With specialised machinery, it may not be possible to make jobs very meaningful.

(*ii*) Job enrichment has proved to be a costly process in certain cases as the expenditure involved is higher than the gains in productivity.

NOTES

(*iii*) Jobs of highly skilled professionals already contain many challenging elements, but they are not necessarily that much efficient.

(*iv*) It is difficult to say that all workers really want challenging jobs. Many of them even like to avoid responsibility. They seem to like job security and pay above all.

(*v*) All those who prefer job enrichment may not have the requisite capability to meet the new challenges.

Job Enlargement vs. Job Enrichment. Both job enlargement and job enrichment are important forms of job redesign in order to enhance productivity and satisfaction of the job-holders. They differ from each other in regard to the following points :

1. **Nature.** Job enlargement refers to expansion of the range of tasks in a job. It involves a horizontal loading or expansion of job, *i.e.*, addition of tasks of the same nature. But job enrichment refers to an improvement of the quality of a job in terms of its intrinsic worth. It involves vertical loading of functions and responsibilities of the job-holders.

2. **Purpose.** The purpose of job enlargement is to reduce the monotony in performing certain repetitive jobs by lengthening the cycle of operations. But job enrichment is meant to make the job more lively, challenging and satisfying. It satisfies the higher level needs such as ego satisfaction, self-expression, sense of achievement and advancement of the job holders.

3. **Need for Skills.** Job enlargement may not necessarily call for acquisition or utilisation of higher skills on the part of the job holders. But job enrichment calls for development and utilisation of higher skills, initiative and innovation on the part of the job holders.

4. **External Direction and Control.** Job enlargement does not reduce the need for direction and control of the superiors. The job-holder may need more supervision in view of enlargement of the scope of his responsibilities. But in case of job enrichment, the job-holder needs less of external supervision. He utilises his capabilities for self-direction and control.

3.10. SOCIO-TECHNICAL SYSTEMS APPROACH TO JOB DESIGN

The consideration of both the technology production and the social aspects of the work environment is called the socio-technical approach to job design. What is sought is a design that provides for high levels of productivity and quality and at the same time ensures a satisfying job and work environment.

The **socio-technical systems** approach to job design attempts to develop jobs that adjust the needs of the technology to the needs of the worker and workgroup. The approach developed from studies of weaving mills in India and Coal mines in England around 1950. These studies revealed that work group could effectively deal with many production problems better than management if they were allowed to make their own decisions. The Socio-technical approach has been adopted in many countries. The rationale underlying these studies is that the individual or work group requires a pattern of work activities incorporating :

NOTES

(*i*) **Task variety**

(*ii*) **Skill variety**

(*iii*) **Feedback**

(*iv*) **Task identity** implies that sets of tasks should be separated from others by some clear boundary.

(*v*) **Task autonomy.**

One of the major drawbacks of this approach is the reluctance of managers to give more authority to workers.

On the basis of studies carried out at the Tavistock Institute, the following guidelines for job design are offered at the level of the individual :

1. Optimum variety of tasks within the job.
2. A *meaningful pattern of tasks that gives each job a semblance of a single*, overall task.
3. Optimum length of work cycle.
4. Some scope for setting standards of quantity and quality of production and a suitable feedback of knowledge of results.
5. Inclusion in the job of some of the auxiliary and preparatory tasks.
6. Inclusion in the job of some degree of care, skill, knowledge or effort that is worthy of respect in the community.
7. Perceivable contribution of the job to the utility of the product for the consumer.

In considering the role of people in work, operation managers must take a socio-technical approach ; that is, they must consider not only the technical aspects but also the social atmosphere of the job. In addition to work design methods, human engineering/ergonomic considerations need to be kept in mind while examining the physical workplace, the physical environment and the social environment. All these must come together to create an effective job that will meet the organisational objectives of low cost, high productivity and worker satisfaction towards a better quality of work life, higher standard of living and ultimately a better quality of life itself.

STUDENT ACTIVITY

1. What job you are doing in organization ? Are you satisfied with your job ? If not what you want to do.

2. Is worker specialisation is necessary in your organization ?

3. Is job rotation is necessary in your organization,?

4. Is job enlargement is necessary in your organization ?

NOTES

SUMMARY

1. Work system design is concerned with the study and design of work system in any type of organization.
2. **Job specification** states the minimum acceptable qualifications that the incumbent must possess to perform the job successfully.
3. **Goods job design** is a means of reducing job stresses. It involves knowledge committment and time on the part of management and users.
4. Job satisfaction is the favourableness or unfavourableness with which employees view their work.
5. Job enrichment is procedure of redesigning work content to make the job more meaningful and enjoyable by involving employees in planning, organising and controlling their work.
6. The **socio-technical systems** approach to job design attempts to develop jobs that adjust the needs of the technology to the needs of the worker and workgroup.

TEST YOURSELF

1. Define work system design.
2. What is work station design ?
3. Define job, job family, job analysis, job description, job specification, job design, job satisfaction, Job depth, job scope, job evaluation.
4. Write about job design techniques.
5. Write about job satisfaction.
6. Write about job rotation.
7. Write about job enlargement.
8. Write about job enrichment.
9. Define job evaluation.
10. Is job enrichment is necessary in your organization ?

TRUE OR FALSE

1. Job evaluation and merit rating are the same things.
2. Job analysis is related to only a few of the functional dimensioning arrangement.
3. Job description information and job specification information can be obtained through a job analysis.
4. Under job enrichment employees are given less responsibility through more planning opportunities in job performance.
5. Job enlargement refers to horizontal expansion of jobs.
6. Job rotation is used to give the trainee varied experiences with a limited time.

NOTES

OBJECTIVE TYPE QUESTIONS

1. A job specification would be unlikely to specify requirements for
   (*a*) Level of performance expected (*b*) Knowledge
   (*c*) Previous experience (*d*) Physical characteristics.
2. Job enrichment is not
   (*a*) Providing the opportunity for increased recognization
   (*b*) Providing the opportunity for growth
   (*c*) Assigning more work
   (*d*) Providing the opportunity for advancement.
3. The key to job enrichment is
   (*a*) Structuring the job correctly (*b*) Theory
   (*c*) Work argumentation (*d*) None of these.
4. Job enlargement relates to
   (*a*) Redesigning of job (*b*) Value engineering
   (*c*) Plant Layout (*d*) Ergonomics.
5. In job design the various elementary movements are called
   (*a*) Micromotions (*b*) Elements
   (*c*) Jobs (*d*) Therbligs.
6. Which of the following is not a strategic decision ?
   (*a*) Facility location (*b*) Capacity planning
   (*c*) Work and job design (*d*) Plant layout.
7. Which of the following motivates the employees
   (*a*) Job enlargement (*b*) Job enrichment
   (*c*) Job rotation (*d*) All of the above.

NOTES

CHAPTER

4

WORK STUDY

LEARNING OBJECTIVES

- Introduction
- Techniques of Work Study
- Procedure of Work Study
- Method Study
- Procedure of Methods Study
- Method Study Charts
- Work Measurement
- Tools Used in Stop Watch Time Study
- Stop Watch Time Study
- Performance Rating
- Allowances

4.1. INTRODUCTION

As per B.I.S. (Bureau of Indian Standards) 6363, Work Study is defined as a generic term for those techniques particularly method study and work measurement, which are used in the examination of human work in all its contexts and which used systematically to the investigation of all the factors which affect the efficiency and economy of the situation being reviewed in order to effect improvements. In India about 60% organizations uses work study techniques.

Work study has been widely known for years as **Time and Motion study** as employed in USA.

4.2. TECHNIQUES OF WORK STUDY

Work study embraces

I. Method study

II. Work measurement.

I. Method study

It is concerned with the reduction of unproductive work elements.

II. Work measurement

It is concerned with the investigation and reduction of any ineffective time. It establishes time Standards *for the operation in improved method.*

Process information, Visual motion study, Micromotion study, Time study (work measurement study).

NOTES

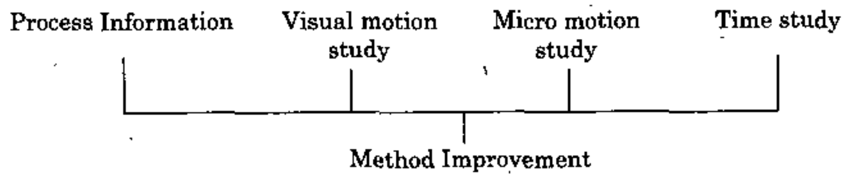


Fig. 4.1. Relationship of method study and work measurement.

4.3. PROCEDURE OF WORK STUDY

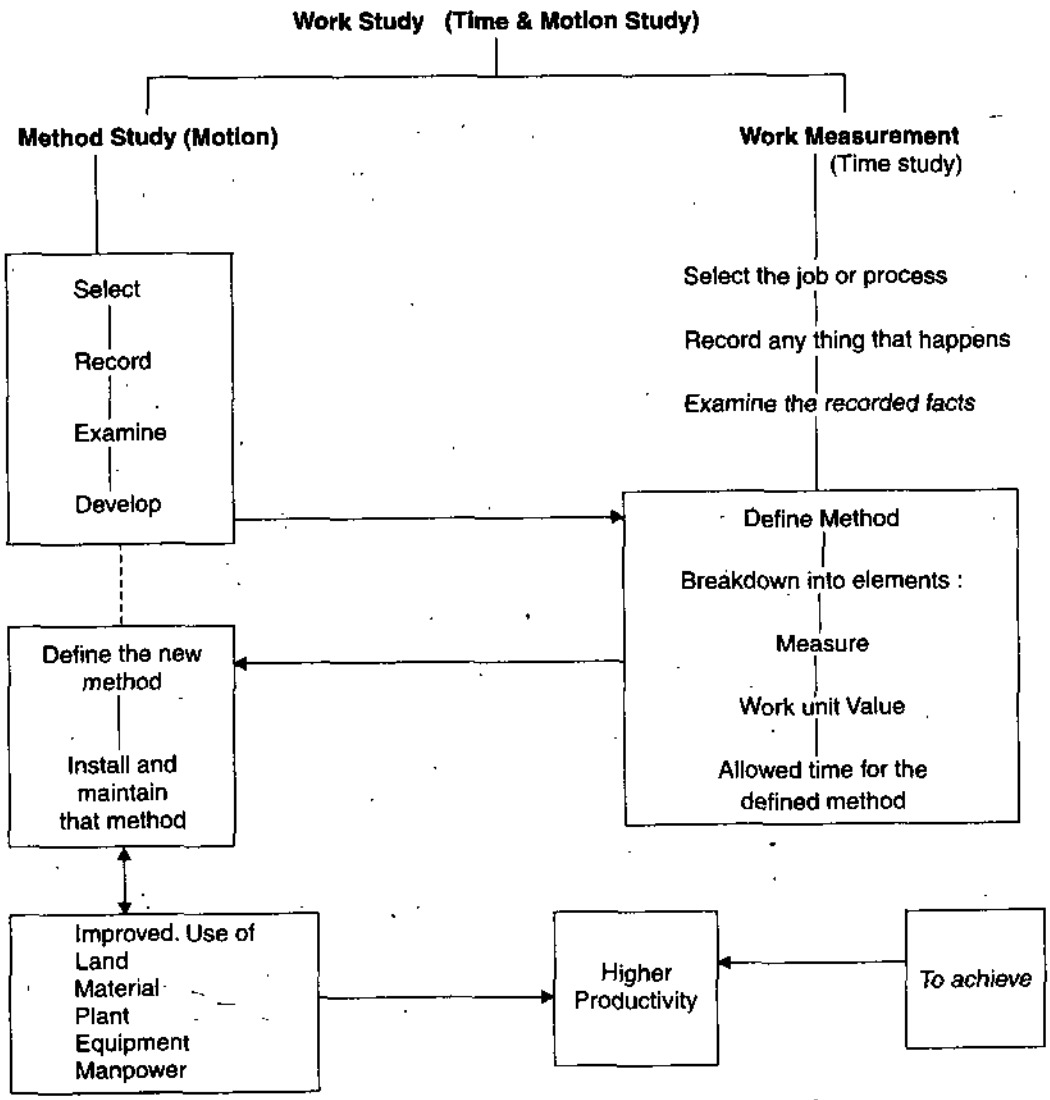


Fig. 4.2

NOTES

(a) Select the job or process (MS and WM)
(b) Record everything that happens (MS and WM)
(c) Examine the recorded facts (MS and WM)
(d) Develop the most economic method (MS)
(e) Measure the quantity of work involved in the method selected (WM)
(f) Define the new method (WM)
(g) Install the new method (MS)
(h) Maintain the new standard (MS).

4.4. METHOD STUDY

Methods Study is the systematic recording and critical examination of the factors and resources involved in existing and proposed ways of doing work, as a means of developing and applying easier and more effective methods and reducing costs.

Methods Study basically deals with finding better ways of doing work and it helps improve productivity by eliminating unnecessary work, avoidable delays and other types of waste. These are achieved by

- Improved working, procedures
- Improved layout
- Improved working environment
- Improved product design.

Objectives of Method Study

Improvements in

I. Labour utilization, worker condition.
II. Machinery utilization.
III. Materials utilization.

Standardization of operations.

Cost/times of operations.

Performed by

— Gathering relevant information about method, representing the relevant facts—process flow chart, man m/c chart etc.
— Critically examining/analysing information obtained to identify avenues for improvement.
— Come up with alternatives.
— Evaluating alternatives
— Checking acceptability
— Implementing
— Follow up.

In motion study analysis, a job is usually divided into four distinct divisions for the purpose of study and measurement :

1. **Process.** A process includes all the steps in the procedure for completing a job.

2. **Operation.** An operation is the subdivision of a process. Ordinarily an operation is divided into a series of closely related component parts.

3. **Element.** When an operation is subdivided into its component parts, each part becomes an element (suboperation), indicating simple motions. A simple motion

carried out in less than 0.03 of a minute must be combined with another motion to form a combined element for visual observation and timing by the stopwatch method.

NOTES

4. **Therblig.** A therblig is the minutest subdivision of an element. It constitutes a *micromotion.* A *micromotion can* be measured in units of 0.0005 of a minute with special equipment, and in units of 0.001 of a minute with an ordinary motion picture camera. A micromotion study is undertaken only after the entire process has been *charted and analyzed to ascertain whether the expenditure is warranted.*

In a simple motion study, a single operation or a series of operations is studied visually by means of a stopwatch.

4.5. PROCEDURE OF METHODS STUDY

Consists of the following six steps :

(*a*) **Select** the work to be studied

(*b*) **Record** all the relevant facts of the present/proposed method

(*c*) **Examine** the facts critically

(*d*) **Develop** the most practical, economic and effective method, with due regards to, all contingent circumstances

(*e*) **Define** the proposed method

(*f*) **Install** *the developed method as standard practice*

(*g*) **Maintain** the standard practice by periodic reviews.

(*a*) **Select**

To identify problem

(*i*) Poor use of labour, materials, machine capacity resulting in high cost.

(*ii*) Unnecessary *movement* of materials

(*iii*) High work fatigue

(*iv*) Existence of bottlenecks

(*v*) Excessive overtime

(*vi*) Frequent accidents

(*vii*) Poor quality of the product.

The following factors may be considered while carrying out a method study investigations of a particular job :

(*i*) **Economic**—*Bottle-necks, movement of materials over long* distance, operations involving repetitive work.

(*ii*) **Technical**

(*iii*) **Human reaction**

The function which influence the designation of work priorities are

(*i*) Management preferences

(*ii*) Cost and benefit factors which quantify and qualify the value of the study.

(*iii*) Providing solutions to such problems as excessive fatigue, health, safety hazard; jobs which are *excessively dirty, boring and leaves the worker unsatisfied.*

(*b*) **Record**

The techniques include—observation discussion

— Charts

— Diagrams

— *Models*

— Photographs/Video recording.

NOTES

(c) **Examination**

The purpose of examination is to determine the true reason underlying each event and to draw up a systematic list of all possible improvements. It is carried out by means of two sets of questions :

(i) Primary questions which seek to establish the need for activities.

(ii) Secondary questions which seek alternatives and select those which will lead to acceptable solution.

(d) **Develop**

The purpose is to develop an easier and more economic way of achieving, the selected objective, Techniques used to develop solutions to problems :

(a) Work design
(b) Work place layout
(c) Brain storming
(d) Attribute listing
(e) Heuristic procedure

Choice and evaluation

To identify the most appropriate solution to each problem. The most common critarions are

(a) Pressure of time
(b) Technical factors
(c) Economic factors
(d) Human factors
(e) Organizational factors
(f) Statutory provisions
(g) Decision tree (Cinzanto chart)
(h) Decision matrix
(i) Cause and effect diagram
(j) Net work analysis
(k) Function analysis system techniques.

(e) **Define**

Define the proposed method.

(f) **Install**

The installation of an improved method is a combined management/management service function and change over plans and schedule should be proved.

(g) **Maintain**

Work study man should review the job from time to time to identify discrepancies between the job specification and current practices and to develop further improvements.

Techniques used for critical examination in Method Study with a questioning attitude may be used. Some questions which may arise during his investigate given below :

4.6. METHOD STUDY CHARTS

Other way to represent steps in the applications of MS are

(A) For aims

(a) Possibility guide or list
(b) Activity chart

(c) Machine load chart
(d) Work distribution chart
(e) Functional form analysis chart.

(B) For Analysis

NOTES

(a) Flow process chart
(b) Flow diagram
(c) Procedure analysis chart.

Man

(a) Flow process chart
(b) **Flow diagram**
Work place layout
Operation process chart.

Multiple activity analysis—

(a) Man and machine operation chart
(b) Man and machine operation time chart
(c) Man and machine process chart
(d) Man and machine process time chart
(e) Multiman operation chart
(f) Multiman operation time chart
(g) Micromotion study
(h) Two hand
 (i) Right and Left hand.
 (ii) Process chart.
(i) String diagram
(j) Gang process chart
(k) Man-m/c chart
(l) Travel chart
(m) Activity relationship chart
(n) SIMO Chart
(p) Memo motion Chart
 (i) Cyclegraphic records
 (ii) Chrono cycle graphic records

(C) Critism

Same as for aims and Analysis.

(D) Innovation

Same as for analysis.

(E) Test

Same as for Critism.

(F) Trial

(G) *Application*

Standards charts/Forms

Most people find the graphical or pictorial representation of information valuable when they are faced with a mass of facts.

Most study systematically because there is less chance of over looking any detail.

Charts help the investigator to understand present procedure more carefully. It also assists him in quest for improvements. Charts enable an invegator to discuss procedure more effectively with operating staff.

NOTES

Advantages of charting

(a) Charts may be prepared more quickly than written descriptions of procedures and activities.

(b) Charts convey the facts more meaningfully.

(c) Charts provide a more effective means of comparing present and proposed procedures.

(d) Charts provide greater impact.

(e) Charts will readily show when documents enter a procedure, their title and purpose.

(f) A chart is a compact method of presentation.

(g) Omissions are more easily detected on a chart.

(h) Duplication excessive movement and delay are more clearly defined on a chart.

(A) For Aims

(a) Possibility guide

TYPE OF CHART-POSSIBILITY GUIDE

METHOD	______	MACHINE No.	______
OPERATION	______	OPERATION No.	______
CRITERION	______	CHARTED BY	______
PART NAME	______	DATE	______
OPERATOR	______		

SUGGESTION No.	CLASSOF CHANGES	DESCRIPTION AFFECTED	OTHER CLASSES

Fig. 4.3. Possibility guide.

This is a systematic list of all possible changes suggested by the person familiar with the activity or product under scrutiny. It also shows the consequences of each suggestion.

Performa of possibility guide Fig. 4.3.

(b) Activity chart

This is a chronological record of various activities of an individual performing a variety of tasks. It includes a summery of the nature of each activity. The work units produced and the time spent at each activity. The performa of activity chart is Fig. 4.4.

TYPE OF CHART—ACTIVITY CHART

__________________ NAME

__________________ DATE

__________________ UNIT

__________________ GRADE

NATURE OF ACTIVITY	REMARKS	TIME BEGAN	WORK UNITS PRODUCED	ELAPSED TIME (MINUTE)

NOTES

Fig. 4.4. Activity chart.

(c) Machine load chart

Records the activities of a machine

(*d*) Work distribution chart (Fig. 4.5)

Organizational Unit Charted				WORK DISTRIBUTION CHART														
❑ Existing Organ. ❑ Recommended Organization				NAME—			NAME—			NAME—			NAME—			NAME—		
CHARTED BY—				Position	GRADE		Position	GRADE		Position	GRADE		Position	GRADE		Position	GRADE	
Activity No.	Activity	Work Count	hrs/Weeks	Tasks	Work Count	Hrs/Weeks	Tasks	Work Count	Hrs/Weeks	Tasks	Work Count	Hrs/Weeks	Tasks	Work Cout	Hrs/Weeks	Tasks	Work Count	Hrs/Wecks

Fig. 4.5. Work distribution chart.

A tabulation of the various tasks performed by the individuals in an organization classified in an accordance with the major activities of that organization. Time spent by each individual on each task is indicated so that a completed chart will show the total man hours spent on each activity.

NOTES

FUNCTIONAL FORM ANALYSIS CHART																						
ACTIVITY O.I.G.DIV. A.G.O. DATE OF ANALYSIS— ACTIVITY NO.— SUBJECT OR OPERATION—	TO ADJUST	TO APPLY FOR	TO ASSIGN	TO AUTHORISE	TO BILL	TO CERTIFY	TO CLASSIFY, RATE	TO CONTRACT	TO DIRECT	TO FOLLOW UP	TO IDENTIFY	TO INSTRUCT	TO ORDER PROCURE	TO RECEIPT FOR	TO RECEIVE	TO RECORD	TO REPORT	TO REQUISITION	TO ROUTE	TO SCHEDULE	TO SHIP	TOTAL
TRANSPORTATION																						
ALLOTMENT		1				2																
RECRUITMENT																						
CIR. PERSONNEL																						
TELEPHONE																						
EQUIPMENT																						
COMMUNICATION																						
APPROPRIATION																						
PRINTING																						
ENLISTED THEN																						
EDUCATION																						

Fig. 4.6. Function from analysis chart

(e) Functional form analysis chart

This is a tabular presentation of activities of an organization and the forms used at each step in performing each activity. It indicates areas in which form overlap are inadequate or are too numerous.

(B) For Analysis

(a) Flow process chart

These are used to indicate clearly interrelationships between the various types of activities.

A flow process chart is constructed by means of symbols, a form of systems. Short hand for describing the nature of each activity in a procedure.

· The activity number for each type of activity is inserted in each symbol.

Relational lines are used for connecting activity symbols which are interrelated.

Descriptive details in abbreviated form are indicated on the right of each symbol in order to classify the activity.

Charts are drawn normally vertically.

Distances involved may be shown when forms or documents are subjected to movement.

Activities are summarised by type.

A chart is usually drawn to show the present procedure or system which is redrawn to display the proposed procedure after a revised procedure has been formulated.

Otis Flow Process Chart (Fig. 4.7)

NOTES

PRECEDURE :	SALES INVOICE POSTING (THREE-IN-ONE POSTING BOARD)	CHARTED BY : ________
DEPARTMENT :	SALES LEDGER	DATE : ________
PERSON OR FORM :	INVOICE AND ASSOCIATED DOCUMENTS	SHEET NO : 1 OF 2

SUMMARY

SYMBOL	ACTIVITY	PRESENT	PROPOSED	DIFFERENCE OR SAVING
○	OPERATION	11	10	1
□	INSPECTION	3	1	2
→	TRANSPORT	2	2	–
D	DELAY	2	2	–
∇	STORAGE	7	6	1
TOTAL DISTANCE				
TOTAL TIME				

ACTIVITY NUMBER	DETAILS OF PRESENT METHOD PROPOSED	OPERATION ○	INSPECTION □	TRANSPORT →	DELAY D	STORAGE ∇	DISTANCE	TIME	POSSIBILITIES: ELIMINATE	COMBINE	SEPARATE	IMPROVE	SIMPLIFY	CHANGE: SEQUENCE	PLACE	PERSON	METHOD	FROM	NOTES
1	DETAIL INVOICES FROM INVOICE SECTION			•															
2	PLACES INVOICES IN "IN" TRAY				•														
3	PRE : LIST INVOICES FOR CENTRAL TOTAL	•																	
4	DELIVER INVOICE AND PRE LIST TO ACCOUNT CLERK			•															
5	PLACE INVOICES AND PRE LIST IN "IN" TRAY				•														
6	POSITION PROOF SHEET ON POSTING BOARD	•																	
7	FULL LEDGER ACCOUNTS AND STATEMENT OF ACCOUNT	•																	
8	PLACE INVOICIAL LEDGER ACCOUNTS AND STATEMENTS OF ACCOUNT ON POSTING BOARD	•																	REPEAT UNTIL ALL INVOICES ARE POSTED
9	POST STATEMENT OF ACCOUNT LEDGER CARD AND PROOF SHEET FROM INVOICES	•																	
10	REMOVE STATEMENT OF ACCOUNT AND LEDGER CARD FROM POSTING BOARD	•																	
11	TOTAL PROOF SHEET	•																	
12	COMPARE PROOF SHEET TOTAL WITH PRE-LIST TOTAL FOR ERRORS		•																

NOTES

CONTRIBUTION SHEET	SHEET 2 OF 2 REF. NO. 10
13	POST TOTAL OF DAY BOOK TO SALES ACCOUNT
14	RECORD TRANSACTIONS IN STATEMENTS OF ACCOUNT
15	CHECK STATEMENTS OF ACCOUNT FOR ERRORS
16	CORRECT ERRORS
17	FILE INVOICES COPIES
18	FILE PRE : LIST
19	FILE STATEMENT OF ACCOUNT
20	FILE DAY BOOK
21	FILE LEDGER CARDS
22	FILE SALES LEDGER CENTRAL ACCOUNT
23	FILE SALES ACCOUNT

Fig. 4.7. Otis Flow process chart.

O—operation, t—transport; i—inspection, s—storage

Provision for noting possibilities of changes that may be made to the existing procedure.

Eliminate—Combine—Separate—Improve—Simplify

Change sequence, place, person, method, form.

Objectives of flow process chart

(*a*) To present a complete visual record of all events in the sequence which is followed during production.

(*b*) To assist in establishing a proper sequence of events.

(*c*) To assist in planning layout and material handling.

(*d*) To eliminate delays and reduce the extent of storage in between two successive operations.

(*e*) To compare the present method and proposed method.

The information required for drawing a flow process chart is obtained by direct observation on a shop floor. It should not be prepared on the basis of memory or experience or information in files or by questioning persons.

How to make flow process chart (Fig. 4.8)

(*a*) A form may be used or a blank sheet of a paper may be substituted.

(*b*) If possible actually observe the process if the item is not in process or if direct observation is inconvient, use a scale flow plan. Actual observations is more desirable since discrepancies often exist between the supposed process and the actual process.

(*c*) Pick a convenient starting place for analysis

(*d*) Classify the first step according to the categories.

(*b*) Flow diagram (Fig. 4.9)

A diagram or model substantially to scale which shows the location of specific activities carried out and the routes followed by workers, materials or equipments in their execution.

NOTES

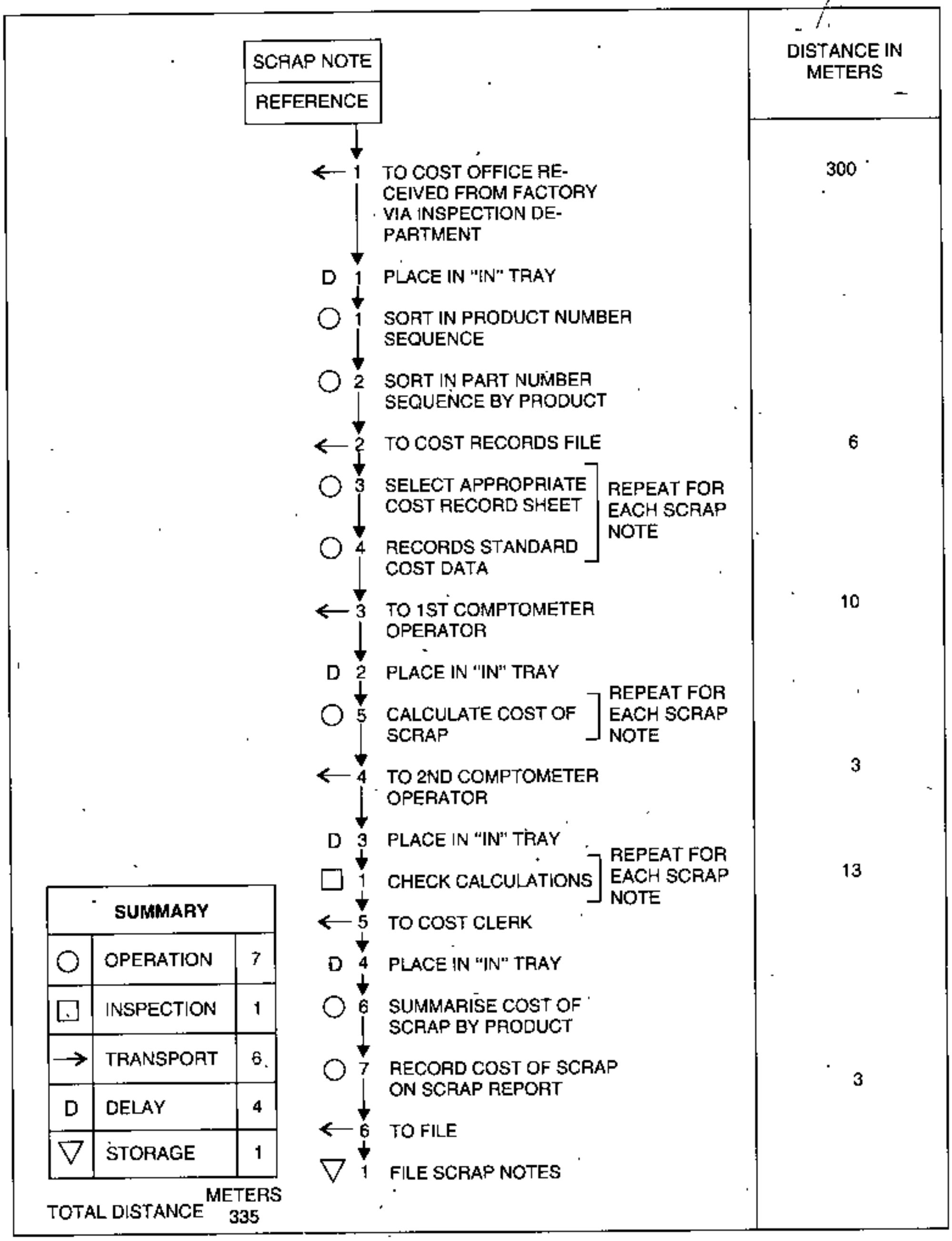


Fig. 4.8. Flow process chart—basic use of symbols. Scrap note procedure—valuation.

NOTES

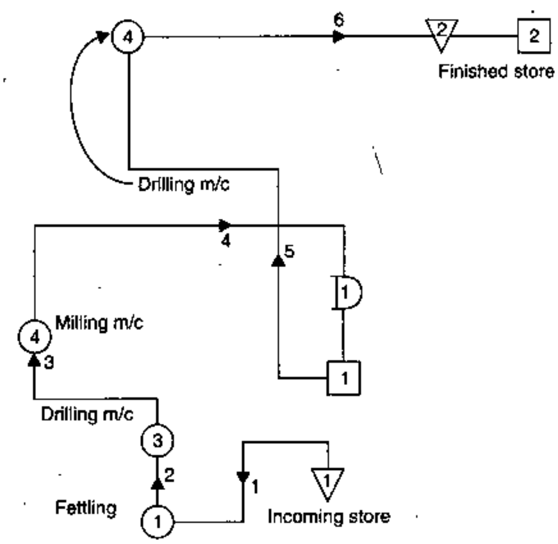


Fig. 4.9. Flow diagram.

(c) Procedure Analysis Flow Chart (Fig. 4.10)

▢	Origin of a firm
▢▢	Origin of more than one copy
○	Operation on form
→	Movement
▽	Permanent job
▽	Temporary job
	Information transfer
⋮	Interlink between firm
	Delibrate delay
	Dispose of firm
◇	Decision
□	Check or updates
	Information take off

Fig. 4.10. Procedure Analysis Flow Charting.

This analysis is a graphical presentation of the separable steps of activities with forms of other work showing the interrelationship of the various papers, forms or copies involved.

Man

(*a*) Flow process chart (Fig. 4.11. Operator movement study sheet).

(*b*) Flow diagram.

Work place layout

This is a dimensioned sketch usually showing both plan and profile views of the place at which a man works. It helps the analyst to understand the body and eye movements required to perform the task. The path of motion may be added as in a man flow diagram.

NOTES

OPERATION PROCESS CHART, OUTLINE PROCESS CHART

This is a graphic representation that describes the different operation (O) and *inspection* (□). Fig. 4.11. In a sequential manner including information regarding time location etc.

Method Present _______
Charted by _______
Date _______
Sub.—Reconditioning of Brake Shoes.

Location Cross field Garge
Chart begins—Inspection pit
Chart ends—Road test

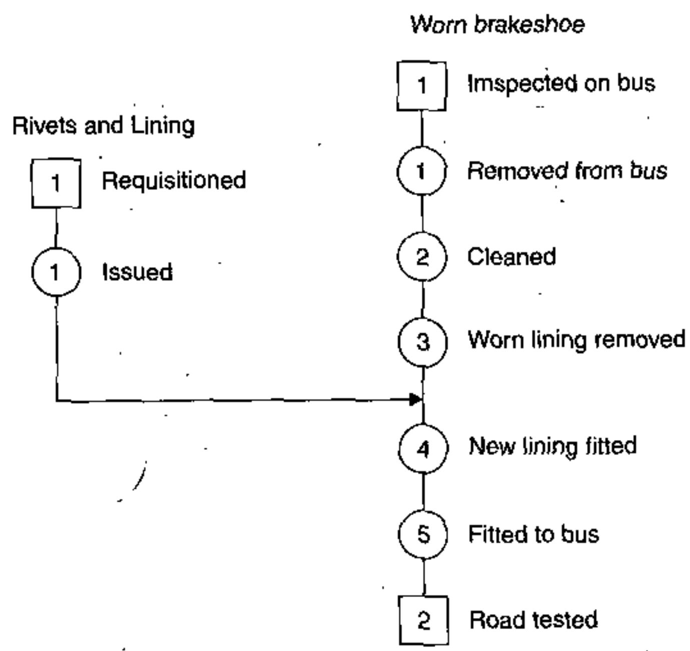


Fig. 4.11

Multiple activity analysis

(*a*) Man m/c operation chart
(*b*) Man m/c operation time chart
(*c*) Man m/c process chart
(*d*) Man m/c process time chart
(*e*) Multiman operation process chart
(*f*) Multiman operation/process time chart.
(*g*) **Micromotion study**

THERBLIGS—SUB DIVISION OF WORK

For detailed and useful study of method or time, a subdivision of work into its component elements is necessary.

The term therblig is derived from the Neman Gibreth spelled backward.

The therblig symbol or a graphic colour scheme are used when making left hand and right hand charts to show what each hand is doing during the entire operation.

NOTES

SYMBOL	NAME OF SYMBOL	COLOUR SUBSTITUTE SCHEME	NAME OF COLOUR	EXPLANATION
	Search		Black	Eye Turned As If Searching
	Find		Gray	Eye Straight As if Fixed on Object
	Select		Light Gray	Reaching for Object
	Grasp		Lake Red	Hand Open for Grasping Object
	Transport Loaded		Green	A Hand with Something in it
	Position		Blue	Object Being Placed by Hand
	Assemble		Violet Heavy	Several Things Put Together
	Use		Purple	Word "Use"
	Disassemble		Violet Light	One Part of an Assembly Removed
	Inspect		Burnt Ochre	Magnifying Lens
	Preposition		Sky Blue	A Ninepin which is Set Up in a Bowling Alley
	Release Load		Carmine Red	Dropping Contents Out of Head
	Transport Empty		Olive Green	Empty Hand
	Rest to Overcome Fatigue		Orange	Man Seated As if Resting
	Unavoidable Delay		Yellow Ochre	Man Bumping his Nose Unintentionally
	Avoidable Delay		Lemon Yellow	Man Lying Down on Job Voluntarily
	Plan		Brown	Man with His Fingers at His Brow, Thinking
	Hold		Gold Ochre	Magnet Holding Steel

Fig. 4.12. Standard Symbols and Colours for Therbligs.

(*h*) **Right Hand and Left Hand—Simo Chart, Layout Chart, Operator Chart**

This chart shows the various left hand and right hand motion needs by the worker in performing all the elements in an operation. Each hand motion is observed and records. Thus the analyst is able to determine if one hand is performing most of the work while the other is at rest, with this information he can then search for a new method to balance the hand activity in order to eliminate fatigue and avoid delay.

NOTES

Two Hand Process Chart

Job _______ Present Method _______
Chart begin _______ Charted by _______
Chart ends _______ Date _______

Left hand			Right hand		
Description	Symbol	Time winks	Description	Symbol	Time winks $\frac{1}{2000}$ minute

Fig. 4.13 Two Hand Process Chart

(*i*) **String Diagram (Fig. 4.14)**

It is a scale diagram on which is plotted usually by means of continuous thread movement within a given area and over a given period of time.

Uses

(*i*) Frequency of movement between various points.
(*ii*) Determining the distance covered.
(*iii*) Movement of workers are studied (Different coloured threads).
(*iv*) Can deal with complex movements and range over many classes of work.

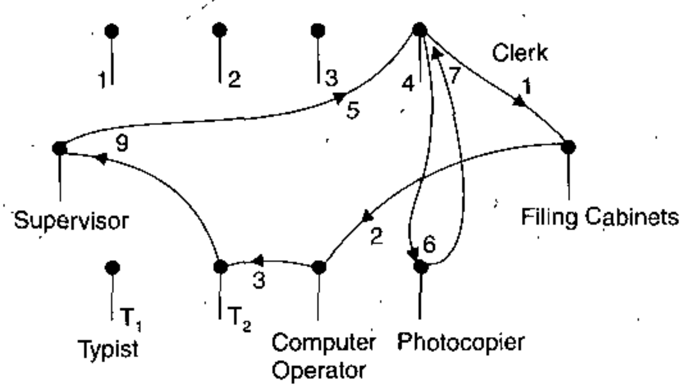


Fig. 4.14. String diagram.

NOTES

(*j*) **Gang Process Chart** (Fig. 4.15)

3 Men, 2 Women

To take iron rods from road to store.

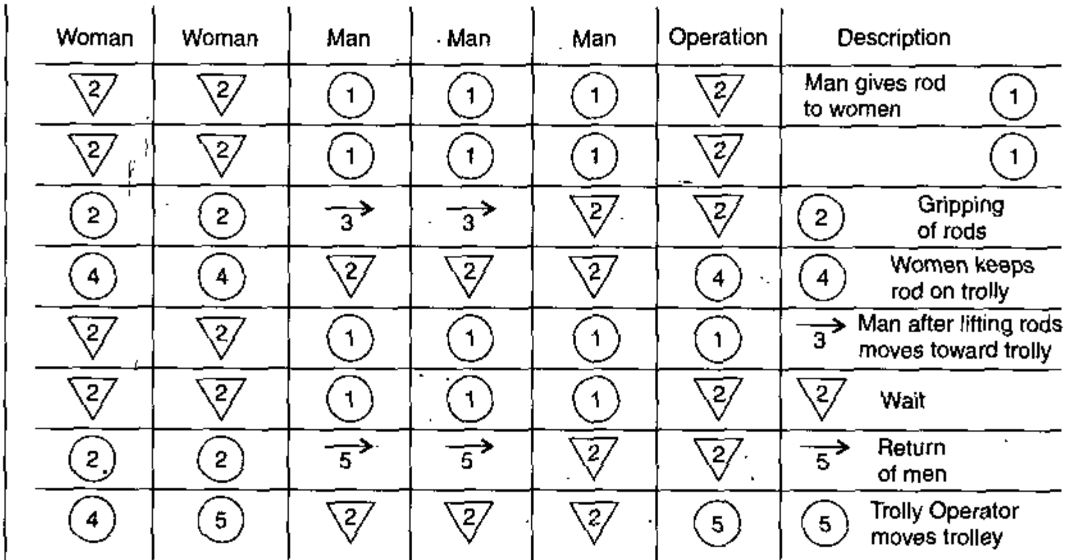


Fig. 4.15

(*k*) **Man m/c Chart**

On a vertical time scale indicate the variation activities done by man and m/c both on the same chart for carrying out a certain operations by the man m/c team.

Better coordination between man and m/c.

Reduction/elimination of idle times of man and m/c.

Exploration of alternative man m/c arrangements.

The activities of more than one subject (worker, m/c or equipment) are recorded on a common scale to show their inter relationship.

Time	Man	M/c

Fig. 4.16. Multiple activity or man m/c chart.

(*l*) **Travel Chart** (Fig. 4.17)

Operation	Casting	Forging	Drilling	Machining	Metrology	Electric	Welding	Inspection	Total
Casting			7	10	4	4	3	10	38
Forging			3	5			2	6	16
Drilling				2				12	14
Machining			4		5		2	6	17
Metrology								14	14
Electric								4	4
Welding								7	7
Inspection					5				5
Total	0	0	14	17	14	4	7	59	115 / 115

Fig. 4.17

NOTES

Fig. 4.17 shows numbers of trips from one shop to another shop.

Travel chart can be used to decide the flow of roads in relation to factory layout.

Travel charting is an analytical technique for efficient layout of shops in a plant so that the overall materials movement between different shops is minimized.

(*m*) **Simo Chart**

It is an extremely detailed left and right hand operation chart.

It shows on a comman time scale the simultaneous minute movements (Therblig) performed by the two hands of an operator, besides hands the movements of other limbs *of an operator* may also be recorded. The time scaled is representat in winks (1/2000 of a minute).

Simo chart *is generally used for micromotion analysis* of (*a*) short cycle repetitive jobs (*b*) High order skill jobs and find application in jobs like components assembly, packaging, *repetitive use of jigs and fixtures*, inspection etc.

Operation ______ Date ______
Name of the Worker ______ *Film No.* ______
Component Name ______ Operation No. ______
Method—Present/Proposed

Left hand description	Symbol	Time	Right hand description	Symbol

Fig. 4.18

NOTES

(*p*) **Activity Relationship Chart (Fig. 4.19)**

The ratings are used to express the desired closeness for the final arrangement of the areas.

Rating	*Description*
6	Closeness absolutely required
5	Closeness highly desirable
4	Closeness desired
3	Ordinary closeness
2	Closeness not essential
1	Closeness not preferred

The usefulness of the relationship chart is dependent upon the planners' awareness of the need to compromise. Indicating that all areas of a facility have to be close to all other areas negates the purpose of the relationship chart.

A suggested relationship chart of areas for one type of foodservice facility is shown in Fig. 4.19. It is important to note that other types of foodservice facilities may have a greater or fewer number of areas listed on the left side of the chart.

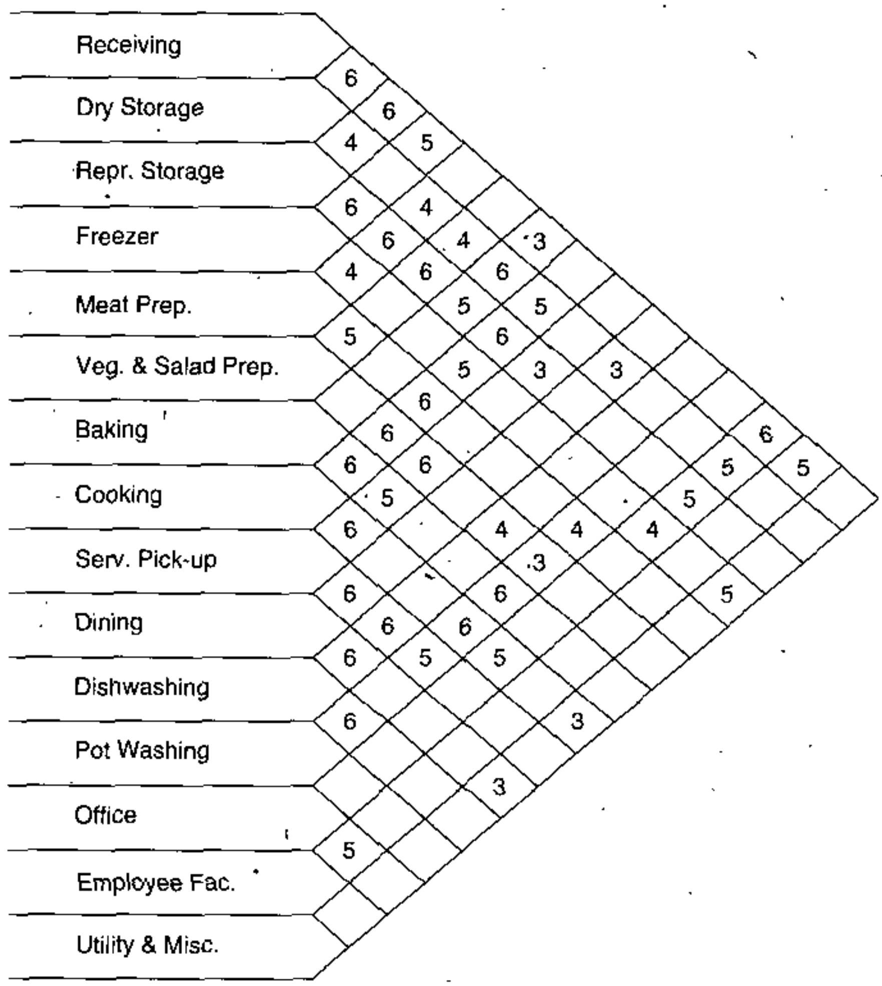


Fig. 4.19. Relationship chart with closeness ratings for a typical foodservice facility.

NOTES

4.7. WORK MEASUREMENT

Work measurement is the application of techniques designed to establish the work content of a specified task by determining the time required for carrying it out at a defined standard of performance by a qualified worker from a limited number of observations.

Work measurement involves accurate determination of the time required to do a given piece of work.

Eliminating or reducing ineffective time during which no effective work is being performed.

Techniques of work measurement

(*a*) Time study including production study

(*b*) Ratio delay study, activity sampling

(*c*) Synthesis from standard data.

(*d*) Predetermined motion time standards,

(*e*) Analytical estimating.

Purpose of work measurement

I. Ineffective time revelation, reasons for it
hold up due to lack of raw materials
hold up due to plant break down.

II. Set standard time for different operations.

Uses of work measurement

I. For setting standards
Compare the efficiency of alternative methods, determining best method.
To balance the work of members of team.
To know number of machines an operator can run.

II. Time standards
Evaluating proposed method in advance of actual production.
Planning and scheduling of production
Plant and labour requirements.

III. Estimates for tenders setting price and delivery promises.
Machine utilization standard
Labour performance

IV. Computation of wages, incentive schemes
Labour cost control.
Standard costs
Capital budgeting/Budgetary control.

Objectives of work measurement

(*i*) To analyse the operation with the view that the improvement is to be done on existing methods. It minimizes human effort.

(*ii*) To establish and standardize the condition for an efficient operation.

(iii) To control machine and labour utilization by assessing the plant capacity accurately.

(iv) To standardize the standard of performance

(v) To determine the man/machine assignments.

(vi) To determine the time standard to be used as a basis for wage payment to the direct labour and for future reference. It also helps to plan and schedule of production to estimate the setting prices and delivery dates.

(vii) To formulate a proper incentive scheme.

(viii) Improvement in operating efficiency.

(ix) Reduce ineffective time.

Procedure for work measurement

I. Select the work to be studied, defining the objectives.

II. Record all the relevant data relating to the circumstances in which the work as being done, the methods and elements of activity in them.

III. Measurement

Each element in terms of time over a sufficient number of cycles of activity to ensure that a representative picture has been obtained.

IV. Examine

The recorded data and element time critically to ensure that unproductive and random elements are separated from productive elements. The recorded times of each element and determine a representative time for each.

V. Compile

A time for the operation which will provide a realistic standard of performance and will include time allowances to cover suitable rest, personal need, contingencies, etc.

VI. Define

Precisely the series of activities and the method of operation for which the time has been allowed and issue the time as standard for the activities and methods specified.

4.8. TOOLS USED IN STOP WATCH TIME STUDY

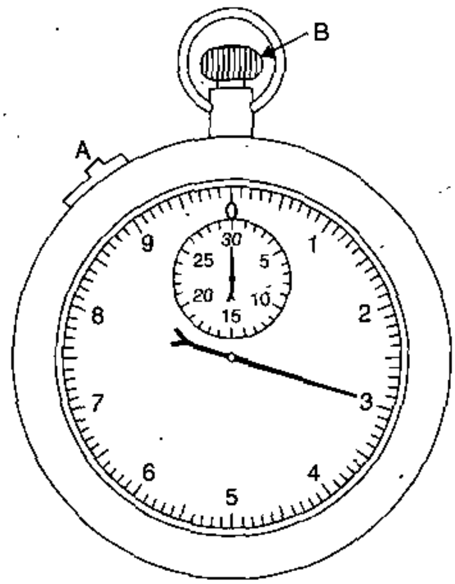
(i) **Stop watch/Electric timer**

The hands of the stop watch are controlled by the slide and winding steps. The starting and stopping of the watch are controlled by the slide.

(ii) **Motion picture camera, Video Recording equipment**

The time for the elements of an operation can be obtained from motion pictures of the operation or by placing a micro-chronometer in the picture where the operation is filmed.

NOTES



A—Slide for stoping and starting the moment.
B—Winding knob. Pressure on this knob returns the hands to zero.

Fig. 4.20. Decimal—Minute Stopwatch.

(*iii*) **Electronic data collector and computer**

(*iv*) **Electrical and mechanical time recorders**

Time recorder is a spring driven instrument which records time on a wax coated paper disc by means of a stylus attached to a small pendulum within the instrument. The recorder is fastened to a machine or piece of equipment and the vibration of the machine causes the stylus to record running on the disc. When the machine stops, the pendulum stops, vibratins and the instrument records down time on the disc.

Study board Fig. 4.21 pencil, steel rule, tape, micrometer, techometer.

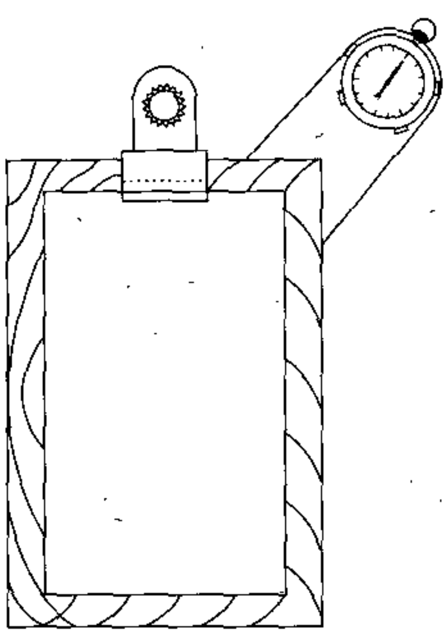


Fig. 4.21. Study board for general purpose form.

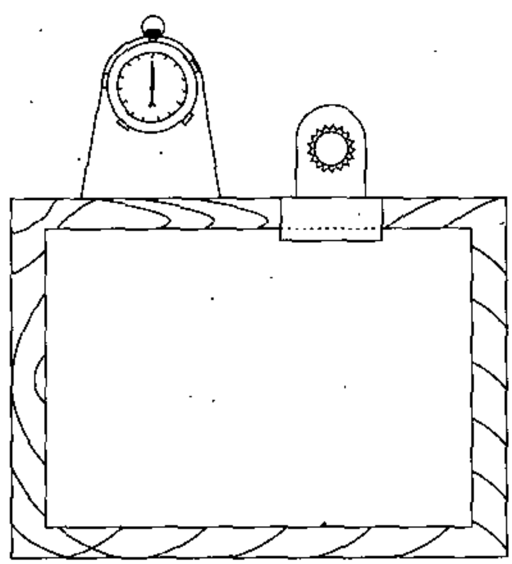


Fig. 4.22. Study board for short cycle form

NOTES

4.9. STOP WATCH TIME STUDY

Stop watch time study is the most commonly used method of measuring the work.

The stop watch times study procedure involves an analyst observing an operator and measuring the amount of time required to complete a task.

Stop watches are :

(a) Flyback stop watch

The watch is started from the zero position at the beginning of the study by moving the side slide forward. At the end of each element the analyst simultaneously note the reading and depress crown as soon as the hands reach zero. The crown in released and the hands begin rotating again.

(b) Non-fly back type decimal minute stop watch

It contains winding stem knob. The first pressure on the knob start the watch, second step it is net track and the third pressure sends the hands back to zero.

(c) Split hand stop watch

Decimal hour stop watch

Forms used

Time study sheet	Continuation sheet
Analysis sheet	Summary sheet

Selecting a job to be time studied

(a) The job in question is a new one.

(b) A change in method has been made and a new time standard is required.

(c) A complaint has been received about the time allowed for an operation.

(d) A particular operation requires a production study.

(e) A change has occurred in management policy such as introduction of an incentive plan.

(f) As a preliminary to make a method study.
Where it is desired to compare the efficiency of two proposed methods.

(g) To investigate the utilization of a piece of plant where the cost of a given job appears to be excessive.

Steps of stop watch time study

(a) Obtaining and recording all the information available about the job, the operator and the surrounding conditions.

(b) Recording a complete description of the method and breaking down the operation in to elements.

(c) Measuring and recording the time taken by the operator to perform each element of the operation. (number of cycles).

(d) Assessing the effective speed of working of the operator relative to a predetermined human speed.

(e) Converting the observed time to normal time
Normal time = Observed time × performance rating.

(f) Determine the allowances to be made over and above the normal time.

(g) Determine standard time

Standard time = Normal time + allowances

= Observed time × Performance rating + Allowances

$$= \text{Normal time} \times \frac{100}{100 - \text{percentage allowance}}$$

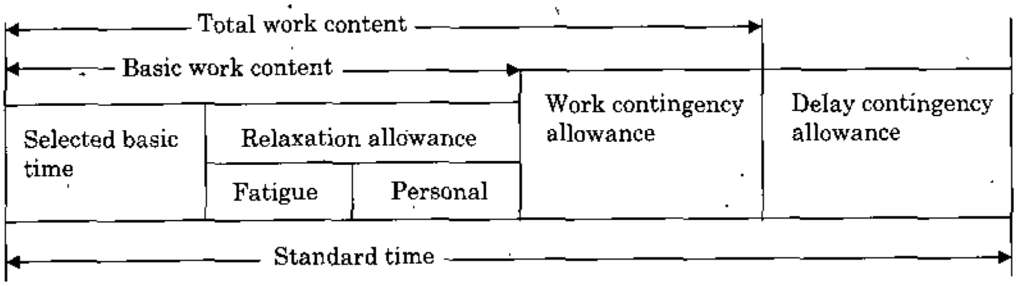


Fig. 4.23. Build-up of standard time.

Job element

It is subdivision of operation, the operation is broken down into elements for *time study purpose.*

Job should be broken down into elements due to

(a) To ensure that production work is separated from unproductive activity.

(b) To permit the rates of performance to be assumed more accurately.

(c) To enable elements involved high fatigue to be isolated and to make the allocation of rest allowance more accurate.

(d) To enable time standards to be checked so that the later omission or insertion of elements can quickly be detected.

(e) To enable a detailed job specification to be produced.

(f) To enable standard time values for frequently occurring elements.

Work cycle

It is a complete sequence of the elements necessary to perform a specified activity or task or to yield a unit of production.

Elements

(a) Repetitive elements—occur in every cycle.

(b) Constant elements—raise drill spindle specified distance.

(c) Variable elements—Dimension, weight of an object to be moved.

(d) Occasional elements—Occur at regular or irregular interval.

(e) Foreign elements—Not necessary part of the operation.

(f) Manual elements.

(g) Machine elements.

(h) *Governing elements.*

Rules for breaking down job into elements

(a) Element should be easily identified with definite beginning and ending.

(b) Element should be as short as can be conveniently timed by a trained observer.

(c) Elements should be as unified as possible.

(d) Hand time should be separate from machine time.

(e) Constant elements should be separated from variable elements.

(f) Elements which do not occur every cycle should be kept separate from those which occur regularly.

Number of cycles to be timed

NOTES

Number of cycles to be timed varies directly as the amount of variation between the time values as recorded for each element when repeated on successive cycles.

A job which is repeated for large number of times should be more accurately measured.

$$N^1 = \left[\frac{40\sqrt{N\Sigma X^2 - (\Sigma X)^2}}{\Sigma X} \right]^2$$

where N^1 = Required number of observations to predict the time within ± 5% accuracy 95% confidence level.

ΣX = Summation of individual observations

N = Number of observation already taken.

IMPROVEMENT OVER STOP WATCH STUDY

In memomotion study 50 to 100 frames/minute. It can be used where time study is possible.

Memomotion study is used for long cycle studies.

Time study observation sheet/form

Name of operator

A descriptions of the operation

The department in which operation is taking place

Layout of the work place—

List of equipments, tools, jigs, fixtures, materials.

Observed time :

Element	*Rating*	*Watch reading*	*Observed time*	*Ineffective or check time*	*Normal time*

NOTES

Element	*Time in Minutes*						*Average observed Time (Neglecting abnormal values)*
	1	2	3	4	5	6	
A	3.6	3.4	2.2	3.5	3.8	3.5	3.5, neglecting III reading
B	6.8	7.2	7.0	**9.5**	6.9	7.1	7.0, neglecting IV reading
C	4.5	4.9	4.8	4.9	4.7	4.4	4.7

Observed Time	Personal Allowances ....
Level or rating factor	Fatigue Allowance ....
Normal Time	Preparation Allowance ....
	Standard Time ....

Fig. 4.24. Time Study Record Sheet.

Question 4.1 :

The elemental time recorded on a time study sheet by snap back method for a single manual work element indicates the following times in decimal minutes.

0.14, 0.15, 0.14, 0.21, 0.15, 0.21, 0.18, 0.17, 0.19, 0.18, 0.14, 0.17, 0.19, 0.13, 0.15, 0.17, 0.17, 0.19, 0.14, 0.17, 0.18, 0.16, 0.14, 0.16, 0.13, 0.19, 0.14, 0.13, 0.14, 0.17, 0.12, 0.13, 0.14, 0.18, 0.14.

Determine the number of observations required to give a desired precision of ± 5% with a confidence level of 95%.

Solution :

x	f	fx	fx^2
0.12	1	0.12	0.0144
0.13	4	0.52	0.0676
0.14	9	1.26	0.1764
0.15	3	0.45	0.0675
0.16	2	0.32	0.0512
0.17	6	1.02	0.1734
0.18	4	0.72	0.1296
0.19	4	0.76	0.1444
0.21	2	0.42	0.800
Σx	Σf = 35 N	Σfx = 5.57	Σfx^2 = 0.9045

$$N = \frac{B^2}{A^2}\left[\frac{\sqrt{N\,\Sigma fx^2 - (\Sigma fx)^2}}{\Sigma fx}\right]$$

$$= \frac{2^2}{0.05^2}\left[\frac{\sqrt{35 \times 0.9045 - 5.57^2}}{5.57}\right] = 19.62 = 20.$$

NOTES

4.10. PERFORMANCE RATING

To rate is to assess a worker's rate of working relative to an observer's concept of the rate corresponding to the average rate at which a qualified worker will naturally work provided he keeps to the specified method and is motivated to apply himself to the work.

$$\text{Performance rating} = \frac{\text{Observed performance}}{\text{Normal performance}}$$

Following are basic requirements :

(a) There must be some clear definition of what is normal performance.

(b) The concept of normal performance must be installed in the mind of each rater.

(c) The rater must develop the ability to apply this concept consistently to various operations.

Necessity of performance rating

When number of operators are performing the same activity then output will not be same. If slowest worker is considered as standard then efficient operator will be considered a very fast and ultimately there will be lot of difference in their earnings and thereby it will cause dissatisfaction among the workers.

There should be some standard of performance for all the processes which satisfies almost all groups of work. Both place and skill displayed by the operator is judged.

The representative/average worker—

A representative worker in relation to any given class of work is one with the intelligence and physique necessary to undertake the work adequately and with sufficient experience to perform it to satisfactory standards of quality whose skill and performance are average to the group under consideration.

Normal performance is the working rate of the average worker working under capable supervision but without the stimulus of an incentive wage payment plan. The place can easily be maintained day after day without under physical or mental fatigue and is characterized by the fairly steady exertion of reasonable effort.

Qualified worker

One who is physically and mentally suited the job given to him and who has acquired necessary skill and knowledge to carry out the work, it involves satisfactory standards of safety, quality and quantity.

Factors affecting performance which are beyond the control of worker

(a) Variation in the quality of material used.

(b) Changes in the operating efficiency of tools or equipments.

(c) Minor changes in methods of operation.

(d) Variation in the mental attention necessary for the performance of certain elements.

(e) Changes in climate and other surrounding conditions such as light, temperature etc.

NOTES

Factors within control of an operator—

(a) Acceptable variation in the quality of product.

(b) Variation due to his attitude of mind.

Factors which govern the optimum pace of the worker.

(a) Physical effort demanded by the workers.

(b) Care required on the part of the worker.

Scale of rating

Rate normal performance as 100%. This scale of rating is called 100 Normal Scale.

$$\text{Observed time} \times \frac{\text{Rating}}{\text{Normal rating}} = \text{Normalised time}$$

Group all observed time under the headings fixed time, setting times, lost time etc.

Sequence of operations and the times should be critically studied and investigate the mistakes in the sequence of operations and if possible try to improve it.

Rating systems

Requirements

(a) Attainment of consistant results

(b) It should be simple.

Following are the types of Rating systems :

1. Westinghouse system

A four factor system for rating operation performance was developed at Westinghouse Electric Corporation (1927). These four factors are (a) skill, (b) effort, (c) conditions, (d) consistency.

A scale of numerical values for each factor was supplied in tabular form and the selected time obtained from time study was normalized or levelled by the sum of the rating of the four factors.

Westing house system

(a) **Skill**	(b) **Effort**
+ 0.15 A_1 super skill	+ 0.13 A_1 Excessive
+ 0.13 A_2 Super skill	+ 0.12 A_2 Excessive
+ 0.11 B_1 Excellent	+ 0.10 B_1 Excellent
+ 0.08 B_2 Excellent	+ 0.08 B_2 Excellent
+ 0.06 C_1 Good	0.05 C_1 Good
+ 0.03 C_2 Good	+ 0.02 C_2 Good
+ 0.00 D Average	0.00 D Average
– 0.05 E_1 Fair	– 0.04 E_1 Fair
– 0.10 E_2 Fair	– 0.08 E_2 Fair
– 0.16 F_1 Poor	– 0.12 F_1 Poor
– 0.22 F_2 Poor	– 0.17 F_2 Poor

NOTES

(c) Conditions	(d) Consistency
+ 0.06 A Ideal	0.04 A Perfect, Ideal
+ 0.04 B Excellent	+ 0.03 B Excellent
+ 0.02 C Good	+ 0.01 C Good
+ 0.0D Average	– 0.00 D Average
– 0.03 E Fair	– 0.02 E Fair
– 0.07 Poor	– 0.04 F Poor.

2. Skill and effort rating (1916) Charles E Bedaux

Beaduax used 60 points equal to standard performance. An operator working at a normal pace is expected to produce 60 B's per hour. B-is a scale. B values represent standard minute and content work component and relaxation component.

(a) Divide the operation into measurable elements and time. The time the element with the help of stop watch having 60 divisions on its dial.

(b) Estimate the efficiency for each work element in B values

(c) Relaxation factor per work element is added

Relaxation factor

Light work	1.1. to 1.2
Medium heavy work	1.2 to 1.35
Heavy work	1.35 to 1.5
Very heavy work	1.5 to 3

B Value per work element

$$= \frac{\text{Observed speed time of work}}{60 \times 60} \times \text{Relaxation allowance}$$

Question 4.2 :

The observed time	= 0.45 min.
Skill excellent B_1	= 0.11
Effort Average D	= 0.00
Conditions good C	= 0.02
Consistency Average	0.00D
	0.13

Time = 0.45 × 0.13 = 0.51 minute.

3. Objective rating

Operator speed is rated against a single pace which is independent of job difficulty. Observer rates speed of movement or rate of activity only.

An allowance is added to the pace rating to take care of the job difficulty.

Job difficulty

(a) Amount of body used

(b) Foot pedals (types)

(c) Bimanualness—Type of hand motion

(d) Eye hand coordination, various degrees

(e) Handling requirements (degree of force)

(f) Weight (lifted or used)

Normal time = Average time × pace rating × secondary adjustment factor.

NOTES

Question 4.3 : Time = 0.25 min.

Pace rating = 110

(*a*) Amount of body moved Trunk	8% Adjustment
(*b*) Foot pedals	0
(*c*) Bimanualness Hands help each other	0
(*d*) Eye hand coordination, moderate vision	2
(*e*) Handling requirements—can be handled roughly	0
(*f*) Weight 2 Kg by by arm lift	10
	20%

$$\text{Time} = 0.25 \times \frac{110}{100} \times \frac{120}{100} = 0.33 \text{ min.}$$

4. Synthetic rating

Evaluating an operator is speed from predetermined motion time values.

(*a*) Make a time study.

(*b*) Compare the actual time with motion time values for the same elements

$$\text{Ratio of } \frac{\text{Motion time value}}{\text{Actual time value}}.$$

(c) Performance rating factor $= \dfrac{\text{Predetermined motion time standard}}{\text{Average actual time value}}$.

5. Physiological evaluation of performance level

Change in heart rate is measure of muscular activity.

Person work at his job for a specified period and then measure his heart rate at the end of this period and at the end of 1, 2, and 3 minutes after stopping the work.

4.11. ALLOWANCES

The allowances are added due to the reasons as the workstudy man has only been taking into account the productive work done by the operator.

In effective time on the part of the operator or m/c including any period of rest taken by the operator has been excluded.

It must how be brought back into picture on the part of the operator it may be result of

(*a*) Having to wait for the completion of a m/c cycle or two motor operator to complete his part of the pack.

(*b*) The need to rest to recover from effort expended in the course of his work.

(*c*) Having to satisfy certain personal needs such as going to lavatory, a washing or getting a drink of water.

(*d*) Having to wait for material, the repair of a machine, break down outside his control. The effective time on the part of a machine may be due to (*a*), (*b*), (*c*) and (*d*) above and also to.

(*e*) The operator being engaged in loading or unloading the machine of other work necessary to the operator which can not be done while the machine is working.

NOTES

(f) An operator incharge of several machines being engaged in attending to one when other stops and has to remain until he has completed the work he is doing.

Types of allowances

(a) Contingency/delay allowance

(b) Relaxation allowance—fatigue, Rest, allowance

(c) Process allowance

(d) Other allowances—special allowance—periodic activity allowance, Interference, policy allowance.

(a) **Contingency Allowance.** A contingency allowance is a small allowance of time which may be included in standard time to meet legitimate and unexpected items of work or delays. The precise measurement of which is uneconomical because of their infrequent and irregular occurrence.

Unavoidable and beyond the control of the operator delays are given allowance.

Contingency allowance = 5%.

(b) **Rest allowance/Relaxation Allowance.** Intended to provide his work with an opportunity to recover from the physiological and psychological effects of expending energy in the performance of specific work under specified conditions and attention to personal needs.

Normal work 12%

Heavy muscular work 20%.

(c) **Process allowance/unavoidable delay allowance.** A process allowance is an allowance of some given to commensurate for inforced idleness which would otherwise cause loss of earning power/on the part of an operator due to the character of the process or operation on which he is employed.

Type of Allowance	*Male*	*Female*
Personal allowance	5%	7%
Basic fatigue allowance	4%	4%
Standing allowance, Exacting work, Monotony, Tediousness	2%	4%
Abnormal position allowance, Awkward bending	2%	3%
Very awkward	7%	7%
Use of force		
Weight lifted Kg		
5 Kg	1%	2%
10 Kg	3%	4%
18 Kg	9%	13%
35 Kg	22%	22%
Close attention		
Fine or exacting work	2%	2%
Very fine or very exacting	5%	5%

NOTES

Noise level Intermittent loud	2%	2%
Mental strain very complex	8%	8%
Monotony medium	1%	1%
Tediousness very	5%	2%

These are given for :

(*a*) Where machine is working automatically for part of work cycle.

(*b*) When one or more operator are running a number of machines under condition said above.

(*c*) Where operators are in control of process and their work is to take action only in response to certain changes in behaviour rate or reading.

(*d*) Other allowances.

1. Special allowances

These may be given for any activities not normally part of the operation cycle but essential to the satisfactory performance of the work. Such allowances may be permanent or temporary.

Periodic activity allowance

These are allowances made for work carried out periodically in the course of manufacturing a given batch of work or of carrying out a given activity over a specified period of time.

Allowances for activities carried out at definite intervals or after performing a specified number of cycles *e.g.*, regrinding tools, resetting machine, periodic inspection or check.

Allowances for activities carried out once only in the course of a batch or order irrespective of the size of the batch or duration of the work *e.g.*, setting up a loom for a given work.

Interference allowance

Machine interference occurs when an operator is inchange of two or more machines and one or more of them stop while he is attending to another.

(*a*) Cyclic Interference is machine interference occurring at fixed intervals of the three different machines.

(*b*) Random interference is machine interference occurring at random on different machines.

Policy allowance

A policy allowance is any allowance given at the discretion of the management over and above allowances given due to features inherent in work under consideration.

Policy allowances are usually given to live up. The basic allowed time as computed with the requirements of wage agreement between employer and leaders.

Allowance may be made to new operators before they become fully proficient at their operation into order to give them some encouragement. These are known as "learner allowance".

NOTES

Question 4.4

In a stop watch time study the work study supervisor noted the times of elements on cumulative timing systems. The ratings recorded are given below :

Element member	*Time in minutes*	*Rating observed in %*
1	0.15	80
2	0.30	60
3	0.50	110
4	0.65	100
5	0.75	90
6	1.00	120

Assuming allowances to be equal to 10%. Calculate the standard time.

Solution :

Element no.	*Element time*	*Normal time*	*Standard time*
1	0.15	0.12	
2	0.15	0.09	0.97 × 1.1
3	0.20	0.22	= 1.067 min.
4	0.15	0.15	
5	0.10	0.09	
6	0.25	**0.3**	
		0.97	

Question 4.5

Following data are given for a continuous method of stop watch time study on a particular job :

Element	*Number of observations Cumulative timings*				*Rating factor*
	1	2	3	4	
A	0.20	1.38	2.56	3.78	120
B	0.60	1.76	2.96	4.20	80
C	1.20	2.34	3.58	4.80	90

Four observations of each element are recorded in minutes. Assuming the allowance to be equal to 10%. Calculate standard time.

NOTES

Solution :

Element	Cycle No.				Average time	Rating	Normal time
	1	2	3	4			
A	0.20	0.18	0.22	0.20	0.20	120	0.24
B	0.40	0.38	0.40	0.42	0.40	80	0.32
C	0.60	0.58	0.62	0.60	0.60	90	0.54
							Σ 1.10

Standard time = 1.1 × 1.1 = 1.21 minutes.

Questions 4.6

A time study was taken at a drill press operator drilling a hole in a flat plate using the continuous timing method. The stop watch readings in minutes at the transmission points between each operation element were as shown in table.

The average time was used as the base time for each operation element. The time study man rated the overall performance on the study at 115%. The allowances determined from an interruption study were 5% for personal and fatigue together and 5% for unavoidable delays. Determine the standard allowed time.

Table

Operations element	Piece number		Cycle		
	1	2	3	4	5
(*a*) Load piece into jig and clamp	0.08	0.60	1.16	1.69	2.20
(*b*) Place jig under drill and lower spindle	0.14	0.66	1.21	1.74	2.25
(*c*) Drill automatic feed	0.44	1.00	1.53	2.05	2.35
(*d*) Raise spindle of drill	0.46	1.02	1.56	2.07	2.57
(*e*) Remove piece from jig	0.52	1.09	1.62	2.13	2.63

Solution :

Time for First cycle 0.52 – 0.08 = 0.44

Second cycle 1.09 – 0.60 = 0.49

Third cycle 1.62 – 1.16 = 0.46

Fourth cycle 2.13 – 1.69 = 0.44

Fifth cycle 2.63 – 220 = 0.43

Average cycle time = 0.45

Normal time = 0.45 × 1.15 = 0.5175

Allowance = 5 + 5 = 10%

Standard time = 1.1 × 0.5175 = 0.57 minute.

NOTES

Question 4.7

A time study was carried out for two elements job. The observations recorded in hundredth of a minute in a continuous method are as given in table.

Assuming a performance rating of 95% and a delay and fatigue allowance factor of 20%. Find :

(*a*) *Average time*

(*b*) *Normal time*

(*c*) *Standard time*

(*d*) *Productivity Standard*

Cycle	*Element I*	*Element II*	*Cycle*	*Element I*	*Element I*
1	14	20	11	184	207
2	31	36	12	218	222
3	48	53	13	235	237
4	65	70	14	249	256
5	80	86	15	267	289
6	97	104	16	301	306
7	117	122	17	318	338
8	134	134	18	350	355
9	151	156	19	368	372
10	167	171	20	384	387

Element I.

Observed time

31 – 14 = 17
48 – 31 = 17
65 – 48 = 17
80 – 65 = 15
97 – 80 = 17
117 – 97 = 20
134 – 117 = 17
151 – 134 = 17
167 – 151 = 16
184 – 167 = 17
218 – 184 = 32 Abnormal
233 – 218 = 17
249 – 235 = 16
269 – 249 = 20
301 – 269 = 32 Abnormal
318 – 301 = 17
350 – 318 = 32 Abnormal

NOTES

368 – 350 = 18
384 – 368 = 16

Ignoring abnormal values

Average time = 17.125 units. = 0.17125 minute
Normal time = 0.95 × 0.17125 = 0.1627 minute
Standard time = 1.2 × 0.1627 = 0.195 minute

Similarly standard time for element II can be found.

Question 4.8

A continuous time study was made on a collating job in an office and the following data were obtained :

Elements	*Cycle minutes*						*Performance rating percentage*
	1	2	3	4	5	6	
(*a*) Applying glycerin to fingers	0.04	0.25	0.46	2.88	3.10	3.36	120
(*b*) Get four pages with each hand	0.16	0.35	0.63	2.99	3.24	3.55	105
(*c*) Collate eight sheets	0.19	0.39	2.83	3.04	3.28	3.59	110
(*d*) Staple and put aside	0.22	0.41	2.83	3.07	3.30	3.62	90

The person dropped the 8 sheets on the floor. Calculate normal time for collated set. Considering an allowance of 15%. Find the standard time per set.

Solution :

(*a*) **Applying glycerin to Fingers**

0.16 – 0.04 = 0.12
0.35 – 0.25 = 0.10
0.63 – 0.46 = 0.17
2.99 – 2.88 = 0.11
3.24 – 3.10 = 0.14
3.55 – 3.36 = 0.19

Average = 0.138 minutes
Normal time = 0.138 × 1.2 = 0.166 minutes

(*b*) **Get four pages with each hand—**

0.19 – 0.16 = 0.03
0.39 – 0.35 = 0.04
2.83 – 0.63 = 2.20 Abnormal reject
3.04 – 2.99 = 0.05
3.28 – 3.24 = 0.04
3.49 – 3.45 = 0.04

Average time = 0.04 minutes
Normal time = 0.04 × 1.05 = 0.042.

Similarly for other elements normal time can be found.

STUDENT ACTIVITY

1. Do time study of work preformed by you ?

2. Role the orthis performance of the operator working in your organization.

NOTES

SUMMARY

1. Methods Study is the systematic recording and critical examination of the factors and resources involved in existing and proposed ways of doing work, as a means of developing and applying easier and more effective methods and reducing costs.
2. Work measurement is the application of techniques designed to establish the work content of a specified task by determining the time required for carrying it out at a defined standard of performance by a qualified worker from a limited number of observations.
3. The allowances are added due to the reasons as the workstudy man has only been taking into account the productive work done by the operator.

TEST YOURSELF

1. What is work study ?
2. Why work study is important ? What is purpose of work study ?
3. What are advantages of work study ? What are techniques of work study ?
4. Write the procedure of work study.
5. What is method study ? What are objectives of method study ?
6. What is basic procedure of method study ?
7. Write about m/c load chart, flow process chart, flow diagram, Flow chart. Right hand and Left hand chart man and m/c chart.
8. An analysis of activities made in connection with having a slot milled in a bracket revels the existence of following activities along with their time estimates :

Return table rapid traverse	0.0024 hrs.
Remove finished part	0.0666 hrs.
Clean vise	0.006 hrs.
Place new bracket in vise	0.008 hrs.
Clamp	0.0061 hrs.
Advance table and start cut	0.0329 hrs.
Milling	0.67 hrs.

Draw a man and machine chart. Calculate idle time for man and machine. Find how many machines at most can be operated by the operator.

9. A method study man observed that a worker operating an automatic machine takes 4.5 minutes to set the machine including stopping, removing job, loading new job, starting and walking if any. Which machining element takes 8 minutes. Study man suggested to put one more machine of same nature and process under his operation.

Draw appropriate chart for the new situation and answer the following questions :

(*a*) Percentage utilization of the time for man and machines:

(*b*) Percentage increase in production.

(*c*) Percentage increase in productivity of man and machine.

NOTES

10. Under what circumstances the following techniques can be used (*i*) Left hand and right hand process chart.

(*i*) Simo Chart

(*ii*) Three dimensional flow diagram.

11. A high volume component of a calculating machine must be operated on by a standard milling machine with automatic feed. Two successive milling operations are required both utilizing the same type of machine. In both instances the operator may leave the machine during the machining operation of the cycle. The volume of parts required throughout the years is 1000 pieces per day. The operating characteristics of the two operations are indicational as follows :

Operating characteristics	*Operation—1*	*Operation—2*
Unload	0.12 minute	0.1 minute
Load	0.19 minute	0.15 minute
Mill	0.30 minute	0.47 minute

On the average these machines are producing approximately 85% of the 8 hours work day.

What arrangements of men and machines would you recommended. Support your answer with appropriate multiple activity charts. Machines may be located in whatever fashion which is convenient for the setup proposed.

12. You are employed as work study engineer in an organization to improve the procedure followed by instructors in sending a letter. You have studied the present method. It involves the following steps :

Letter is written in long hand.

The request for typing is made out and attached to the letter, the letter is taken to the clerical office 30 meters on the same floor (second).

Letter is typed.

Stamped envelope is addressed.

Letter is delivered back to the writer's office

Letter is proof read by the writer.

Letter is signed, folded and sealed in the envelope.

Letter is carried to the mail box located in front of the building on the ground floor (50 meters).

Letter is deposited in the mail box.

Make a flow process chart and flow diagram both of the present method and your proposed method. The object to be charted is the letter. Your analysis should start with the letter as it is written at the instructor's desk and should end as it is deposited in the mail box. Assuming that 100 letters are written per day and that the above procedure is typical of the ones followed by the faculty with offices on the second floor. The objective is to improve this procedure.

13. As assembly line for that assembly of components of an ordinary two pin electrical socket consists of a work bench where the operator places the ceramic base (body, near the work place, position of the two brass hollow pins on slots provided in ceramic, puts the plastic cap cover over, screens in a set screw at the

centre with a screw driver and sets aside the assembly in a pin. The base, hollow pin, plastic cap and central screw are available into the pans.

(*i*) Draw a neat sketch of the layout of work piece you propose for the operator ;

(*ii*) Make a two handed operation chart for the assembly and

(*iii*) Suggests improvements in the method and in product development for ease in assembly, if any,

NOTES

14. The inspection of existing system of loading and unloading in a cold storage as follows :

(*a*) Two men unload potato bags from trucks to trolley 2 minutes.

(*b*) Two men push the trolley weighing m/c 1.5 minutes.

(*c*) Weighing time 1 minute.

(*d*) 2 men push trolley to storage 2 minutes.

(*e*) 1 man returns trolley to truck 3 minutes. Make a multiple activity chart for the above operation and then suggest an improved for minimising labour cost. Any number of men and trolleys can be employed.

15. The activities performed by an operator in connection with assembly of a washer and nut to bolt are as under :

The operator moves simultaneously his left hand to bin 1 for bolt and right hand to bin 2 for washer. The left hand grasps bolt while the right hand grasps washer. Both hands carry their objects back to assembly position where left hand holds bolt while right hand positions washer over bolt. Right hand then moves to bin 3 for a nut, picks up nut, carries it back to assembly position, positions nut over bolt, threads nut and checks nut for lightness. Left hand then moves over to bin 4 and disposes off the completed assembly into it.

Prepare two handed process chart for the above activities.

16. A despatch clerk is observed to perform broadly the following mailing task from four stacks of cyclostyled sheet (8 pages per mail) placed before him serially.

"Pick one sheet from each stack, check for defect, collect by rapping them on the table vertically by one corner turn and rap them by the second corner to align staple at left hand corner- break and fold four times all sheets together, by hand. Pick a long envelope from rack on left side-rubber sender's address—fill folded paper inside envelop—paste gum on lip of envelope and stick fast by folding—write the adress in ink, from a ledger—set aside pasted envelope in dispatch bin on the right."

17. What is Work Measurement ? What are techniques of work measurement ?

18. What is purpose of work measurement ? What are uses of work measurement ?

19. What are objective of work measurement ?

20. Write the procedure for work measurement.

21. What devices are used for measuring work ?

22. Write about stop watch time study.

23. In a time study the following observation were noted by the observer while worker was performing a specific task repeatedly. In order to make the study reliable with 95% level of confidence and that the precision needed for predicting the final result is ± 5%, find out how many more observations the observer will have to take.

NOTES

24. A manufacturer is considering buying one of two types of equipment, type A or type B Initial equipment cost is Rs. 10,000 for either A or B. Operating costs are estimated as follows :

	A	*B*
Maintenance (per month)	Rs. 750	Rs. 500
Supplies (per unit)	0	.052
Operator (per hour)	9	9.

The companies selling the equipment each arranged for experimental demonstrations in which stop watch time studies of operator/machine performance for five cycles were measured with, the following results :

Task	*Task Times (in minutes) for A*					*Task Times (in minutes) for B*				
	Cycle					*Cycle*				
	1	*2*	*3*	*4*	*5*	*1*	*2*	*3*	*4*	*5*
LoadMachine	0.32	0.29	0.28	0.31	0.30	0.30	0.27	0.25	0.22	0.21
Machine time (machine paced)	2.73	2.61	2.68	2.71	2.63	2.62	2.57	2.59	2.51	2.54
Unload Machine										
Inspect product	0.14	0.10	0.09	0.12	0.11	0.12	0.09	0.10	0.11	0.09
Apply label to	1.21	0.08	1.29	1.15	1.20	0.92	0.94	0.86	0.79	0.87
Product*	—	—	—	—	—	0.05	0.04	0.05	0.05	0.04

*Lable application is automatic for A and manual for B.

The analyst rated the operator at 115 per cent on equipment A and 110 percent on B. It is estimated that during their daily 8-hour shift, operators will receive two 15-minute coffee breaks. Unavoidable delays are estimated to be 40 minutes for A and 25 minutes for B daily. Evaluate the two alternatives and justify your recommendation A and B.

25. A post office mail room receives mail and cancels the postage stamps. After first simplifying work, you make direct time study of the simplified job and obtain the following times in minutes :

Tast	*Description*	*Cycle*				
		1	2	3	4	5
1	Empty mail bags	.16	.31	.14	.15	.16
2	Straighten mail	.60	.60	.60	.60	.60
3	Carry trays to reader	.34	.36	.35	.37	.38
4	Cancellation machine	.50	.50	.50	.50	.50
5	Empty trays	.24	.24	.48	.27	.25

You further determine the following information about this job :

1. Tasks 2 and 4 are machine-controlled and cannot be speeded up by the operator.

2. You observed two irregularities while timing the job. These task times vary by more than 20 percent of each task's average time.
3. You rated the operator at 120 per cent when he was working.
4. Management and the worker's union have negotiated the following allowances for this—Personal—30 minutes/8—hour shift.
   Unavoidable delay—10 minutes/8—hour shift.
   Fatigue—10
5. An operator on this job earns Rs. 20/hour.
6. Material cost per unit is Rs. 50.
7. Total overhead cost is added in at a rate of 150 percent of the sum of direct labour and material cost.
   (*a*) How many pieces should each operator produce during an 8-hour shift ?
   (*b*) What is the total standard cost per pieces ?

26. As a bank officer assume you have your bank tellers count out Rs. 100 bank packs in denominations of six Rs. 10 bills, seven Rs. 5 bills and five Rs. 1 bills. The purpose of this job is supply our bank's night teller service with this bankpack. Suppose a continuous stopwatch time study yielded the following data :

Cumulative task time (in minutes)

Task	*Description*	*Cycle*								*Worker Rating*
		1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*(in percent)*
1	Count 6 Rs. 10 s	.12	.66	1.40	1.95	3.26	3.91	4.52	5.05	110
2	Count 7 Rs. 5 s	.27	.84	1.40	2.12	3.41	4.08	4.66	5.21	115
3	Count 5 Rs 1 s	.38	.96	.151	2.20	3.52	4.18	4.74	5.29	105
4	Count Rs 100 s	.56	1.09	1.80	2.41	3.80[a]	4.36	4.94	5.48	110
5	Place in Chute[b]	—	—	—	3.13	—	—	—	—	90

[a]Teller had to recount because of error.

[b]Occurs once every 10 cycles.

The allowances for this job are set at .15.

(*a*) What is the normal tile for this job ?
(*b*) What is the standard time for this job ?
(*c*) What is the standard output in terms of bankpacks/hours ?
(*d*) How long (in terms of work hours) would it take to package 500 bankpacks, if the tellers assigned to the job worked at a pace on the average at 115 per cent ?

27. Direct time study for a job resulted in the following times :

Cycle	*Average Cycle Time (in minutes)*
1	1.321
2	1.411
3	1.704
4	1.175

A predetermined time standard was set at 2,128 TMU/cycle, which converts to 1.275 minutes/cycle. What time standard would you recommended ? Justify your choice.

28. Job analysis reveals that during a typical 8—hour workday a man- machine operation typically experiences various unavoidable delays totaling 40 minutes and one equipment setup changeover of 20 minutes. Operators need 2-minutes for personal time and take two 15-minutes coffee breaks. Standard time per cycle (to produce one unit) is 10 minutes. How many units are produced by an operator rated at 85 per cent at 115 percent ?

29. A student facing midterm exams decides to start studying in earnest. After one day in the library, the student is dismayed to find that, at her current rate of studying, she will not be ready to take the exams until four days after they are over/A friend volunteer to do a work sample and finds the following :

Study Period	*Number of Observations*	*Number of Observations During Which Studying Occurred*
1	11	8
2	23	11
3	7	3

As a percentage of her study period time, what portion of time is she studying ?

30. Filing clerk in a state department of welfare were considered to be working any time they had paper in their hands. Observations were made for seven days. Results are given below. What portion of time is spent in working ? What work measurement technique is this ? How might one alternatively define working ?

Day	*Number of Observations*	*Observation During Which Worked Occurred*
1	14	10
2	17	10
3	10	5
4	23	14
5	14	10
6	11	9
7	19	13

31. Several laboratory technicians in a hospital are responsible for running the highly automated "Chemistry 12" blood profile test. An experienced technician was monitored over a two-week period (170 hours). The analyst studying the job found that the technician performed 412 blood profile tests, working 60 per cent of the time and idle the rest. Some idleness was due to waiting for the automated equipment to complete the test. The technician was rated at 85 per cent, but the analyst was uncertain about this rating because of the automated equipment. Allowances are set at 10.

(*a*) Determine a standard time for a standard profile test.

(*b*) How could the analyst be more about the worker rating ?

32. A specially wood products company in eastern Kentucky manufacturers handmade miniature wooden dogs. This Dandy Dogie product line is hand-carved, varnished, labelled, and boxed, all by the same-person. But there are wide variances in quality and performance times, which management is no longer willing to accept. In the hope of establishing a standard time, management has

done a direct time study focusing on the 5 cm walnut beagle. The results are shown below. For now, hand-carving is being eliminated from the study. The firms' allowance fraction is .10. Establish a standard time for the remainder of the job.

Task time for Dandy Dogic (in minutes)

NOTES

Job Element	*Cycle*				*Worker Rating (in Percent)*
	1	*2*	*3*	*4*	
Varnish	5	4	5	4	105
Label	0.5	0.4	0.3	0.5	95
Box	2	2	1	2	95

33. A labour standard for over-the-road truck drivers is 320 km/8 hour shift. Current wages are Rs 20/hour under a nationwide contract. The assigned drivers from the some terminal logged 3,525 kms the first week of April and recorded 922 hours of work. A no-overtime policy is in force some-based drivers.

(*a*) What is the labour efficiency variance for the first week of April ?

(*b*) The driver union representative contends that since the drivers log primarily noninterstate km, the standard should be 10 less, or 288 kms day. Operating management would like a comparative labour variance for the first week in April. What do these labour variances actually mean to management ?

34. Continuous stop watch time study figures for a job are given below. Calculate the standard time for the job assuming total allowances are 15%.

Element No.	*Cycle*	*Cycle Time minute*										*Performance rating*
		1	2	3	4	5	6	7	8	9	10	
1		0.09	0.49	0.89	1.31	1.70	2.09	2.50	2.88	3.29	3.71	90
2		0.16	0.56	0.95	1.38	1.76	2.16	2.57	2.95	3.36	3.78	110
3		0.28	0.67	1.07	1.49	1.88	2.28	2.68	3.07	3.40	3.90	120
4		0.41	0.80	1.21	1.61	2.00	2.41	2.80	3.20	3.62	9.03	100

Ans. ST = 0.5 Min.

35. In a candy factory a direct time study was made of the chocolate melting and pouring operation. Two inexperienced industrial engineers and one experienced engineer each made the study simultaneously. They agreed precisely on cycle times (shown below) but varied on rating the work. The experienced engineer rated the worker 100 per cent, and the other engineer rated the worker 80 per cent and 110 per cent. The firm uses a 15 per cent allowance factor.

Cycle Times (Minutes)	*Time Observed*
25	1
29	2
30	2
31	1

(i) Determine the standard time using the experienced industrial engineer's judgements.

(ii) Find the standard times using the data of each in experienced engineer. What is your interpretation when compared to Part (i) ?

NOTES

36. An operator is observed to complete a job in 0.33 minutes at a rating 75. If he works at ratings of 60, 80, 90 and 100, how long would it take to complete the job in each case.

37. Time study has been carried with the help of stopwatch of an activity 'assemble and rivet flanges to hub of metal spool'. This activity consists of two elements.

(a) Assemble flanges to hub of metal spool (manually)

Number of observations = 40

Average time = 40 seconds

(b) Rivet (machining operation)

Number of observations = 40

Average time = 30 seconds

Number of observations are sufficient and so the standard time is to be calculated for the above activity. The rating has been observed 80% and the other allowances are 50% of normal time.

38. The following data cover the assembly and packing into a container of wooden wash board. The wash boards are made up of two side pieces. One top cross piece, one middle cross piece, one bottom cross piece and a wooden back piece for the upper section of the board and a corrugated glass scrubbing board. The pieces are fitted together and help in place by six nails, six wash boards are packed in a container. The following is a copy of the observation sheet, the times recorded are continuous watch readings, are in hundredths of minutes. The number of full minutes is shown only when it changes.

Element	*1*	*2*	*3*	*4*	*5*	*6*	*7*
(a) Assemble to be first side	0.12	1.58	0.43	0.36	0.25	0.15	6.01
(b) Assemble back piece and middle cross piece	0.29	0.82	0.60	0.55	0.41	0.32	0.19
(c) Assemble scrubbing board and bottom piece	0.44	0.94	0.76	0.70	0.55	0.48	0.32
(d) Assemble second side piece	0.64	2.00	3.02	0.89	0.78	0.63	0.50
(e) Nail six nails and lay aside	0.89	0.33	0.24	4.12	5.04	0.91	0.75
(f) Get and from container	1.08	—	—	—	—	—	0.95
(g) Place six boards in con tainer and get aside	1.51	—	—	—	—	—	7.31

Discard the extremely long and extremely short elemental readings and determine the selected elemental time for each element by averaging and remaining time values. Assume that the time study man rated the man's performance at 110%.

Determine the cycle time for the job before allowances are added. Assume that the allowances for miscellaneous necessary duties, for fatigue and for personal time come to an additional 30%. Determine the time standard for the job. Express the production standard in terms of wash boards to be assembled per hour.

39. The time recorded on a time study sheet by snap back method for a single manual work element indicates the following times in decimal minutes :

0.14, 0.15, 0.20*, 0.15, 0.2, 0.18, 0.17, 0.17, 0.18, 0.14, 0.17, 0.19, 0.13, 0.15, 0.17, 0.19*, 0.14, 0.17, 0.18, 0.16, 0.14, 0.16, 0.13, 0.19, 0.13, 0.14, 0.17, 0.12, 0.13, 0.14, 0.18*, 0.14.

*Indicates that the job got struck to fixture. The rating was judged as 80 on a 60 normal scale. Determine the normal time for the said work element.

Determine the number of observations required to give a desired precision of ± 5% with a confidence level of 90%.

40. What is performance rating. What factors should be taken into account when rating an operator ?

41. If an operator strongly objected to his performance rating factor, upon completion of the study, what would your next step be if you were the time study analyst ?

42. Discuss the various methods of rating a worker in a time study ?

43. Following data is taken from a time study summary sheet for an operation consisting of 4 elements :

Element	*Basic time minutes*	*% RA*
1	0.65	20
2	0.97	15
3	2.39	10
4	0.39	20

Determine :

(*a*) The average relaxation allowance

(*b*) Standard time per part.

44. How would you calculate the standard time if the total representative time to produce a product is 15 minutes. Which is consisting of machining time as 7 minutes and manual time as 8 minutes. The rating factor as given in factory manual is 110%. The permissible allowances are given as

Personal allowance	= 3%	Of the total normal time
Relaxation allowances	= 10%	
Delay allowance	= 2%	

Normal time = 16.5 minutes.

Ans.

Standard time = 18.975 minutes.

45. A study was carried out in the Radiator manufacturing section to find out the time to be allowed for the seam welding of elements on the spot welding machine. The operation is being performed by one operator, the job was broken down into following elements :

(*a*) Pickup element load on machine rollers

(*b*) Clean both sides of the element

NOTES

(c) Spot welding

(d) Unload the welded element and place aside

As this was a highly repetitive job, the timing of various elements were established by using time study technique of work measurement. The following are the results of the time study done for 20 cycles.

S. No.	Element description	Frequency of occurrence	Normal time per occasion	Relaxation Allowance
1	Pick up element load on machine rollers	1	35	20%
2	Clean both sides of the ele ment	1	30	15%
3	Spot welding	1	107	20%
4	Unload the welded element and place aside	1	32	20%

The spot welding machine has to be stopped for 5 minutes for cooling of rollers after every 30 minutes of the operation which forcs idleness on the operator. Keeping this in view, calculate the allowed time per spot welding of element from above data and also find out as how many elements could be seam welded in a shift of 8 hours.

46. During a cumulative stop watch time study the watch reading in minutes for 3 elements were collected for a cycle as shown below. If the relaxation allowances were 10%, calculate the standard time for the job.

Element		Cycles				RF
		1	2	3	4	
(a)	T					
	R	0.2	1.2	2.25	3.40	110
(b)	T	0.6	1.7	2.80	3.8	120
	R					
(c)	T					
	R	0.9	0.20	3.10	4.1	100

47. Determine the standard time for the following job. Add 20% for allowances. The time shown are continuous stop watch readings in hundredths of a minute.

Element	Cycle						
	1	2	3	4	5	6	7
(a) Get two cases	10	—	54	—	04	—	52
(b) Put part into case	21	40	64	82	15	33	59
(c) Fasten parts into position	28	47	72	96	22	40	81

Performance rating of element (*a*), (*b*) and (*c*) were 105%, 115% and 95% respectively. The time taken for an element in a time study for 30 observations revealed the following information :

NOTES

X in seconds	0.05	0.06	0.07	0.08
f Frequency	14	14	1	1

Have sufficient observations been taken for a precision of ± 5% and 95% confidence level.

The answer is yes. But can you tell us how many observations need to have been taken.

An standard allowed time for the operation is 0.3703 minutes.

48. Estimate standard time using the following information :

(*i*) Observed time ≈ 10 minutes
(*ii*) Observed rating (on standard scale) ≈ 125
(*iii*) Relaxation allowances ≈ 15%
(*iv*) Contingency allowances ≈ 4%

49. Average time values of fifteen manual elements recorded in the time study analysts recent study are 0.15, 0.22, 0.23, 0.18, and 0.10 minutes respectively.

The predetermined motion times values for the same elements are 0.13, 0.20, 0.19, 0.20, and 0.10 minutes respectively. Calculate the average performance rating.

50. A milling m/c operator takes 15 minutes to complete the manufacture of a gear at a rating of 80% calculates the standard time of the relaxation and contingency allowance are 8% and 2% respectively.

51. Calculate standard time for 10 units from the following data :

Job element	*Selected time*	*Rating factor*	*Relaxation Allowance*
A	0.75 minute	12.5%	10%
B	1.5 minute	12%	15%
C	0.8 minute	11%	20%

52. The following cumulative time study observation were recorded in minutes for a job having two elements.

Elements	*I*	*II*	*III*	*IV*	*V*
No. I	0.09	0.38	0.67	0.16	1.26
No. II	0.27	0.58	0.85	1.16	1.45

Average rating for element number I is 80% and for element no. 2 is 110%, total allowance and admissible are 15%. Calculate the standard time

53. An operator manufacture 50 jobs in 6 hours and 30 minutes. If this time includes the time for setting his m/c. Calculate the operator efficiency, standard time allowed by the job was setting time 35 min. production time perpiece 8 minute.

NOTES

54. In a time study, the average element time for an operation having 5 elements are, 10 seconds, 12 seconds, 20 seconds, 9 seconds and 15 seconds. If the operator was given a rating of 120% and 5% allowances were allowed, what will be the standard time for the operation ?

55. Determine the standard time for the following job. Add 20% for allowances. The times shown are continuous stop-watch readings in hundredths of a minute.

Element	*Cycle*						
	1	2	3	4	5	6	7
(*a*) Get two cases	10		54		04		52
(*b*) Put part into case	21	40	64	82	15	33	59
(*c*) Fasten parts into position	28	47	72	96	40	81	81

Performance rating of the elements *a*, *b* and *c* were 105%, 115% and 95% respectively.

Write about basic motion time study.

OBJECTIVE TYPE QUESTIONS

1. Work study aims for
   (*a*) Productivity improvement (*b*) Good plant Layout
   (*c*) Capacity planning (*d*) Human Resource Development.
2. Which of the following is not a work measurement technique
   (*a*) Two hand process chart (*b*) Work sampling
   (*c*) PMTS (*d*) Stop watch time study.
3. Rating is used in
   (*a*) Time study (*b*) Method study
   (*c*) Capacity planning (*d*) None of the above.
4. Which of the following is not a technique of method study :
   (*a*) Stopwatch method (*b*) Two hand process chart
   (*c*) Travel chart (*d*) Multiple activity chart.
5. Work study techniques increases productivity because they
   (*a*) Help in optimum utilization of existing resources
   (*b*) Help to increase the resources of industry
   (*c*) Provide jobs opportunity to all concerns
   (*d*) Improve the working conditions for workers.
6. Which one of the following aspects of management is not affected by work study.
   (*a*) Development of new technology
   (*b*) Evaluation of human work
   (*c*) Effective use of human effort
   (*d*) Effective utilization of plant and equipment.
7. The work study is more appropriate technique to be used when basic work content of a job is increased due to
   (*a*) Defects in design of product
   (*b*) Short comings of the management

NOTES

(*c*) Poor attitude of workers
(*d*) Ineffective methods of manufacturing.

8. Work study comprise two main technique which are
(*a*) Method study and motion economy
(*b*) Job evaluation and ergonomics
(*c*) Acceptance sampling and work sampling
(*d*) Method study and work measurement.

9. Work study consists of the following techniques
(*a*) Performance rating and productivity
(*b*) Method study and work management
(*c*) Control chart for variable and control chart for attribute
(*d*) Standardization and SQC.

10. Work study is
(*a*) A procedure to examine all the factors affecting particular job in order to develop the best method or doing the job and to assess how much the job is worth.
(*b*) A procedure to measure the time taken to do a job
(*c*) A management service based on techniques which are used to examine human work in all its contexts and which lead to systematic investigation of all the resources and factors which affect the efficiency and economy of the situation under review in order to effect improvement.
(*d*) The systematic analysis of the activities of a shop or department to determine the proper function and duties of the operators and supervisors.

11. Work study manager should report to
(*a*) Personal manager (*b*) Works manager
(*c*) Finance manager (*d*) Marketing manager.

12. Before work study is commenced it is required to maintain
(*a*) Good human relations
(*b*) Good industrial relations
(*c*) Good Personal relations
(*d*) Good relations with worker under study.

13. The ultimate aim of work study is to improve
(*a*) Management (*b*) Labour relations
(*c*) Productivity (*d*) Product quality.

14. Some statements are given below
(*i*) More effective use of plant and equipment
(*ii*) Develop a new technology
(*iii*) Most effective use of human effort
(*iv*) Does not involves capital investment on plant and equipment.
(*v*) Evaluation of human work.
The Objective of work study are
(*a*) (*i*) (*ii*) (*iii*) (*b*) (*i*) (*iii*) (*iv*)
(*c*) (*ii*) (*iv*) (*v*) (*d*) (*iii*) (*iv*) (*v*).

NOTES

15. The term used to embrace the techniques of method study and work measurement which are employed to ensures the best possible utilization of human and matured resources is carrying out a specific activity is
    (*a*) Work study (*b*) Work sampling
    (*c*) Time study (*d*) Rating.
16. The chart which shows the distance and the number of moves between different departments taken as origin and destination is known as
    (*a*) Flow Process chart (*b*) Travel chart
    (*c*) Pert chart (*d*) REL chart.
17. Chart which indicates the relationship between pairs of department interms of closeness depending upon the activities of the departments is known as
    (*a*) REL chart (*b*) Travel chart
    (*c*) CPM chart (*d*) Gantt chart.
18. A chart is which time values are recorded and motions are classified by therbligs is called.
    (*a*) Simo chart (*b*) Operation chart
    (*c*) Gantt Chart (*d*) Process chart.
19. Method study is a very useful tool for
    (*a*) Determining basis for incentive schemes
    (*b*) Reducing fatigue of operators
    (*c*) Finding standard time of an operation.
20. It is generally agreed that the originator of method study was
    (*a*) RM Brane (*b*) FW Taylor
    (*c*) KFH Murrel (*d*) LM Gilberth.
21. A flow process chart is
    (*a*) A graphic representation of the relationship between the activities performed by various members of team with respect to one another while they are working together on a job.
    (*b*) A graphic representation of activities performed by both hands independently.
    (*c*) A dimensioned plan or model on which the path traced by men, materials or equipment is recorded by winding a string along the path of movement.
    (*d*) A graphic representation of all operations, transportations inspections, delays and storages occurring during process.
22. Among the given situations the job one should pick up first for method study is that which is
    (*a*) Simple and can be measured easily on various available machines.
    (*b*) Important and requires time but can be made in the same department on different machines
    (*c*) To pass through different departments of the industry
    (*d*) Time consuming and requires chasing so as to reach the assembly line in time.
23. The first step of systematic approach to method study after selecting the job is
    (*a*) Develop a new method (*b*) Critical analysis
    (*c*) Record of facts (*d*) Feasibility survey.

24. The need of recording all basic facts relating to the existing method is important because it

(*a*) Simplifies job evaluation of the method

(*b*) Forms a basis for wage incentives

(*c*) Helps in finding out alternatives and their evaluation

(*d*) Assits in improving the working conditions.

25. The proper sequence of method study procedure is

(*a*) Examine, select, develop, install, record

(*b*) Record, examine, select, develop, install

(*c*) Select, record, examine, develop, install

(*d*) Examine, develop, select, install, record.

26. Which activity does the symbol denotes in work analysis

(*a*) Operation (*b*) Inspection

(*c*) Storage (*d*) Transportation.

27. Techniques of method study aim at

(*a*) To reveal and analyse fully the facts concerning any situation

(*b*) To examine the facts critically

(*c*) Both (*a*) and (*b*)

(*d*) None of the above.

28. What activity does the symbol 'D' indicate in work analysis ?

(*a*) Damage (*b*) Dummy

(*c*) Delay (*d*) All of the above.

29. Which of the following is not a technique used in work measurement ?

(*a*) CPM and PERT (*b*) Work sampling

(*c*) Time study

(*d*) Pre-determined motion—time system (PMTS).

30. An operation consists of three elements having normal time of 15, 20 and 18 seconds. What will be the standard time for the operation considering an allowance of 5% for all elements ?

(*a*) 53 (*b*) 55.65

(*c*) 18.55 (*d*) 50.35.

31. The systematic recording, analysis and critical examination of existing and proposed ways of doing work and the development and application of easier and more effective methods, is known as

(*a*) Work measurement (*b*) Method study

(*c*) Time study (*d*) Work sampling.

32. What does the symbol ∇ denote in work analysis ?

(*a*) Storage (*b*) Delay

(*c*) Operation (*d*) Transportation.

33. The standard time for an activity having an average observed time of 10 seconds, rating of 120% and allowance of 10% would be

(*a*) 12 seconds (*b*) 12.5 Seconds

(*c*) 13.2 seconds (*d*) 14 seconds.

NOTES

34. If the standard time for a job element is 1.5 minutes, the rating in 100 scale is 120 and the admissible allowances are 10%. The basic time for that element is
(*a*) 1.2 minutes (*b*) 1.65 minutes
(*c*) 1.8 minutes (*d*) 1.98 minutes.

35. Relaxation allowance is provided to
(*a*) Enable the worker to attend natural personal needs only
(*b*) Enable the worker to attend natural personal needs and to compensate for the vigilance required to do the job.
(*c*) Overcome muscular fatigue due to working on job only
(*d*) Compensate all the above three.

36. When an operator looks after two or more automatic, semi automatic machines. the allowances given in standard times known as
(*a*) Introductory allowance (*b*) Contingency allowance
(*c*) Policy allowance (*d*) Interference allowance.

37. The worker performing his work with 125% rating will have the following description :
(*a*) Steady deliberate unhurried performance
(*b*) Brisk business like performance
(*c*) Very fast exhibiting a high degree of assurance
(*d*) Exceptionally fast.

38. The main objective of work measurement is
(*a*) To evaluate the efficiency of the plant
(*b*) To assist in formulating in incentive scheme
(*c*) To help in preparing complete work schedule
(*d*) To obtain the time necessary for carrying out of the job at a defined level of performance.

39. The allowance provided in time study as expressed as % of the
(*a*) Standard time (*b*) Normal time
(*c*) Observed time (*d*) Average time.

40. The work study man while timing the operator should preferably
(*a*) Stand directly in front of the operator (*b*) Stand very close to the operator
(*c*) Stand on one side slightly to the rear of the operator.
(*d*) Stand at the back of the operator.

41. The element of work which are observed during a time study but which are not a necessary part of the operation, or activity are called
(*a*) Occasional elements (*b*) Therbligs
(*c*) Foreign elements (*d*) Infiltrators.

42. In a time study the relation between the performance observed and the normal performance is termed as
(*a*) Ratio delay (*b*) Therbligs
(*c*) Rating factor (*d*) Productive
(*e*) Snap back.

43. The worker tends to change the rate of working when observed by a time study man in order to :
(*a*) Confuse the time study man (*b*) Get loose time standards
(*c*) Show that he can work at different speeds.

44. For conducting a time study, the operation should be divided into elements and *each element should be timed separately* because :
(*a*) It gives the results quickly
(*b*) Any variation in method used can be detected at a later stage
(*c*) The results obtained are accurate
(*d*) Use of simple stop watch can be made.

NOTES

45. The number of cycles to be timed in a stop watch time study depends upon :
(*a*) The discretion of the time study engineer
(*b*) The time of each cycle and accuracy of results desired
(*c*) The time available to the time study engineer
(*d*) The discretion of the operator being observed.

46. In determining the standard time from normal time of an operation rest allowance is added because
(*a*) Rest periods increase the amount of work done in a day
(*b*) *Worker should take rest when machine is under repair*
(*c*) Standard time must be more than normal time for an operation.

47. The performance rating
(*a*) Speed and skill of the operator is judged
(*b*) Job difficulty and speed of operator is judged
(*c*) Job difficulty and skill of operator is judged.

48. If the lighting provided in the work area is below that recommended, an allowance should be given in determining the time standard for the operation carried out in that work area. This allowance will be termed as
(*a*) Variable rest allowance (*b*) Constant rest allowance
(*c*) *Process allowance* (*d*) *Policy allowance*
(*e*) Interference allowance (*f*) Contingency allowance.

49. The working rate of the average worker working under capable supervision which can easily be maintained day after day without undue metal or physical fatigue is termed as :
(*a*) Normal performance (*b*) Standard performance
(*c*) Average performance

50. Those elements of work cycle which do not occur in every cycle of the task but which may occur at regular or irregular intervals are known as
(*a*) Foreign elements (*b*) Occasional elements
(*c*) Variable elements (*d*) Repetitive elements.

51. When a time study man misses a reading while study is in progress, he should
(*a*) Wait for next cycle (*b*) Ask the operator to repeat
(*c*) Indicate M in the R column (*d*) Use his own judgement.

52. In time study those elements which are identical in specification and time and which occur in two or more operations are known as
(*a*) Constant elements (*b*) Occasional elements
(*c*) Variable elements (*d*) Repetitive elements.

NOTES

53. The process of mental comparison by a work study man of the performance of an operator under observation with his won idea of a standard performance for the method under study is known as

(a) Allowance (b) Fatigue
(c) Performance rating (d) Activity sampling.

54. Which one of the following statements do not hold good for rating as applied in stop watch time study

(a) It is a process of mental comparison of the performance by an analyst.
(b) Normal rating is the rate of working of an average worker under good supervision.
(c) The purpose of rating is to facilitate orderly determination of a worker's worth to the job he is performing.
(d) It is a factor for determining the time required to perform a task by normal worker.

55. An average performance in a time study means that

(a) It is the performance of an average worker
(b) A large number in a group are working as for near to that level of performance
(c) An average skilled man working on that job
(d) It is the performance average of all the workers in a group working on that job.

56. An operator takes 4.2 minutes to complete an average cycle at the 90% rating. What is the standard work content if the allowance amounts to 15%.

(a) 3.93 (b) 4.35
(c) 4.81 (d) 5.36.

57. In which of the following situations as the process allowance provided in a time study.

(a) When idleness is enforced on worker due to some peculiar characteristics of the process.
(b) Where process requires more than one machine to be attended by an operator.
(c) Where process is carried out on a high precision machine.
(d) When more than one person is required to carry out a process.

58. A part of time study by continuous method of time measurement with a decimal stop watch is given below :

Element	*Watch reading*
(i) Get part and load in jig	12
(ii) Position jig and get handle	24
(iii) Drill hole (6 mm diameter)	54
(iv) Remove part end place aside	60

Total time of the cycle is

(a) 0.6 min (b) 1 min.
(c) 1.5 min (d) 2 min. 30 sec.

NOTES

59. A continuous method of stop watch time study has produced the following observations in decimal minute :

Element	1	2	3	4	5
Insert screw	0.80	0.32	0.5	0.72	0.92
Tighten screw	0.2	0.42	0.62	0.82	1.03

What will be observed time in minute for the element (*i.e.*) tighten screw

(*a*) 1.03 (*b*) 0.662

(*c*) 0.206 (*d*) 0.11.

60. The observed time for an element is 15 minutes and RF 115%. The normal time for each element will be

(*a*) 1.5 min. (*b*) 1.94 min.

(*c*) 2.16 min. (*d*) 1.725m min.

61. The work cycle elements which are identical in specification and time are known as

(*a*) Constant elements (*b*) Variable elements

(*c*) Repetitive elements (*d*) Occasional elements.

62. In a stop watch time study the rating factor is

(*a*) Established by the management for all operation in the company.

(*b*) Determined by time study engineer while timing the operation

(*c*) Determined from the relationship between standard time and normal time from the stop watch reading.

63. The rating factor is multiplied

(*a*) To normal time to get standard time

(*b*) To standard time to get normal time

(*c*) To observed time to get standard time

(*d*) To observed time to get normal time.

64. A personal delay allowance is taken into account in determining.

(*a*) The normal time for an operation

(*b*) The standard time for an operation

(*c*) The observed time for an operation.

65. A personal delay allowance

(*a*) Does not vary significantly between different operations

(*b*) Varies significantly from operation to operation dependency upon the fatigue involved in the operation

(*c*) Is used to find the best method of doing an observation.

66. The standard time for an activity having an average observed time of 10 seconds rating of 120% and allowances of would be

(*a*) 12 seconds (*b*) 12.6 seconds

(*c*) 13 seconds (*d*) 13.4 seconds.

67. Which of the following is a technique of work measurement

(*a*) Time study (*b*) Work sampling

(*c*) PMTS (*d*) All of the above.

NOTES

68. Which of the following is not a technique of method study

(*a*) Stopwatch method (*b*) Two hand process chart

(*c*) Travel chart (*d*) Multiple acitivity chart.

69. Some statements are given below :

1. Less cost
2. No specially trained analysts are needed
3. Suitable to determine contingency allowance
4. Does not allow finer break down of activities
5. No record of the methods is made, work sampling has the following advantages.

(*a*) 1, 2 and 3 (*b*) 2, 3 and 4

(*c*) 3, 4 and 5 (*d*) 1, 2 and 5.

70. In which one of the following situations will the time required for basic human motion move to be minimum

(*a*) Move object against stop (*b*) Move object to in exact location

(*c*) Move object to exact location (*d*) Move object to indefinite location.

71. The work measurement techniques in which time established for basic human motions (classified according to the nature of motion and the condition under which it is made) are used to build up the time study for a job at a defined level of performance is known as

(*a*) Analytical estimating (*b*) Stop watch time study

(*c*) PMTS (*d*) Work sampling.

72. If you want to estimate the percentage of time utilized by office staff of your institute which one of the following technique is most suitable for the purpose.

(*a*) Time study (*b*) Job evaluation

(*c*) Work sampling (*d*) Job estimation.

73. Which one of the following work measurement technique does not require any time measuring equipment

(*a*) Time study (*b*) Work sampling

(*c*) PMTS (*d*) Synthesis.

74. For non repetitive, maintenance and construction work, which technique of work measurement will be most suitable and economical

(*a*) Stop watch time study (*b*) P.M.T.S.

(*c*) Work sampling (*d*) Analytical estimating.

75. An operator of an assembly line has to pick up a stud from a bin of studs and fix it on to a hole in a casting, the type of reach motion which he is performing would be classified as

(*a*) D—Reach to a very small object

(*b*) C—Reach to object jumbled with other object in a group

(*c*) B—Reach to single object in location which may vary a little, cycle to cycle

(*d*) A reach to a an object in other hand.

CHAPTER

5

ERGONOMICS

NOTES

LEARNING OBJECTIVES

- Introduction
- Principles of Human Motion Economy
- Normal Working Area and Maximum Working Area for a Sitting Man
- Relationship of Ergonomics with Work Study
- Tools and Techniques Used in Ergonomics
- Design of Handles
- Design of Equipments
- Work Space and Arrangement
- Considerations in Locations of Components
- Guide Lines in Designing Individual Work Place

5.1. INTRODUCTION

The science of ergonomics is concerned with the design of human work.

Ergonomics is the scientific study of work. The people who do it and the ways in which it is done. It is concerned with the tools people use, the places they work in and the procedures and practices that they follow.

Ergonomics sets out to find the best possible match between the physical and mental demand of work and the capacities of individual members of the work force in order to optimise, both the productivity of the organization and the health, safety and well being of its people.

Ergonomics is concerned with *relationships between man, m/c and the environ-*ment which he has created and services to make man, m/c systems more efficient and more safe.

Ergonomics is the study of efficiency of persons in their working environment.

The application of human biological sciences in conjunction with engineering sciences to the worker and his working environment so as to obtain maximum satisfaction for the worker which at the same time enhances productivity.

ILO. The study of the relationship between man and his occupation, equipment, environment and productivity is ergonomics.

Objectives of Ergonomics

NOTES

(*i*) To improve the relationship between people, equipment, work place and the environment in which they interact.
(*ii*) Increasing work efficiency and productivity.
(*iii*) Promote safety and comfort at work situation.
(*iv*) Optimal conditions for the workers.
(*v*) To reduce physical work load.
(*vi*) To improve working postures.
(*vii*) To facilitate psycho seasonial functions in instrument handling.
(*viii*) To avoid unnecessary information recalls.
(*ix*) To assist in job placement of workers.
(*x*) Study the nature of tasks so that disease or its effects are prevented.
(*xi*) The cost of the individual to be minimised by removing those features of design to cause inefficiency or physical disability.

Advantages of Ergonomics :

1. With the better ergonomics design there is higher output.
2. Improve the productivity.
3. Attain maximum output from a worker with minimum fatigue.

Applications of Ergonomics :

Ergonomics is also a useful tool for evaluating the choice of technology, and its implementation. It can contribute to the safe and productive transfer of technology and reduces the number and scale of accidents and catastrophes in industrial operations.

(*i*) Assist in design and operation of man, m/c, environmental study.
(*ii*) Help to know about the human activities, capability and limitations.
(*iii*) Helps to ensure physical and mental use of human beings.

History of Ergonomics

1940— Military World War II
1949— U.K. Ergonomic Research Society
1970— Germany Ergonomics Standard Committee
1973— International Ergonomic Standard Organisation
1975— ISO Technical Committee Established

Ergonomics consist of

(*i*) **Engineering psychology.** It is concerned with perception, decision making and particularly such aspect as how an operator receives and processess informations.

It studies the sensory and mental capacities of man in order to establish the conditions under which a man machine system can most efficiently and safely operate. The importance of engineering psychology in equipment design can be realized most striking in the design of cockpits and space capsule where the magnitude of controls and displays and the tremendous risks involved in possible errors make the ergonomical approach inevitable.

The branch of application of behavioral science in the design of man-machine systems.

NOTES

Man-machine system

Modern weapon systems, dial telephone system. Man as a component in a system. He may be

(*a*) A receiver in order to run a machine, a human operator must get information from it. Such information may come to him through any of the senses through vision, hearing the pressure sense or others.

(*b*) An evaluator

(*c*) A controller

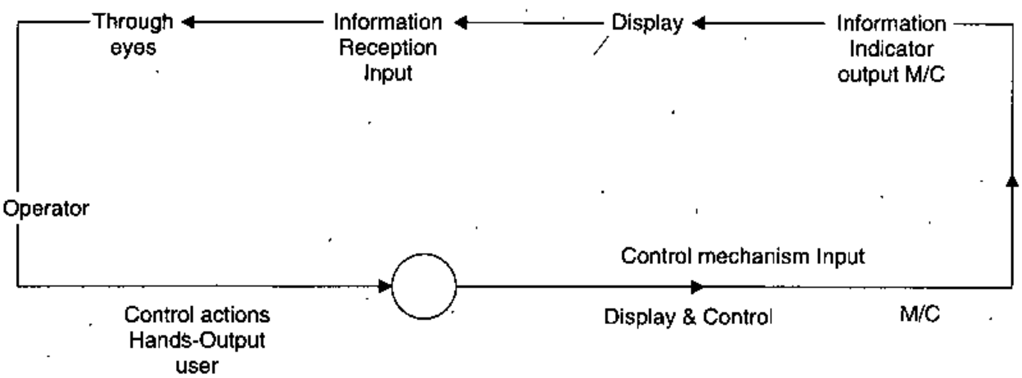


Fig. 5.1. Operator and machine interface.

A man-machine system may be composed of many men and machines or a system may be made up of a single machine and a single man.

A particular man reacts to stimuli arising from some kind of machine display, he make certain decision and carries out certain responses affecting the controls of the machine. These actions in turn cause the machine to furnish him with a new set of stimuli.

Such systems in which there is continuous interaction and feed back between man and machine are called **closed loop system.**

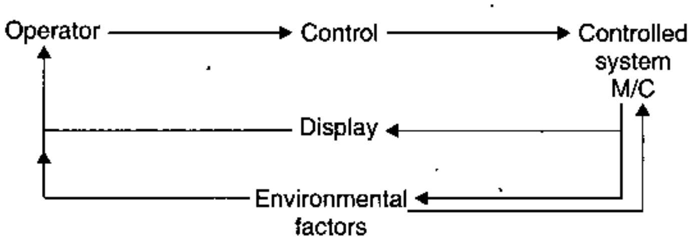


Fig. 5.2

Man may also be used as a component of an **open loop system**, in which the feedback from the machine is remote or intermittent.

The human performance required in man-machine interactions have two kinds of implication for the design of systems :

(*a*) The equipment may be designed to fit what is known about the performance capabilities of man.

(*b*) The total job conceived as a set of operation involving man-machine interaction may be designed to make efficient use of the functions of both man and machine.

NOTES

(*ii*) **Work physiology.** Covers the whole field of body activity particularly with reference to many different types of environments.

(*iii*) **Environmental physiology** connects the study of the inter-relation of the living organisms with the physical factors of environment.

(*iv*) **Anthropometry and Biomechanics** establish the principles and standard for the design of equipments, work place, motion patterns for different operations to bring them into harmony with size, shape, mobility and structure of the human body.

(*v*) **Biomechanics** is the science concerned with the internal and external forces that action of human body and the effects those forces produced.

It provides a sound scientific basis for the analysis of human movements. It is common to mechanics, material, psychology, medicine, surgery, pathology, prosthesis, patience care, dentistry, athletes, sports, environmental studies, safety and mechanics of human tolerance to fatigue and injury.

Biomechanics of motion deals with the various aspects of physical movements of the body and the body members. The operation of the body member can be characterized in term of science of motion (Kinematics), the bones connected at their joints is combination with their muscles, serves as levers.

(*vi*) **Sport mechanics.** Analysis of various styles for best results, equipment design, injury prevention, energy optimization etc.

(*vii*) **Orthopedics.** Design and analysis of prosthetic and orthoetic devices, analysis of surgical procedures, comparison of treatment and heating pattern, design of surgical instruments, physical therapy techniques etc.

(*viii*) **Orthodentics.** Design of braces, materials for dentistry, treatment procedures, etc.

(*ix*) **Surgery.** Design of instruments, analysis of optional indsim orientation, skin heating properties etc.

(*x*) **Biomaterials.** Testing for biocompatability, life cycle etc.

(*xi*) **Functional anatomy and physiology.** Is concerned with the body frame work posture and the use of muscles it can. Therefore it provide knowledge of the best ways in which forces can be applied or object lifted and also about the limits of joint movement.

(*xii*) **Industrial hygiene.** Reduction of toxic and other health hazard.

(*xiii*) **Physiological psychology.** Functioning of the brain and of the nervous system.

(*xiv*) **Experimental psychology.** Human behaviour.

(*xv*) **Industrial medicine.** Define those conditions of work which may prove harmful to the human structure.

(*xvi*) **Physics and Engineering.** Condition that which work is to contend.

5.2. PRINCIPLES OF HUMAN MOTION ECONOMY

(A) Use of human body

(*i*) Two hands begin as well as and their work at the same time.

(*ii*) Both hands should not be idle during the same period of time except for rest periods.

(*iii*) Work of the two hands should follow opposite and symmetric motion patterns.

NOTES

(*iv*) The lowest practical and usable classification of body motion should be employed.

(*v*) Maximum use should be made of the momentum developed by motion.

(*vi*) Smooth flowing motion produces less fatigue and are preferable to short motion involving stops and change in directions.

(*vii*) Ballistic movements are easier, faster and more accurate.

(*viii*) A motion sequence employing rhythm and automatically is less fatiguing and more productive.

(B) Work place Arrangement

(*i*) Tools and materials should have definite location and should be conveniently located for easy accessibility.

(*ii*) Tools, materials and actuating devices should be easily accessible and as close as possible to the work area.

(*iii*) Gravity feed bins should be employed. To make the parts easily accessible to the worker.

(*iv*) Use drop deliveries.

(*v*) Tools and materials should be located so as to employ the best sequence of motions.

(*vi*) Good illumination should be provided.

(*vii*) The height of the work place and chair should be such that the operator can either sit or stand in performing his work.

(*viii*) Operators should be provided chairs that will make good postures.

(C) Design of Tools and Equipments

(*i*) *Hands should not perform any work that can be done more efficiently by jig, fixture or tool operated device.*

(*ii*) Two and more tools should be combined where possible.

(*iii*) *Tools and materials should be propositioned close to the work area.*

(*iv*) Handles and cranks should be designed to permit maximum contact with the hand.

5.3. NORMAL WORKING AREA AND MAXIMUM WORKING AREA FOR A SITTING MAN

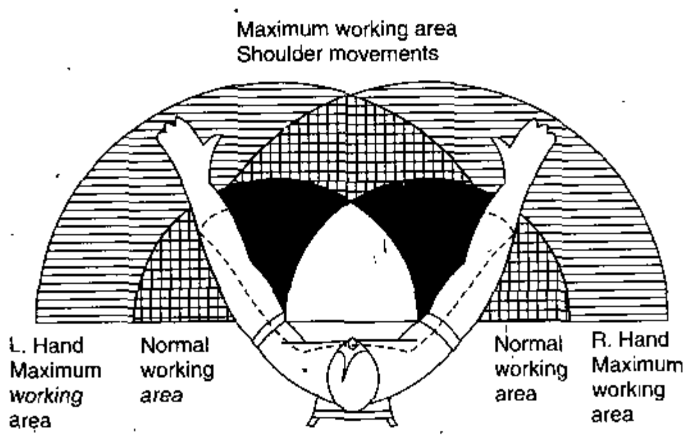


Fig. 5.3

NOTES

5.4. RELATIONSHIP OF ERGONOMICS WITH WORK STUDY

Ergonomics and work study are two interrelated terms. The aim of work study is to minimise the time consumption and to improve the efficiency of a system, so as to achieve the most efficient system.

Now, the efficiency as well as the consumption of energy and time are closely connected to the health and physique and environmental conditions. In order to have maximum work with minimum effort, the various factors (*viz*. environment, psychological factors, mechanincal factors, etc.) should be arranged in such way that the physiological fatigue of the worker is minimum. Hence, to achieve most efficient system, the science of ergonommics is of great use.

5.5. TOOLS AND TECHNIQUES USED IN ERGONOMICS

These are :

(*i*) Experimental design

(*ii*) Mathematical modelling

(*iii*) Field testing

(*iv*) Statistical sampling

(*v*) Operation research techniques.

5.6. DESIGN OF HANDLES

According to the principles of motion economy handles such as those used on cranks and large screw drivers should be designed to permit :

(A) As much of surface of hand to come in contact with the handle as possible.

(B) Minimum surface of hand to come in contact with the handle.

(C) No contact of the surface of hand to come in contact with the handle.

5.7. DESIGN OF EQUIPMENTS

Instruments

Man machine systems

Consumer products

Development of optimum work methods

work environments

A person does three things in performing any task :

1. Receives information through the senses, organs, eyes, ears, touch etc. (Information input and processing).

Make decision — acts on the information obtained and on the basis of his own knowledge.

Takes action — action resulting from the decision that has been made.

Physical — operating machine

Communication — giving oral/written instructions.

NOTES

The designer of machines, equipments, the work methods and the work environments :

(a) The way the human being functions

(b) His body dimensions

(c) His physical limitations

(d) The conditions under which he performs most effectively.

5.8. WORK SPACE AND ARRANGEMENT

Applied Anthropometry and work space

Physical facilities	Physical features and dimensions
Chairs	
Seats	
Tables	
Desks	
Work places	
Clothing	
Comfort Physical welfare Performance of people	Physical facilities fit people

5.9. CONSIDERATIONS IN LOCATIONS OF COMPONENTS

Components—Displays, Controls, Materials, Machines, Work areas or rooms.

Any given component has a generally optimum location for serving its purpose. This optimum location would be predicted on the human sensory, anthropometric and biomechanical characteristics that are concerned (*i.e.*, reading a visual display, activating a foot push button etc.) or on the performance of some operational activity (such as reaching for parts, preparing food in a restaurant or storing material in a warehouse).

5.10. GUIDE LINES IN DESIGNING INDIVIDUAL WORK PLACE

I. **First Priority.** Primary visual tasks.

II. **Second Priority.** Primary controls that interact with primary visual tasks.

III. **Third Priority.** Control/display relationships put controls near associated displays : Compatible movement relationships.

IV. **Fourth Priority.** Arrangement of elements to be used in sequence.

V. **Fifth Priority.** Convenient location of elements that are used frequently.

VI. **Sixth Priority.** Consistency with other layouts within the system or in other systems.

STUDENT ACTIVITY

1. Make a layout of work station in your organization using principles of human motion economy, what improvements can be done in existing work station.

2. How design of handles, leven, dials can be changed in machine used by you ?

NOTES

SUMMARY

1. Ergonomics sets out to find the best possible match between the physical and mental demand of work and the capacities of individual members of the work force in order to optimise, both the productivity of the organization and the health, safety and well being of its people.
2. Ergonomics is also a useful tool for evaluating the choice of technology, and its implementation.
3. Ergonomics and work study are two interrelated terms. The aim of work study is to minimise the time consumption and to improve the efficiency of a system, so as to achieve the most efficient system.

TEST YOURSELF

1. Define Erogonomics. What are the applications of Ergonomics ?
2. What are the objectives of Ergonomics ? What are the advantages of Ergonomics ?
3. Write the history of Ergonomics.
4. Define Engineering psychology, Work physiology, Environmental physiology, Anthropometry, Biomechanics, Sport mechanics, Orthopedics, Orthodentics—Surgery, Biomaterials, Functional anatomy, Industrial hygiene, Physiological, Psychology, Experimental psychology.
5. Write principles of motion economy.
6. What are tools and techniques used in ergonomics ?
7. How ergonomics is related to work study ?
8. What are the considerations in locations of components ?
9. What are guide lines for designing individual work place ?
10. How ergonomics is used for designing equipments ?
11. How work method can be designed ?

OBJECTIVE TYPE QUESTIONS

1. In which of the following areas can be principle of motion economy be applied :
   (*i*) Design of tools and equipments for production
   (*ii*) Arrangement of work place for manufacturing
   (*iii*) Use of human body for production
   (*iv*) Quality control of products during manufacturing
   (*a*) (*i*), (*ii*), (*iii*) (*b*) (*ii*), (*iii*), (*iv*)
   (*c*) (*iii*), (*iv*), (*i*) (*d*) (*iv*), (*i*), (*ii*).
2. Which one of the following is the best work place designed according to the principles of motion economy ?
   (*a*) Principal's table in the office (*b*) Driver's seat on a field tractor
   (*c*) Carpenter work bench (*d*) Book issue counter in a library.

NOTES

3. Through which of the following method study charts could the principle of motion economy be analysed
   (a) Outline process chart (b) Flow process chart
   (c) Left hand, Right hand chart (d) Man machine chart.
4. Application of principle of motion economy would yield maximum gains in which one of the following situation
   (a) Controls at car driver's seat (b) Arrangement of tools in a tool crib
   (c) Location of cash counter in a bank
   (d) Projection room in a cinema house.
5. Which one of the following rules of motion economy relates to design of tools and equipments ?
   (a) Tools and materials should be prepositional wherever possible to reduce searching
   (b) All materials and tools should be located within easy reach of the operator
   (c) Tools and materials should be located to permit the best sequence of motion
   (d) Use of multipurpose tools should be made to reduce tools fixing and removal.
6. A bowler on a cricket field runs through a distance even after bowling the ball to the batsman. Which one of the following principle of motion economy is applying
   (a) Using curved and avoiding straight line movements
   (b) Using ballistic movements then restricted movements
   (c) Rhythimatic movements
   (d) Utilizing momentum.
7. Which one of the following pivot points results in maximum economy and least fatigue to the operator
   (a) Knuckle (b) Wrist
   (c) Elbow (d) Trunk.
8. The pivot about which the body members, forearm hand and fingers can move is
   (a) Knuckle (b) Wrist
   (c) Elbow (d) Shoulder.
9. The lowest classification of body members movement results in maximum economy and least fatigue, the body members for this movement are
   (a) Hand and fingers
   (b) Forearm hand and fingers
   (c) Upper arm, forearm hand and fingers
   (d) Fingers only.
10. Which one of the industrial engineering techniques does not form a basis or a code improving the efficiency and reducing fatigue in mental work
   (a) MTM (b) Work sampling
   (c) Acceptance sampling (d) Principles of motion economy.
11. Principles of motion economy are closely associated with
   (a) Man machine chart (b) Two handed process chart
   (c) Flow process chart (d) Operation process chart.

NOTES

12. The semi-circular area covered by the hand when it is fully stretched with shoulder as the pivot is called

(*a*) Maximum working area (*b*) Normal working area

(*c*) Most convenient working area (*d*) Minimum working area.

13. According to the principles of motion economy handles such as those used on cranks and large screw drivers should be designed to permit

(*a*) As much of surface of hand to come in contact with the handle as possible

(*b*) Minimum surface of hand to come in contact with the handle

(*c*) No contact of the surface of hand to come in contact with the handle.

14. According to the principles of motion economy where each finger performs some specific movement, such as type writing, the load should be

(*a*) Distributed equally among the fingers

(*b*) Distributed in accordance with the inherent capacity of the fingers

(*c*) Distributed only between thumb and forefinger.

15. According to the principles of motion economy tools, materials and controls should be located

(*a*) Close and directly in front of the operator

(*b*) Close and on the side of the operator

(*c*) *Close and just below the height of the working table.*

16. The tools and materials should be laid out in the work place, such as bench, machine, desk, or table in

(*a*) Straight line (*b*) Arc of circle

(*c*) Curve line (*d*) Broken line.

17. The foot pedals whether they are operated sitting or standing, should have return *spring pressure*

(*a*) Just minimum possible

(*b*) Sufficient to support the weight of the foot or leg, as the case may be

(*c*) As large as possible.

18. A field of study concerned with the ability and limitation of human beings in the design of tools instruments, and work place is called

(*a*) Social-technical approach to job design

(*b*) Human Engineering

(*c*) Ergonomics

(*d*) Both (*a*) and (*b*).

19. When the operator is standing, the use of foot pedals, whether for bench work or on machines

(*a*) Should be as much made as possible

(*b*) Should be avoided if possible.

20. The optimum distance of a lever from the front surface of the body is around

(*a*) 8-10 cm (*b*) 25-30 cm

(*c*) 42-45 cm.

Fill in the correct answers from the several given :

1. The tools and parts that must be handled several times during an operation should be located .... the fixture or working position than tools or parts that are handled but once.

(*a*) farther from (*b*) Close to.

NOTES

2. The force that can be applied to a lever .... the distance between the body and lever is increased from the optimum one.
(a) does not vary significantly (b) falls out rapidly
(c) increases rapidly.
3. Maximum accuracy and force are applied to the hand wheel when .... used on the run of the wheel.
(a) right hand is (b) left hand is
(c) both hands are.
4. A force by about 100 N greater can be applied to a hand wheel in .... direction than in a .... direction.
(a) clockwise (b) anticlockwise.
5. The surface of the seat provided for worker in most industrial operations should either be horizontal or a slope .... at an angle of upto about ....
(a) forward/backward (b) 5°/10°/15°/25°.
6. The height of the work place and the chair should preferably be arranged so that ....
(a) Operator can work in the sitting position only
(b) Operator can work in the standing position only
(c) Alternate sitting and standing at work are possible.
7. Principles of Motion economy deals with
(a) Time study (b) Therbligs
(c) Micromotion study (d) Design of work place layout.

NOTES

CHAPTER

6

MATERIALS HANDLING

LEARNING OBJECTIVES

- Introduction
- Selection of Materials Handling Equipment
- Materials Handling Devices
- Advantages of Materials Handling
- Characteristics of Materials Handling Equipments
- *Principles of MH*
- Relationship of Materials Handling and Plant Layout
- Objectives of Materials Handling
- Functions of Materials Handling
- Factors on Which Materials Handling Equipment Depends
- Materials Handling Jobs
- Materials Handling Systems
- Transportion Devices
- Combination Devices
- Materials Moved Longer Distance at Irregular Intervals
- Vertical Package Conveyors
- *Lifting and Lowering Devices* Elevator
- Cranes
- Aerial Transport
- Jacks
- Lifting and Lowering Devices (Hoisting Equipments)
- Lift

6.1. INTRODUCTION

Materials Handling is the art and science involving the movement of packaging and storing of substances is any form.

Materials handling involves movement of materials mechanically or manually in batches or one by one within the plant. Movement may be horizontal, vertical or combination of the two.

NOTES

Materials movement in an industry is inevitable from start to finish. It begins from procurement of raw materials and ends at the marketing of finishing goods. Materials handling is required for movement/transportation at various stages of production process.

Raw material → Receiving → Inspection → Storage
→ Production → Packing → Storage → Marketing.

The materials handling problem is linked closely with the :

(a) Number of item in the inventory

(b) Their location

(c) The space availability

(d) The layout of the stores and the production flow and with the materials itself in terms of the space availability.

The nature of material and the kind of handling suitable to it.

The packaging or container required for the material and the handling suited to it or vice versa.

There are three basic characteristics of materials handling :

(i) Picking up the load

(ii) Transporting the load

(iii) Setting the load down.

Need of the present day is for equipments to handle heavy loads with fast speed, reliability, safety and economy. In order to meet the variety of requirements, equipments of different types and sizes have been developed and manufactured.

Materials handling devices are used for the following main functions :

(i) Movement and positioning of material.

(ii) Lifting a load and landing it down at a desired place may be at a certain distance away or at a particular height.

(iii) Loading of material into transportation equipment.

(iv) Unloading of material from transportation equipment.

6.2. SELECTION OF MATERIALS HANDLING EQUIPMENT

Materials handling devices should be able to give maximum efficiency, economy, life and reliability of service. Under utilization and faulty selection of the materials handling equipment is an responsive luxury, which gives rise to increase in operating costs.

The equipment selected should be according to the requirements of the job in respect to the size, shape, weight of material to be handled etc.

The selection of the materials handling devices depend upon the following factors :

(A) Factors related to Material :

(i) Type of material to be handled

(a) Bulk or units
(b) Large or small
(c) Heavy or light
(d) Shape
(e) Rough or fragile

(ii) Volume of material

(*iii*) Distance over which material is to be transported
(*iv*) Weight to which lifted/lowered
(*v*) Space available for the equipment
(*vi*) Number of times materials are to be handled.

NOTES

(B) Factors related to the equipment :

(*i*) Type and kind suitable for the job
(*ii*) Size and capacity of equipment
(*iii*) Number of hours it is expected to work
(*iv*) Adaptibility to other service
(*v*) *Ease of operation and maintenance*
(*vi*) Expected life of equipment
(*vii*) Comparison of various equipments available in the market with respect to cost of equipment, installation, operation, maintenance, its ease in operation, reliability and other requirements of economy and feasability.

6.3. MATERIALS HANDLING DEVICES

1. Transportation devices :
   (Horizontal motion)
   These include
   (*a*) Wheel barrow and hand truck
   (*b*) Narrow gague rail road
   (*c*) Tractors and trailors
   (*d*) Walkie trucks
   (*e*) Skids
   (*f*) Skids and pallets
   (*g*) Dollies
   (*h*) Pipe line.
2. Combination devices :
   (Lifting and lowering plus transportation)
   (*a*) Spiral chute
   (*b*) Lift truck
   (*c*) Crane truck
   (*d*) Fork lift truck
   (*e*) Plateform truck
   (*f*) Industrial can
   (*g*) Hand stacker
   (*h*) Conveyors of various types.
3. Aerial transport :
   (*a*) Cable ways
   (*b*) Rope ways.
4. Lifting and lowering devices :
   (Vertical motion)
   (*a*) Block and tackle
   (*b*) Winch
   (*c*) Hoist
   (*d*) Elevators
   (*e*) Cranes
   (*f*) Jacks
   (*g*) Lifts

6.4. ADVANTAGES OF MATERIALS HANDLING

Following are advantages of materials handling :

1. minimize the total handling time ;
2. promote easier, safe and cleaner handling ;

3. eliminate idle time of workers and machines which would be there, otherwise, while waiting for the materials for necessary operations ;
4. make material movements fast ;
5. decrease fatigue incurred by the workers ;
6. add to safety ;
7. locate, and stock materials better and in less space ; and
8. their operations can be automated to increase production.

6.5. CHARACTERISTICS OF MATERIALS HANDLING EQUIPMENTS

Every materials handling equipment possesses certain characteristics with respect to

- Materials
  - Bulk
  - Packaged
- Movement
  - Vertical
  - Horizontal
  - Combination of vertical and horizontal
- Supervision required
  - Close
  - Little
  - Equipment is automatic or semi-automatic
- Path followed
  - Variable
  - Fixed
  - Fixed area
- Speed
  - Variable
  - Fixed
  - Either fixed or variable
- Power required for the operation of equipment
  - Electricity
  - I.C. Engine
  - Manual
  - Gravity

6.6. PRINCIPLES OF MH

The following principles are to be followed to achieve the most economic materials handling.

(*i*) Materials handling should never be treated as an ancilliary, and materials handling should always be integrated with the production processes.

(*ii*) Materials should be handled in the largest possible volume by the shortest route in the safest manner and by the cheapest possible method.

(*iii*) Wherever possible gravity should assist material flow.

(*iv*) As far as it can be manual handling should be brought down to a minimum and when justified economically mechanical aids should be introduced.

(v) Optimum utilisation of the equipment, maximum standardisation, sufficient flexibility and an effective preventive maintenance should be aimed at.

(vi) Material movements should be synchronised with the production processes. Effective production results from planned processes coordinate and synchronised and if possible integrated with planned movement.

With the application of these principles it will be possible to enable saving of time, reduction of effort and better utility of space and hence brings down production costs.

6.7. RELATIONSHIP OF MATERIALS HANDLING AND PLANT LAYOUT

Materials handling and plant layout are closely interrelated, and a reciprocal relationship exists between the two. An effective layout involves least materials handling and less costly materials handling equipments. It permits, materials handling without any loss of time, with minimum delays and least back tracking. The total number of movements and the distances moved in one movement are also considerably reduced in a properly designed plant layout. In a poorly planned layout, the aisle's sub-aisle's widths or ceiling heights may not be sufficient to accommodate efficient materials handling equipments : even if used some how or other, the back tracking or duplication of material movements may not permit the materials handling system to be economical.

On other hand, an efficient materials handling system helps building an effective plant layout around itself. Various departments are located such that the materials handling is minimized. Space requirements are considerably reduced. Material movements are much faster and more economical. Bottlenecks and points of congestion are removed. Machines and workers do not remain idle due to lack of material, production line flow becomes smooth.

6.8. OBJECTIVES OF MATERIALS HANDLING

(i) To reduce the costs by decreasing inventories, minimising the distance to be handled and increasing productivity.

(ii) To increase the production capacity by smoothing the work flow.

(iii) To minimise the waste during handling.

(iv) To improve distribution through better location of facilities and improved routing.

(v) To increase the equipment and space utilization.

(vi) To improve the working conditions.

(vii) To improve customer services.

6.9. FUNCTIONS OF MATERIALS HANDLING

(i) Selection of m/cs, equipments and plant layout to eliminate or minimise materials handling requirements.

(ii) Selection of appropriate efficient and safe materials handling equipment.

NOTES

(*iii*) Minimise the cost of materials handling by :

— Minimising movements of semifinished goods during production.

— To plan movement of optimum number of pieces in one unit.

— Minimization of distance moved.

— Increasing the speed of materials handling operation through mechanization.

— Eliminate/minimise back tracking and duplicate handling.

— Utilise gravity for materials handling.

The basic materials handling function has to answer a number of questions such as follows :

(*i*) Why do this at all ?

(*ii*) What materials, is to be handled ?

— unit, bulk

— shape dimension

— quantity

(*iii*) Where and why ?

— Source and destination

— Logistics

— Distance, frequency, speed, sequence

— Transporting, conveying, positioning

(*iv*) How and Who ?

— Load support, container weight, number

— Equipment, manpower, physical restrictions, columns spacing, aisle width, congestion.

6.10. FACTORS ON WHICH MATERIALS HANDLING EQUIPMENT DEPENDS

(*i*) Nature of the production process :

(*a*) Intermittent industries—Mobile truck, Trains, cranes.

(*b*) Mass scale production—Trolleys, conveyor belts.

(*ii*) Layout of the plant.

(*iii*) Building consideration.

6.11. MATERIALS HANDLING JOBS

1. Receiving—handling the coming goods.
2. Transportation—includes the following :

(*a*) Handling the material in work-place.

(*b*) Handling the material in line.

(*c*) Handling the material in interdepartmental or intraplant.

(*d*) Handling the material in interplant.

(e) Handling the material in intercompany.

(f) Handling the material in intersystems.

3. Stocking and storing—carrying the goods to its right place and this process continues until the goods are consumed or sold out.
4. Shipping—handling the outgoing goods.
5. Freight—handling arranging for transportation and delivery of goods, wherever needed.

NOTES

6.12. MATERIALS HANDLING SYSTEMS

(A) **Equipment oriented system :**

(i) Overhead system.

(ii) Conveyor system.

(iii) Tractor trailer system.

(iv) Fork lift truck and pallet system.

(v) *Industrial truck system.*

(vi) Underground system.

(B) **Material oriented system :**

(i) Unit handling system—containerization. Pallet, shrink, wrap, strech.

(ii) Bulk handling system.

(iii) Liquid handling system.

(C) **Method oriented system :**

(i) Manual.

(ii) Mechanised or automated system.

(iii) Job shop handling.

(iv) Mass production handling systems.

(D) ***Function oriented system***

(i) Transportation devices trucks.

(ii) Conveying system

(iii) Transferring system

(iv) Elevating system.

(E) **Path**

Fixed path—Conveyor, hoist, lifts, cranes, pallets

Variable path Tractors, Trucks, Railways, Aircraft, water.

(D) **Functions oriented system :**

6.13. TRANSPORTION DEVICES

Under this type those devices which allow horizontal motion are dealt :

(a) **Hand truck.** The simplest transporting devices are the wheel barrows and hand trucks. These are still used by a number of small industries.

All such equipment involve a large amount of manpower for a relatively small load. The chief advantage of this equipment are its very low cost, great flexibility and easy portability from one job to another.

NOTES

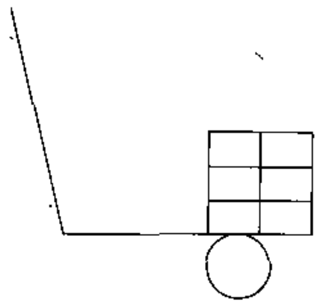


Fig. 6.1. Two wheeled hand truck or trolley

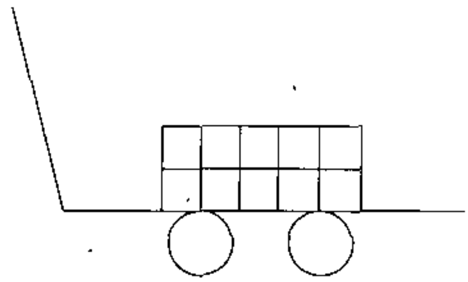


Fig. 6.2. Four wheeled truck.

(b) **Narrow gague rail road.** In general little use is made of such equipment because it requires heavy investment in the road bed and tracks, and has little flexibility and is difficult to change at a later date. These were used in the days before the development of rubber type equipment. These are still used in metal working industry [blast furnaces, copper refineries and steel rolling operations] and in mining activities where it is cheaper to lay tracks than pave the entire area.

(c) **Tractors and trailers.** These are the most common of the horizontal mode transportation. Great flexibility is achieved as tractors can be used to haul a variety of different types of trailers. Trailers can be left loaded and can be picked up by different tractors. This system has advantage of great flexibility plus all the advantages of industrial railways and there is no investment in laying trucks. This is one of the most important method of handling materials inside the plant or work area and from one building to another.

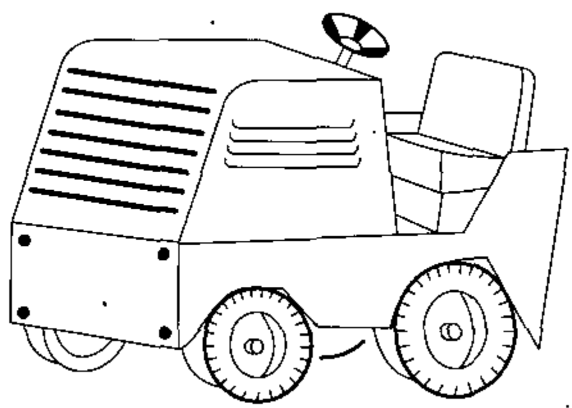


Fig. 6.3. Industrial tractor.

(d) **Walkie Truck.** A walkie truck, where the operator guides the truck by means of a handle.

You will have a choice of low-lift or high-lift walkies. These trucks can be counterbalanced by a combination of the batteries and the distance of the load from the center of gravity and by outriggers in high-lift units. In the low-lift model the load wheels in the forks never leave the ground ; the wheels are raised and lowered by a cam action in the lifting mechanism.

Since the operator guides the walkie truck by means of a handle, his controls are in this handle. It is important to have included in the handle controls a warning horn button and a safety or "panic" button. The panic button should be of the reversing type.

(*e*) **Skids.** These are used with lift trucks. Goods may be loaded into skids and then picked up with lift trucks. The skids can be loaded as a unit and transferred from position to position without subsequent loading and unloading

NOTES

(*f*) Both skids and pallets raise the load off the supporting surface and allow the easy insertion of conveying means.

(*g*) **Dollies.** *Some materials are stored on* dollies. This can be moved on their casters. Other material is stored on skids. The most common skids which can be picked up in either direction consist of a wooden platform and four steel legs.

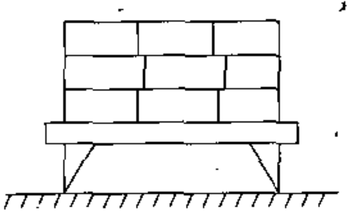


Fig. 6.4. A skid with load.

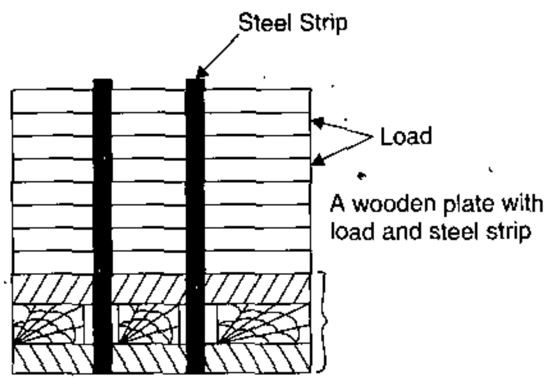


Fig. 6.5. Skid and pallet.

(*h*) **Pipe line.** Pipe lines are also used for horizontal transportation of commodities. Most obvious among these is oil which is pumped at great distance through pipe line. Natural gas is also carried through pipe lines. Water is similarly transported.

6.14. COMBINATION DEVICES

Lifting and lowering with transportation.

(*a*) Slides and chutes —
- Straight
- Spiral
- Wood/steel
- Vibrating

They transfer small jobs which can slide down under gravity, Vibrating slides transport materials up an incline also (cigarette factories). Chutes have sheet metal or roller base for transferring components down the incline. Chutes generally feed parts (*which they receive from*, say sheet metal presses) to the conveyor which takes the parts to their destination.

(*a*) **Spiral Chute.** One of the simplest device that have both vertical and horizontal motions is a chute which may either be straight or spiral. In this gravity is utilized to move the material. Chutes are common in railways and air terminals for handling package and baggage.

(*b*) **Lift Truck.** The lifting feature in a lift truck provides clearance from the floor for the skids and permits horizontal transportation.

NOTES

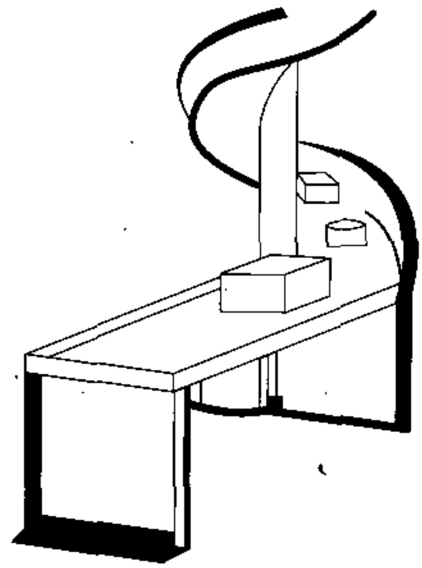


Fig. 6.6. Spiral chute.

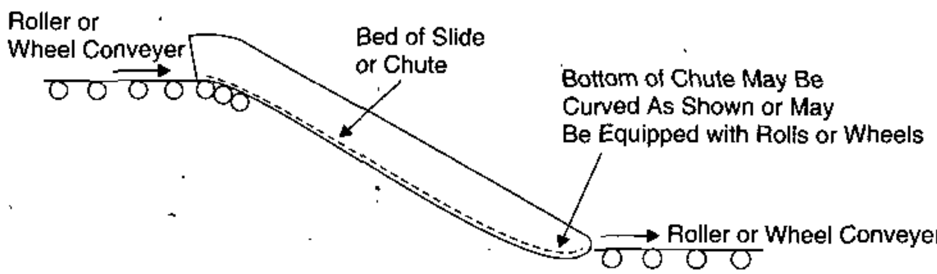


Fig. 6.7. Straight chute.

(*c*) **Crane Truck.** Small crane trucks operate on the same principle as lift trucks. They are used for materials that cannot be put on skids or not available for skids at the present time, or too much heavy to handle in the lift trucks. This moves quickly over smooth even and hard ground. This can be carried at will and to any place. In these crane trucks the solid rubber tyres are used. The cranes are rotary type so that load can be lifted from any position.

(*d*) **Fork lift truck.** Auto trucks need no particular explanation except for the development of tail board called fork, which will receive the load at the ground level and elevate it hydraulically to the level of ceiling, heights so that all manual lifting is avoided. When the load to be shifted from one shop to another fork trucks are used. These trucks do not require any extra man, driver operating the truck can lift, carry and unload the materials. Self loading and unloading can be carried out by providing a fork at the front end of the truck.

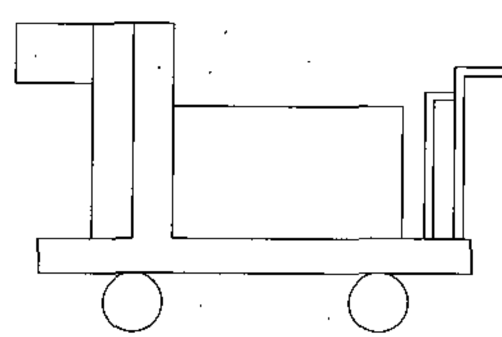


Fig. 6.8. Fork lift truck

Front attachment *of the truck varies with the type of load to be lifted and may* consist of crane scoop, hydraulic clamp, hydraulic wood clamp, hydraulic pipe clamp or hydraulic bucket etc., instead of the fork.

Fork lift trucks are used widely in workshops, stores and in crates bags etc., and by using various attachments they can also be utilized for timber handling including logs, heavy coils, sheet metal, large size drums, tyres etc.

(*e*) **Platform truck** (Fig. 6.9 and Fig. 6.10)

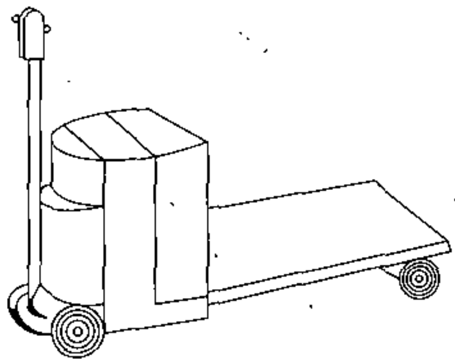


Fig. 6.9. Platform truck (low-lift type).

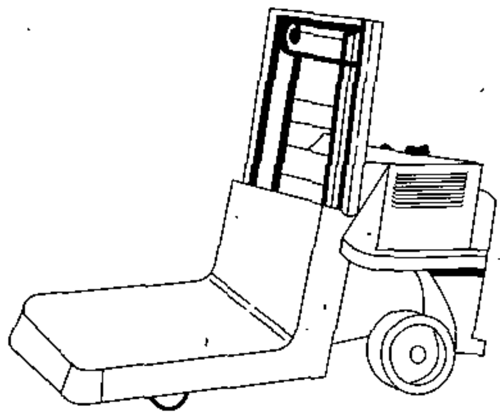


Fig. 6.10. Platform truck (high-lift type).

(*f*) Industrial can.

(*g*) Hand stacker.

(*h*) **Conveyors.** If the path for the flow of material is fixed then the provision of the conveyor at suitable level eliminates a good deal of lifting and lowering of materials. *Conveyors require no stopping or starting but is continuous in operation.*

In these transportation is affected by friction between materials being transported and the belt. These conveyors have the advantage that they largely save labour cost but have disadvantage that they take up considerable space, are relatively fixed and in most cases investment is high.

Conveyors may be used for horizontal, vertical [also known as elevators] or unlined conveyoing of materials.

1. **Belt conveyor.** (Fig. 6.11). Belt conveyor is one of the most common form of material handling system used in mining industries and in construction projects. Heavy *industries* like steel, fertilizer chemical and cement etc., can not function without the belt conveyors. In construction projects the belt conveyors are used for handling the materials in asphalt plants, Crushing and screening plants aggregate mixing plants etc. In coal mining and other mining industries these are used for handling of coal or other raw materials. The belt conveyors are capable of conveying large quantities of material continuously over long distances at a fast speed.

Fig. 6.11. Belt conveyor.

NOTES

For transporting the material for short distance conveyor may be a portable or a fixed unit. When a belt conveyor system is used to transport materials for a considerable distance upto several kilometers in some cases the system consists of a number of flights. Each flight is complete conveyor unit discharging its load into the tail and of the successive unit.

Belts used in the system are costly and perishable item and hence need to be carefully maintained. The belts are generally made of rubber covered over cotton or rayon laid up in piles. The strength of the rubber belt depend on the number of piles. Canvas piles woven wire mesh and steel belts are also used depending upon the strength required for the conveyors to convey various types of materials, their temperature, quantity to be transported etc. Belts are specified by width number, piles and weight of each layer of ply.

Belt conveyors consist of a belt running over drums or pulleys provided at the end and are supported at intervals by a series of rollers known as idlers. These idlers are supported on the conveyor frame. These idlers help to support the conveyors and reduce the sag of the belt and prevent the loose material from spilling.

These three idles are free to move on bearing. Since 1000 to 1200 idlers are provided per kilometer length of the belt, it is important to design, select, and maintain for maximum life and to give best performance. Selection of proper bearings with minimum friction value, standardisation, strict quality control and proper finish/tolerance of shafting is essential. The dust proof bearings packed with lubricant with efficient seals require no further attention for years. The spacing of idlers depend upon the weight of the material handled, if the idlers are widely spaced, the sag between them becomes excessive which will result in wastage of power, increase in belt wear chances for spillage of material due to impact at each idler.

Advantages of Belt Conveyor :

(*i*) It is capable of handling light or heavy, fine or coarse, wet or dry material.

(*ii*) It can handle thousands of tonnes of material. Per hour for several kilometers.

(*iii*) It can handle hot materials upto 160°C or so.

(*iv*) It is lighter in weight and consumes less power.

(*v*) It operates without noise.

(*vi*) It gives a continuous discharge and quality of which can be varied by varying the speed of conveyor belt.

(*vii*) It can carry material horizontal or in an inclination.

(*viii*) It is used for carrying the material over rough country where use of other means is difficult and costly.

2. **Roller Conveyor.** (Fig. 6.12) This is used to transport various shapes of products such as boxes or materials which extend over several rollers. This type consists

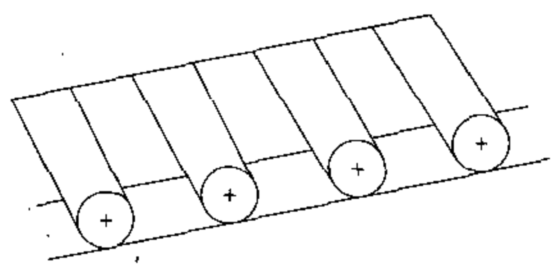


Fig. 6.12. Roller conveyor.

of rollers supported in frames over which materials are allowed to move. They are drawn by power or gravity. These are of different varieties and can move materials in horizontal direction as well as from upper floor to lower floor etc.

NOTES

3. **Chain or Cable Conveyor.** (Fig. 6.13) This is moved by chains or cables in horizontal direction and installed flush with floor or a little above it. This is used for moving barrels and heavy boxes. This is also used for moving grates of big boilers.

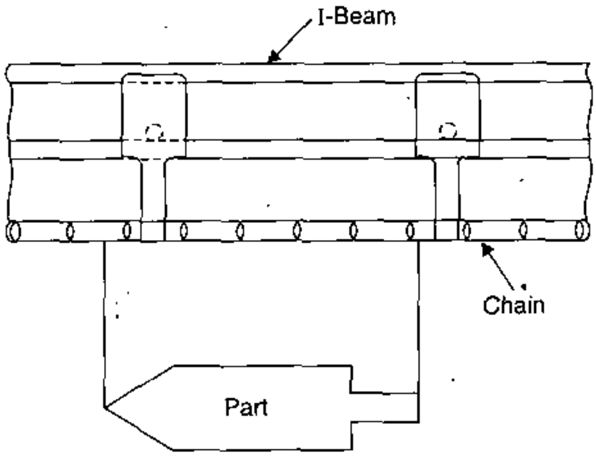


Fig. 6.13. Chain conveyor.

4. **Screw Conveyor.** This type is used for transmitting materials in paste or powder form with the application of rotating screw.

These are driven by a motor from one end and consists of a helix mounted on bearings at the ends and also at intermediate points. This type of conveyors is also dust free by enclosing it the material enters from one end and is carried to the other end by the screwing action. Screw conveyors can also be used for handling pulvarized coal (for feeding into the furnace) or other granular materials.

5. **Elevating Conveyor.** The elevating conveyors are used for transporting dry granul materials. The material that will not stick to the buckets) in the vertical direction with the help of buckets and trays. These are also known as bucket elevating conveyors or bucket elevators and carry the material in buckets to vertical or near vertical positions.

These are either chain bucket elevators in which buckets are attached to one or two chains which move on two end wheels or belt bucket elevators in which buckets are attached to the belt moving on pulleys provided at two ends.

6. **Bucket Conveyor.** (Fig. 6.14) Freely swinging buckets are carried between a pair of parellel endless chains which can follow any path from vertical to horizontal. The buckets are loaded by a specially designed feeder and are tripped or inverted to discharge. The device that causes the bucket to discharge can be set at any point along a horizontal run of the conveyor and can be remotely controlled. By this means material can be delivered into any one of a number of bankers and a materials of different types can be fed into the buckets controlled mixing can be achieved.

NOTES

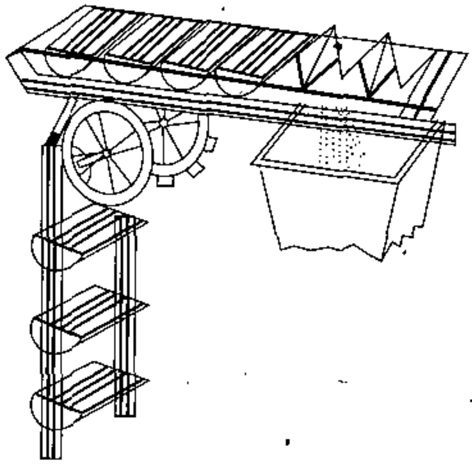


Fig. 6.14. Pivoted bucket conveyor

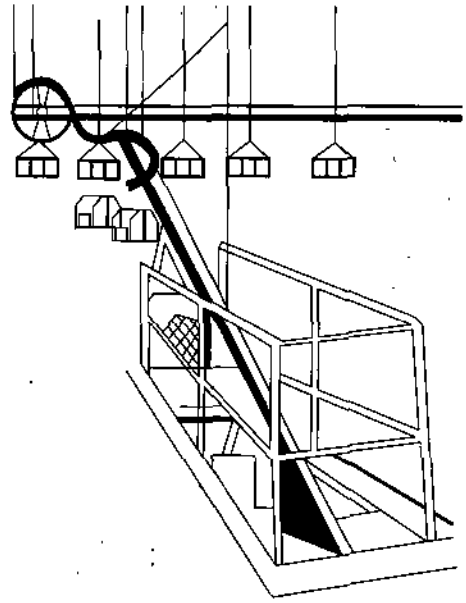


Fig. 6.15. Trolley conveyor.

7. **Trolley conveyor.** (Fig. 6.15) are versable installation capable of moving various loads along completed three dimensional routes through the entire process. In this capacity they fully meet the requirements of modern manufacture for the transfer haulege. In line production is the main sphere of application where trolley conveyors in addition to the function of transportation are used for the performance of meaning processing operations such as for example blast cleaning, strain hardening, pickling impregnating, painting, drying etc.

8. **Flight Conveyor.** Bulk materials may also be moved up steep incline by dragging along a trough with transverse flights pulled by a chain or cable. The angle of climb is limited by the height of the flights and the tendency of materials to fall backward when the incline is too steep.

9. **Pusher bar Conveyor.** (Fig. 6.16) For other materials of larger size, smaller dragging action is accomplished by transverse bars to drag the material up an incline. The carrying surface must be smooth metal or hardwood and the objects so moved must be of regular shape and free of projections and rough surfaces at least on the underside. These bars are generally carried along by two chains powered from sprockets on a common head drive pulley. Pusher bar conveyors normally used for inclined handling can be designed for vertical elevating of uniformly sized containers if provision is made to keep the units from falling off the line by means of an enclosing shield.

10. **Floor Flush tow conveyor (sliding type).** (Fig. 6.17) It is used to move all kinds of loads that have their own carrying mediums, such as wheels, casters or slides running in guides. The connecting medium between conveyor and load is usually a removable link like a chain with hooks, a rigid draw bar, a removable dog to push one or more loads.

11. **Enmasse Conveyor.** The enmass type is an enclosed conveyor with an internal skeleton consisting of a chain or coiled wire materials, of small lump particle size or smaller can be moved economically within this closed column by the principle of the coherence of the mass. This is a movement of one whole mass induced by one

skeletonized or framed flights. It provides dustless movement horizontally at any angle or turning and may also be used where vertical movement is required, volume carried are very large.

NOTES

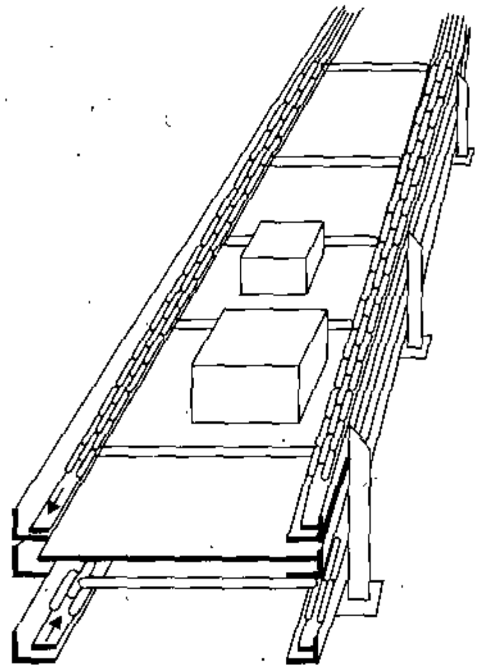


Fig. 6.16. Pusher-bar conveyor.

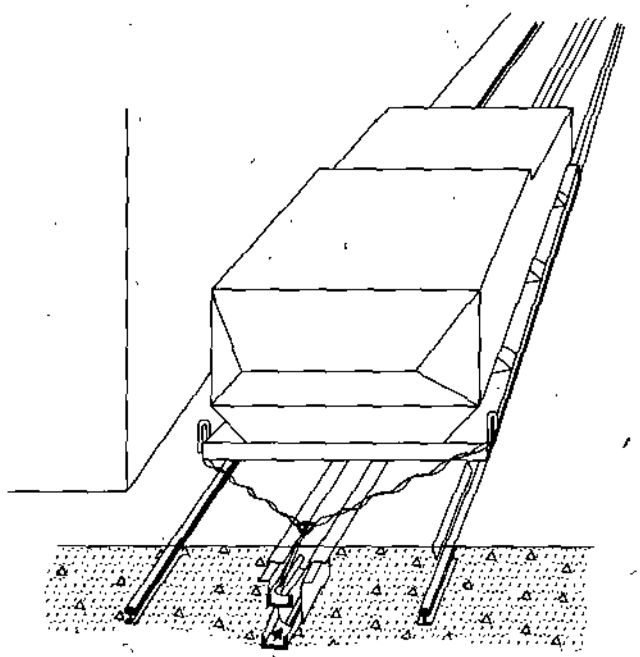


Fig. 6.17. Floor-flush two conveyor (sliding type).

NOTES

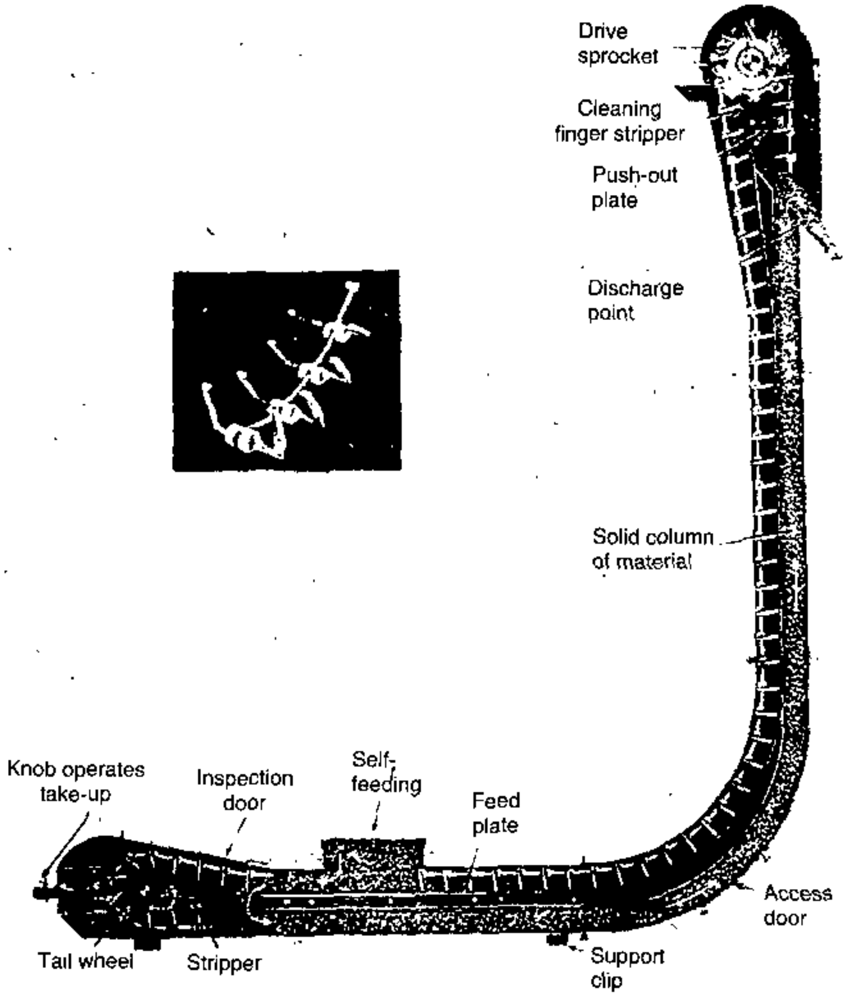


Fig. 6.18. Redler en masse conveyor using skeleton-type flights.

6.15. MATERIALS MOVED LONGER DISTANCE AT IRREGULAR INTERVALS

(*a*) **Monorail Conveyor.** For the intermittent overhead movement of materials where greater distances in the plants are involved. The monorail conveyor with the numerous attachments and controls are available for it, provides a system of handling adapted to a wide variety of uses. For the small shop with limited weights to be lifted, a 7.62 cm, I-beam rail is often adequate for the horizontal movement of the hoist whether operated by hand or by electricity. In larger installations, heavier hoists and electrically powered drives will handle greater loads at considerably more speed and for longer distances where a more intensive system is required. Automatic controls may be set on each drive unit to take its load to any one of a number of different stations and discharge or carry it through a variety of processes. For closer operator control, telpher systems with the operator riding in a cab suspended from the overhead monorail permit the movement of one or a dozen individual carriers along the overhead monorail system. Its use is restricted to fixed line but it handles quite large quantities.

(*b*) **Wire Conveyor.** Multiple strands of wire or cable provide a continuous bearing surface of parts through heat treating and they are adopted to the movement of light weight flat objects.

(*c*) **Portable wheel Conveyor.** This type of conveyor is also made in 3.048 m. lengths and mounted on light adjustable triped stands A.

6.16 VERTICAL PACKAGE CONVEYORS

(*i*) **Arm Conveyor.** The arm conveyor consists of an endless belt or one or more chains or other linkages, which are attached to projecting arms or cars for handling packages or objects. This type of conveyor is frequently installed at an incline to elevated loads and so installed is usually used to elevate round objects such as barrels, kegs, drums etc.

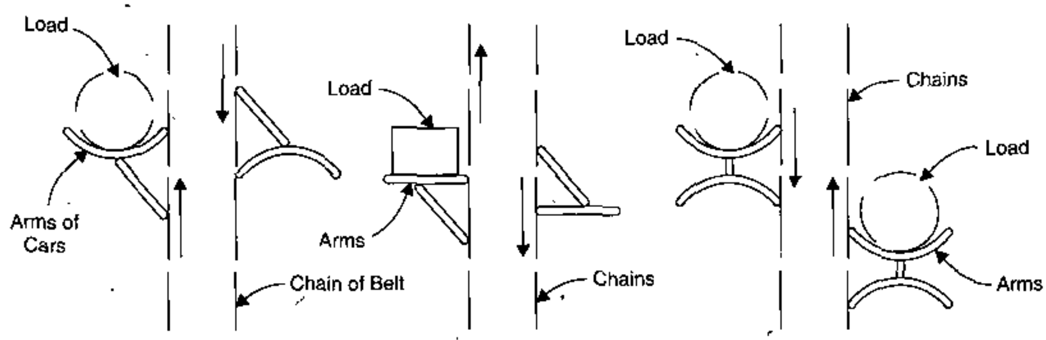


Fig. 6.19. Arm conveyor.

(*ii*) **Vibrating/oscillating Conveyor.** The movement of hot abrasive materials is often accomplished on long metal troughs which advance the material due to its intermittent contact by means of a reciprocating or vibrating action. It is ideal in movement of hot sand and castings, clinkers and chips and turning as well as fine or stringly (not stuky or tacky) materials, coal grannular.

Electromagnetic action is also used to feed small parts into machines in a specifically oriented position without hand sorting or positioning. This has been applied successfully to the feeding of zippers in a specified oriented position, nuts to a tapping m/c at the rate of 290 per minute.

A vibrating conveyor consists of an open trough or pipe, supports 2 and the drive 3. The trough is given a reciprocating motion at an angle to its axis. As the supports are inclined. The trough moves forward as well as upward during the forward stroke, while during the backward stroke it moves backwards and downwards.

Owing to the inertia of the material, the force of friction between the trough and the material during the forward stroke is very large and the material moves forward together with the trough. At the end of the forward stroke the material gets separated from the trough and flies forward by the inertia of motion while the trough recedes back. This process is continuously repeated so that the material moves in successive jumps along the trough instead of sliding. For this reason the trough wear is insignificant in vibrating conveyors. As large amounts of dust is raised with dry materials, pipes are used, instead of troughs with such materials.

The conveyor advance their loads by relatively slow forward strokes and quick return strocks.

NOTES

Vibrating conveyors can be used for horizontal, down hill or uphill (upto 150-200) conveying. Vertical transport of material upwards can be effected by installing such conveyors along a spiral of suitable gradient.

$$\text{Length } \frac{800 \text{ m}}{1510 \text{ m}}, \frac{250 \text{ m}^3/\text{hr}}{1000 \text{ t/hr.}}$$

Advantages of Vibrating Conveyor :

1. Not only does it convey material but during its motion it removes the over-sized and under sized material and also it rejects faulty material. This is achieved by incorporating in the design of transport trough a section which acts as a rejector or a screen.

2. Compact and neat in design.

3. There is reduction in the amount of mechanical moving equipment.

4. Increase efficiency.

Vibrating conveyors are generally used to convey in foundaries, chemical industries, mining, agriculture, glass industry, metal working, metal producing etc.

5. Damage due to abrasive and corrosive materials is greatly reduced. This is because the contact time with tray and load is only very brief as the material is the own upwards during the forward motion and hence the movement of the material is virtually in air to prevent the trays on which the material is. They are generally made of corrosive resistance material such as stainless steel, aluminium. Plastic etc.

6. Food stuff can be conveyed with unmatched cleanliness because of dust tight covers, smooth unobstructed stainless steel and galvanised trough.

Screening or settling devices may be incorporated in the system when vibrating conveyors are used.

The vibrating mechanism may be either electrically or mechanically driver.

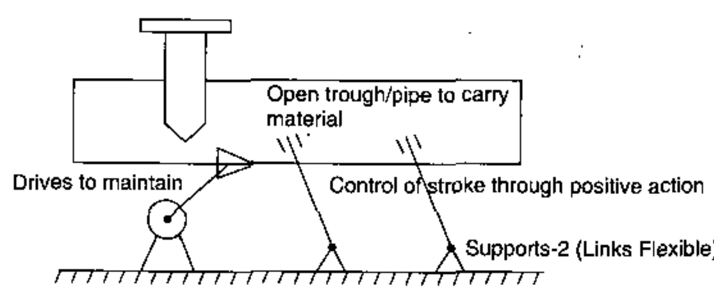


Fig. 6.20. Vibrating conveys

Electrical units have an electromagnetic motor with either alternating current or pulsating direct current passing through the stator. This creates a sense of interrupted magnetic pulls on the armature. The armature is pull through leaf springs which provide a restoring force when the magnetic force is interrupted. A reciprocating action then is provided with each electrical impulse, if mounted to the conveyor bed at an angle. This provides on oscillating action to the bed.

(*iii*) **Heavy Duty Drag Converyor.** Heavy duty drag conveyors are made for handling extremely large lumps. They are similar in form to the standard machines but have wider and deeper troughs, higher and heavier flights and heavier plate of feed end.

NOTES

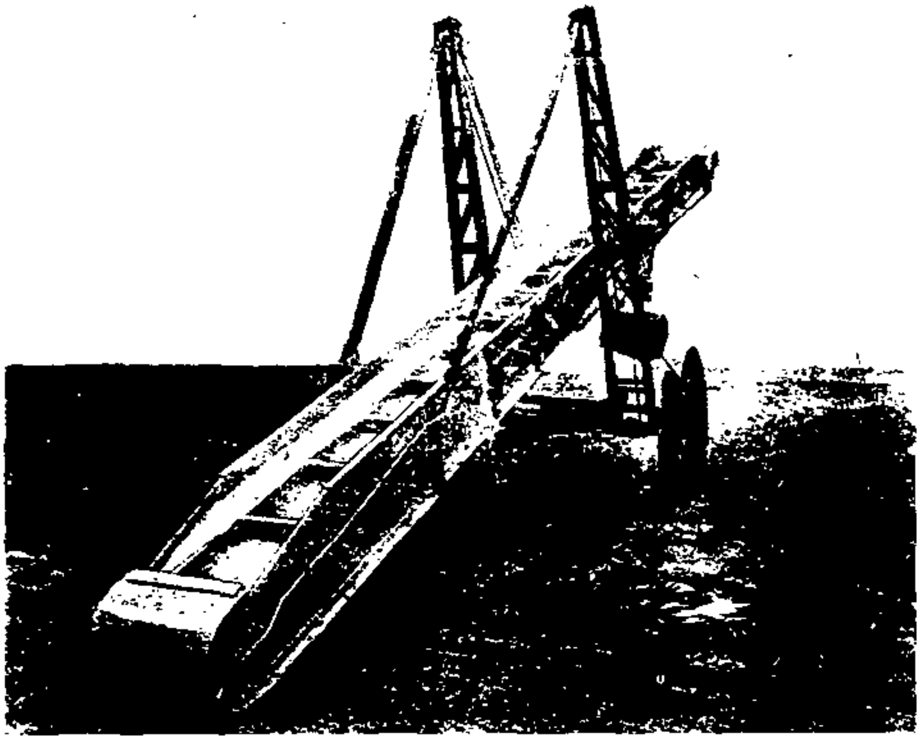


Fig. 6.21. Heavy-duty drag conveyor.

(*iv*) **Pan Feeder Conveyor.** This is one of the more common type in general use. The advantage of arrangement of closely overlapping aprons and end plates is when handling fine materials. Pans are different for different type of carrying arrangement.

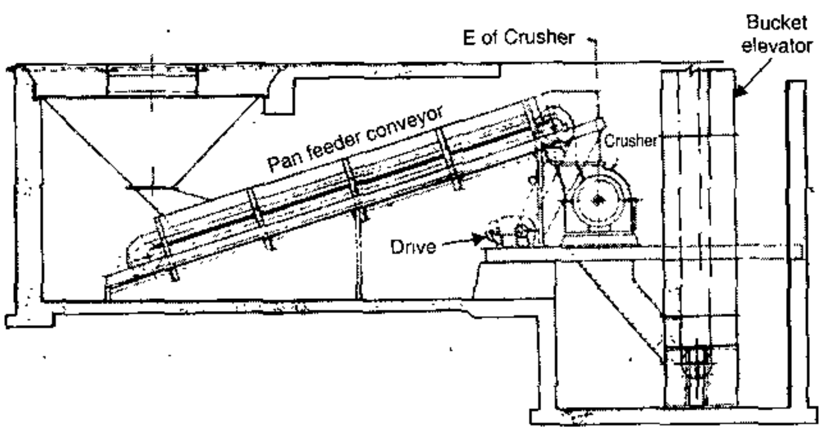


Fig. 6.22. Pan feeder conveyor receiving material from a track hopper and feeding to a crusher.

(*v*) **Pneumatic pipe line Conveyor.** In this type of conveyor the rotary positive air lock feeder will require that material be fed into the transport piping system from a bin or container, and that it can be transported through the piping system to some designated storage or process use point. By feeder we can perform dual function :

(1) Feed the material into piping system.

(2) Maintain a positive air seal between the incoming material and the systems transport air. The ability of the feeder to maintain a positive air lock against the air

pressure required for material conveying generally indicates the application area for this type of equipment.

NOTES

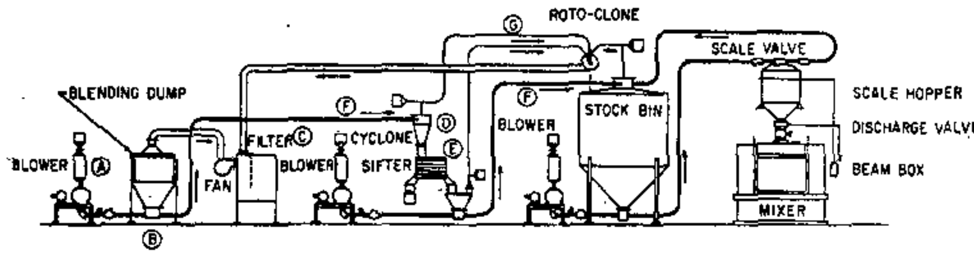


Fig. 6.23. In-plant pressure pneumatic pipeline conveying system.

Air, as a conveying medium has been given increased attention by industry within recent years, and its utility within the materials handling field is being constantly extended. In fact, depending on the material to be conveyed, pneumatic pipe conveying is usually considered and evaluated for all bulk conveying problems along with screw conveyors, bucket elevators, belt conveyors and other types of mechanical conveyors.

Pneumatic conveying piping system in which air flow is produced by applying reduced pressure or partial vacuum at the discharge end are commonly referred to as vacuum or suction conveying systems. Vacuum conveying systems are manufactured by several well known companies, both here and abroad.

Vacuum or suction type of pneumatic pipeline conveying system is perhaps most successfully applied in unloading material from bulk carriers such as box cars, barges and special types of rail or motor truck carriers.

(*vi*) **Cross bar Conveyor.** Consist of endless chains supporting spaced, removable or attached sticks or cross members from which materials are hung or festooned while being processed. It also consist of endless chain consist of cross connected at intervals by bars or rotatable pushers which moves packages or objects along up or down stationary wood, metal or roller conveyor beds, or troughs.

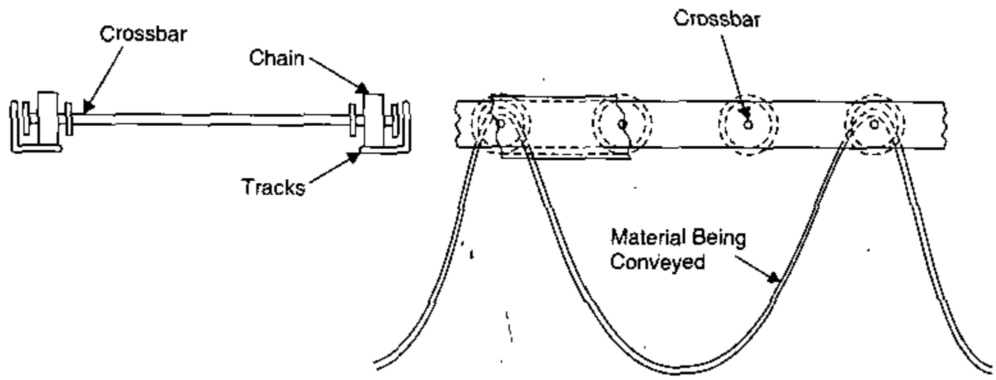


Fig. 6.24. Cross-bar conveyor.

(*vii*) **Slat Conveyor.** Ideally adaptable for storage of blocked loads. The loads or packages can be blocked at will without effecting driving medium, because the free turning rolls can readily revolve under the blocked load. Conveyor can be used successfully with fragile loads.

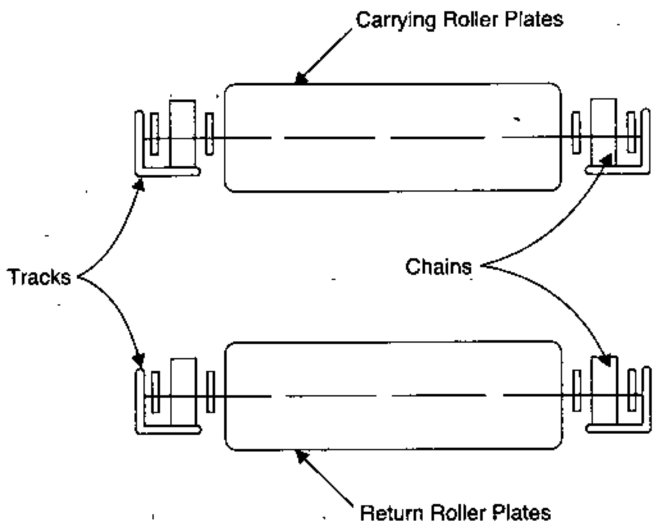


Fig. 6.25. Roller-type slat conveyor.

NOTES

(*viii*) **Overhead tow Conveyor.** The overhead tow conveyor is commonly used for towing or pulling trucks, dollies or cars over a defined path by means of an endless chain with tow hitches, and strung from trolleys running in, or on, a track located above the floor at sufficient elevation to give headroom for cross traffic.

Generally the path of the conveyor is level and is at a uniform distance from the floor of about 2.4 to 2.7 m. This distance allows sufficient headroom for manual movement of materials by means of hand trucks and gas or electric trucks.

The overhead tow conveyor where tonnage warrants the initial cost, is probably the most economical way in which to transport material in freight terminals and transfer stations, warehouses, port depots, and the like.

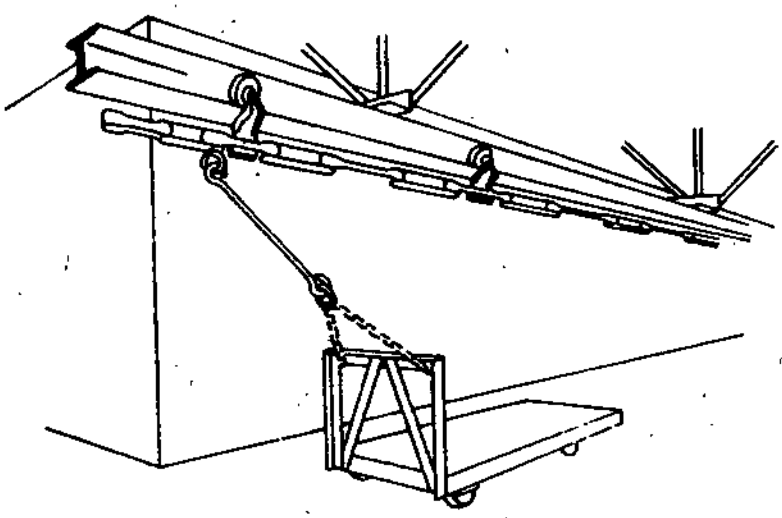


Fig. 6.26. Typical overhead tow conveyor.

Incoming materials may be easily delivered to the stocking areas or directly transferred or dispatched to outgoing stations.

6.17. LIFTING AND LOWERING DEVICES ELEVATOR

NOTES

A machine or an arrangement to transport materials, freight, personnel.

Types of elevators :

Electric elevator, Electrohydraulic motors.

(*i*) **Drum Type Freight Elevators.** Light duty freight elevators may be of drum type. It consists of a cylinder or a drum around which the rope is firmly attached, on the other end rope is fastened to the elevator car. An electric motor turns the drum through reduction gearing, usually a worm and gear. When drum turns it winds up the rope raising the car. A counterweight equal to car weight and one third for duty is produced to lift the car by a motor of given horse power.

Traction Type Freight Elevators. To overcome the limitations of drum type elevators it was developed. It consists of a car connected to a counterweight by cables or ropes running over a driving sheave. The car is attached to one end of set of ropes and counter weight to the other end. Traction between ropes and sheaves raises and lowers the elevator.

Car and counterweight each move on their own set of rails. The motor that drivers the sheave, controls of motor, safety devices are also installed.

Weight of rise is not limited by size of sheave. Should the motor continue to run and permit either car or counterweight to strike bottom, traction would be lost, preventing either car or weight to hit structure.

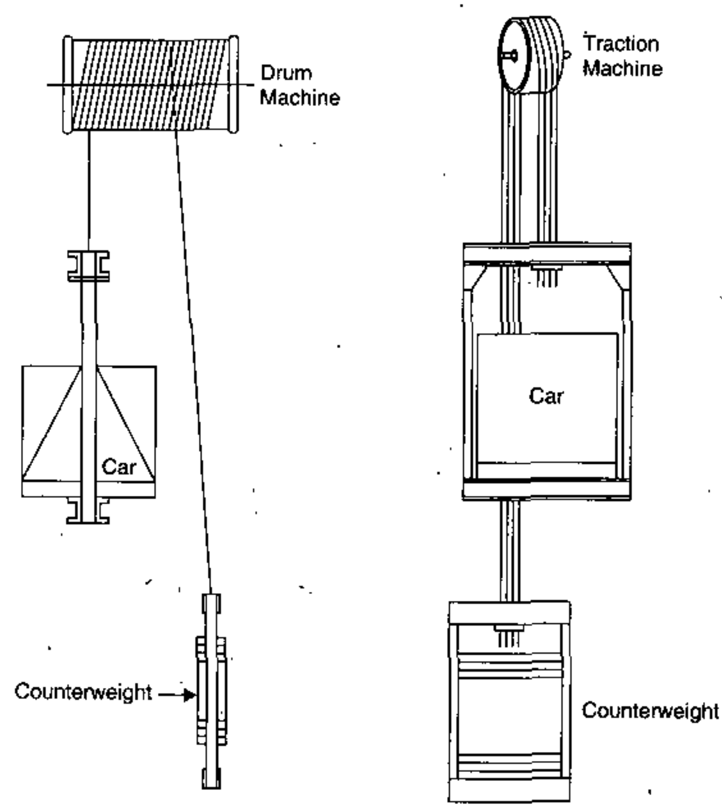


Fig. 6.27. Elements of a drum-type freight elevator.

Fig. 6.28. Elements of a traction-type freight elevator.

Beneath both the car and weight buffers are placed to absorb impact in case they over travel lower terminal. At the top of hoistway is a governer which slows down the driving motor if the elevator overspeeds and sets the safety mechanism to halt the car. Located with the machine in the room are controller, selector and motor generator.

(*ii*) **Bucket Elevators.** Installations for the conveying of materials vertically or close to that are termed bucket elevators. Referring to inclined bucket elevators have that carrying run supported by rollers 6 or guides 7. The return run has a unsupported sag or is provided with some means of support. Vertical bucket elevators are the preferred arrangement dispensing with casings of the awkword type of construction (as this is the case with inclined installations) and angle tracks for the return run.

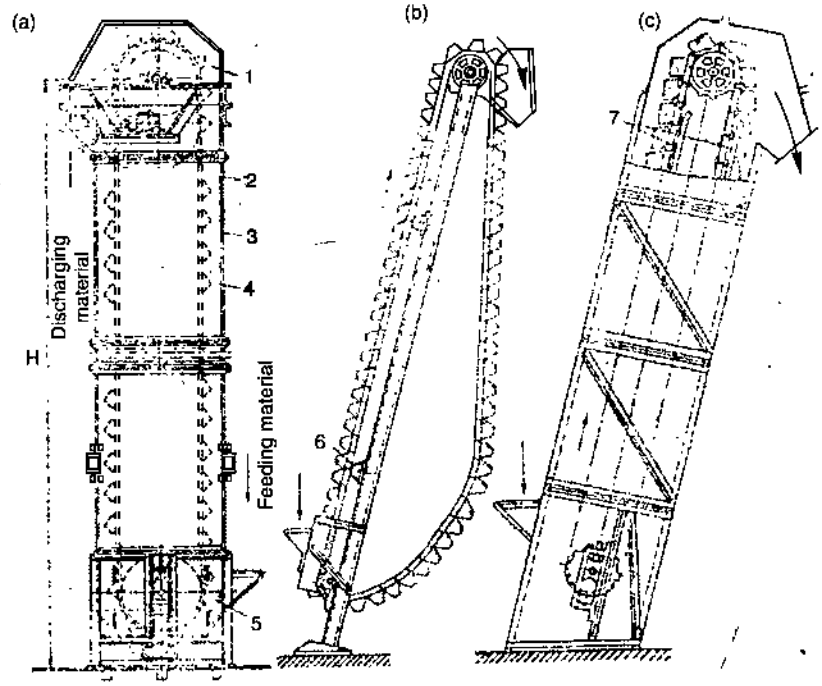


Fig. 6.29. Bucket elevators.
(*a*) vertical elevator, (*b*) inclined elevator with unsupported sag in return run ; (*c*) inclined elevator with supported return run ; **1**—head wheel and drive ; 2—chain or belt ; 3—chasing ; 4—bucket ; 5—boot with take-up ; 6—rollers ; 7. guides.

The driving traction element is a chain or a belt of the kind used on belt conveyors. The choice depends on the desired performance of the elevator and the type of the load intended for handling. So, free-following material can be conveniently handled with belts affording speeds of up to 3.5 m/s. High-lift installations for the conveying of coarsely broken or hot materials given preference to chains, the speed being commonly not higher than 1.25 m/s.

6.18. CRANES

Cranes have wide application in construction, shipping and in industry. These are used for lifting the loads (may be construction materials, loose materials, packages, containers, finished and semifinished products in industries etc.) and placing them at desired place. For this purpose cranes have namely three motions hoisting, derricking and slewing. The cranes are generally electrically operated, diesel operated or may have diesel electric drive.

NOTES

NOTES

Fixed Crane

1. **Fixed Crane.** Among the almost numberless kinds of materials handling equipment used throughout the range of manufacturing and transportation activities, fixed loading and unloading cranes and towers renders a most important economic service. If it were not for such equipment, the vast amount of manpower needed to load and unload cargo would raise the cost of such operations to an almost prohibitive level, placing a most burden some to it on all industry and transportation.

(*a*) **Revolving Pillar Jib Crane.** Revolving pillar jib cranes, base mounted for 360° complete rotation, consists of three essential parts : The jib, the coloumn with a welded base and the head.

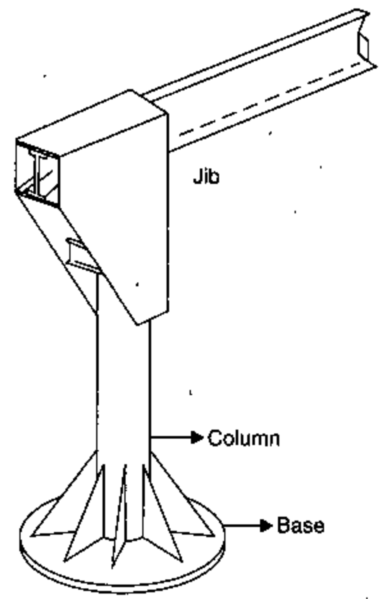


Fig. 6.30. Revolving Pillar Jib Crane

The jib is constructed of a standard I-beam section, high carbon, hydraulically straightened, from which trolley and hoist are suspended.

The coloumn consists of structural pipe varrying india from diameter 20 cm to 60 cm in depending upon capacity.

(*b*) **Swinging Pillar Jib Crane.** The swining pillar jib crane, base mounted, consists of a column of structural pipe ranging in diameter from 20 to 60 cm and weight from 30 to 300 kg/m. the fitting supports are welded to the column. The tie rod and boom fittings are then fastened to the fitting supports. The boom is a structural I-Beam section and has end stops at both ends to prevent over travel to the trolley. Double tie rods are attached to the bottom and top fittings to allow accurate levelling of boom in relation to the column. The fittings carry bronze bearings mounted in steel castings with alemite fittings for proper lubrications. The base consists of steel plate which may be in diameter from 75 to 150 cm. It is welded to the column and is supported by gusset plate which are also welded to the column and base.

The base is then bolted to the foundation by means of anchor bolts. Two types of base plates are available.

(*c*) **Fixed Gantry Crane.** Cranes of this types are the same as the travelling gantry bridge cranes, except that the supporting a frames are anchored to fixed foundation instead of being mounted on wheels and travelling on runways.

Either one or both ends of the bridge griders may be cantilevered beyond its supporting a frame. These cranes are used only where the working area to be served is directly under the crane and hoisting and trolley travel operations are all that is required, as in a rail road freight yard. Here they are used for loading or unloading heavy or bulky freight and for transferring it from a car to a truck or from one car to another for rest reshipment.

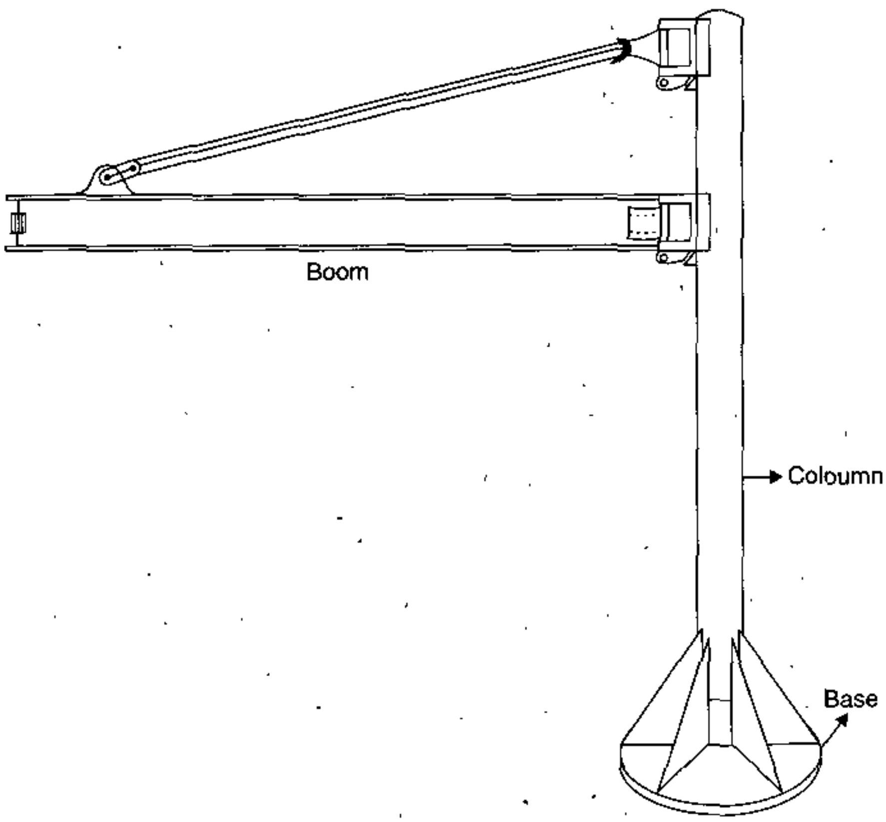


Fig. 6.31. *Swinging pillar jib crane—base-mounted.*

Either one or both the cantilevered bridge grider extensions may be hinged, which is desirable when crane is located on a pier or dock and is used for lowering and unloading ships. These cranes are equipped with the same type of trolleys as overhead travelling bridges cranes and travelling gantry bridge cranes.

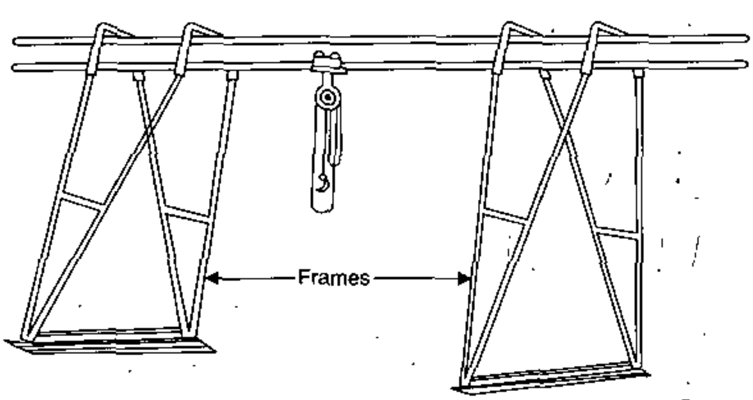


Fig. 6.32. Gantry crane.

NOTES

2. **Mobile Crane.** Included in this group are a variety of hoisting mechanism mounted on self propelled automative vehicles. These mobile cranes can be used to lift and transport materials in, into and out of plants, in yards and to and from transportation vehicles and terminals. These versatile cranes can readily be adapted to the handling of many objects, but there are certain well defined conditions where their application is especially indicated :

1. Where the load must be reached for, obstructions being so placed that the handling equipment must remain at a distance.
2. For the unloading, from ground level, of gondola cars, box cars, trucks and tractors.
3. For handling irregularly shaped objects not readily palletized.
4. For handling loose bulk material in containers or with bucket or magnet.

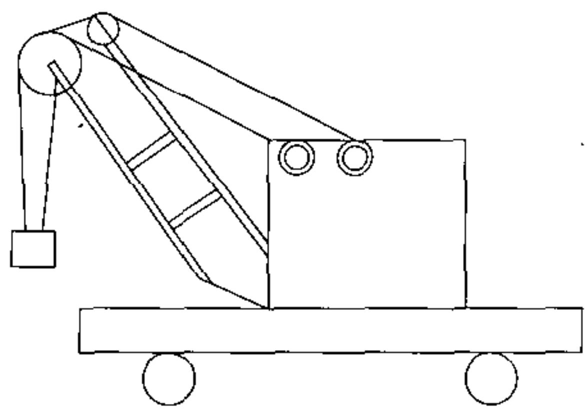


Fig. 6.33. Mobile crane.

Although the several classifications of wheeled cranes are widely different in appearance, design and construction, they all have one characteristic in common that the load is handled on a hook.

Truck and Wagon Crane. Wheeled cranes are mounted on solid or pneumatic rubber tires, or on steel rim wheels. Steel rim wheels are obsolete except for light, simple cranes. Capacities vary from a fraction of a tonne to approximately 50 tonne. Basic crane rating is maximum allowable lift with the shortest boom at its minimum operating radius. Rated capacities are generally 85% of tipping loads. Many wheeled cranes are adapted for use as shovels, back hoes, and draglines for handing bulk material.

(*a*) **Full swing turn table truck crane with revolving (Controls).** This class covers the usual commercial types of truck cranes. The crane consists of three major component—The revolving turntable, the carrier mounting and the boom. The revolving turn table consists of a bed plate which supports the turn table power plant on 2 engine m/c, the mechanism for hoisting, swing and boom luffing, and the controls. The bed plate also includes an A frame or similar structure for boom outer end support, and hinge pins for boom inner-end support.

3. **Portable Floor Crane.** Non self propelled portable floor cranes are in general used in m/c shops, plant assembly departments, out door yard service, and warehouses, at transportation terminals, and in gargaes. They are frequently employed in shipping and receiving departments for unloading incoming raw material, large and heavy cases, lumber, etc., and loading outgoing shipments. They are likewise employed to supplement over head travelling cranes and other power operated equipment. In many small manufacturing plants, they are aside from hoists and other local service equipment—the only kind of materials handling equipment in use.

NOTES

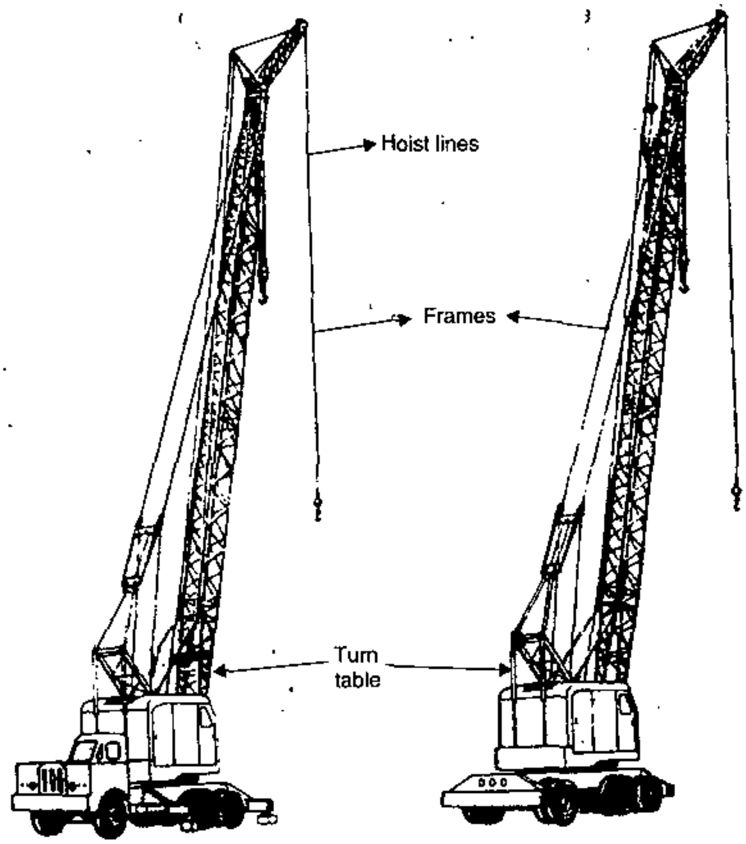


Fig. 6.34. Truck and wagon crane.

In selecting a portable floor crane, it is frequently necessary to give first consideration to the height of ceiling and door ways in the location where the crane is to be used. The over-all height of crane and the distance it will lift from floor level should then be considered, in addition to the crane's lifting capacity.

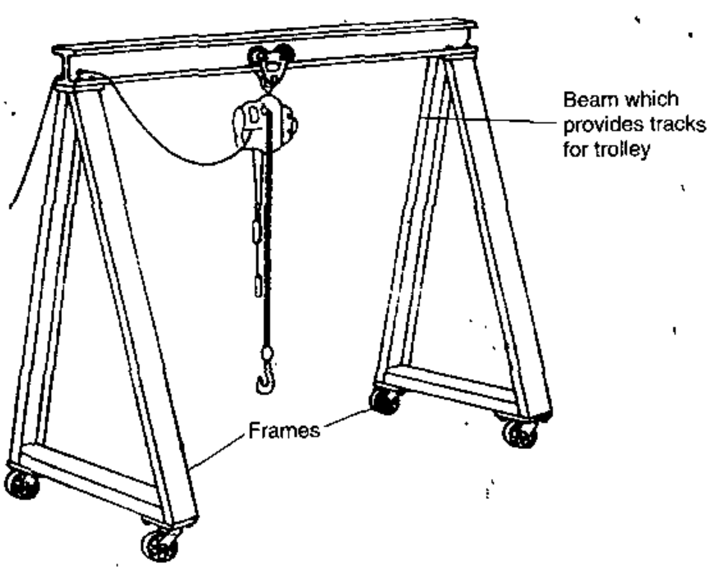


Fig. 6.35. Portable gantry crane.

NOTES

Portable Gantry Floor Crane. Portable gantry cranes are generally available in one and two ton capacity. The gantry cranes are of two A frames, jabricated of structural steel or pipes, connected by a beam providing track for a trolley.

The frames are usually of welded construction for permanent shop floor use and can be equipped with wheels. Such cranes point; and permits the load to be lowered by reversing the crank. It provides accuracy of control and is to be preferred for many applications. Portable shop cranes are very handy tools in gargens, assembly departments, and machine shops, for moving motors, in engines, casting etc., into and out of m/c tools, or dies into and out of punch presses.

4. **Floating Crane and Derrick.** Floating cranes and derricks consists of hulls or pontoons on which are mounted some form of unit-load-or bulk material-handling equipment similar in function, arrangement and detail to that used on land. In some cases, the installations are very elaborate and have no similarity to land equipment. They furnish a means for handling material on, around and from the water to locations in acussible to other equipments. In the field of heavy lifting equipment they furnish a mobility not readily available in any other class of portable cranes. Floating cranes and derricks are used for salvage work, harbour clearing dredgings, excavating, pipe laying along shore and off shore construction, ship servicing, and ship repairs and for package and bulk cargo loading or discharging. They may be equipped with hooks, buckets, grabs, pile leads, or any device needed for special operations capacity varies from the smallest to as large as 800 tonnes.

The hull may be single pontoon of wood or steel, or may consists of number of smaller pontoons of such a size as will permit disassembly of the floating cranes for shipment by rail to land-locked water. This disassembly feature is usually confined by floating cranes of smaller capacity, up to perhaps 50 tonnes of maximum.

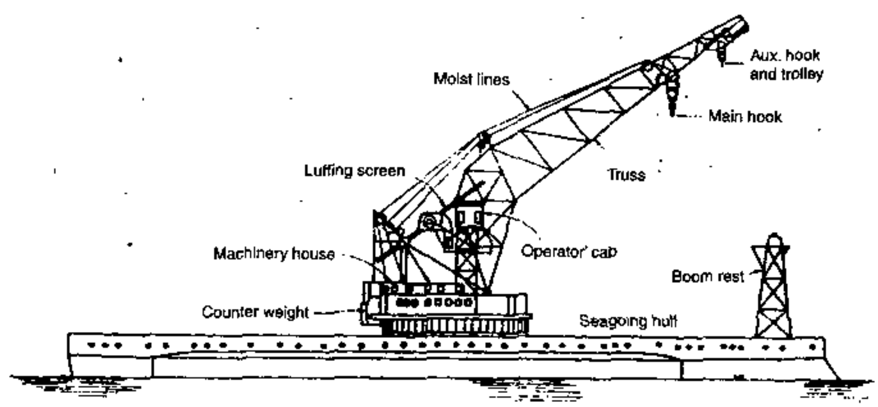


Fig. 6.36. Crane ship *Kearsarge*—capacity, 250 gross tonnes.

Hulls may be arranged for towing, or may be self propelled and equipped with rudders. Self propelled cranes, except for crane ships are usually of slow speed, primarily for manner very.

NOTES

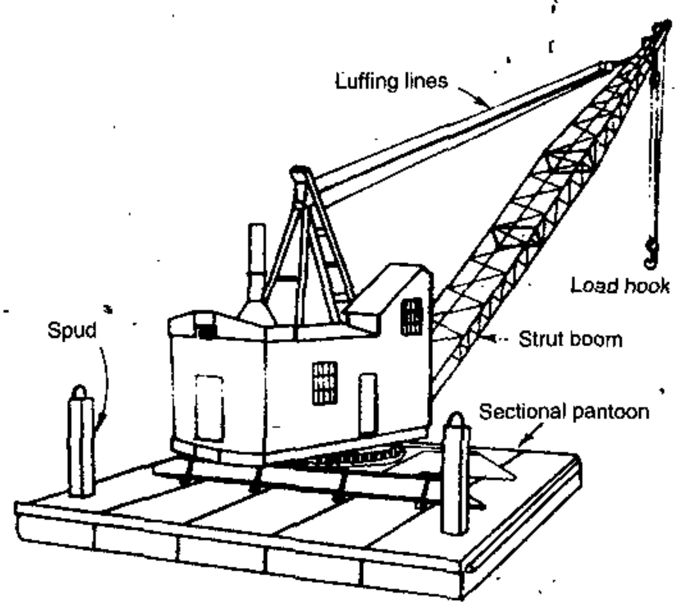


Fig. 6.37. Full-revolving floating crane with rope-luffed strut boom.

Guyed Derrick. The guyed derricks consists of a rotating mast and boom, the *mast being vertical and supported at its upper end by a number of fixed guyed wire.*

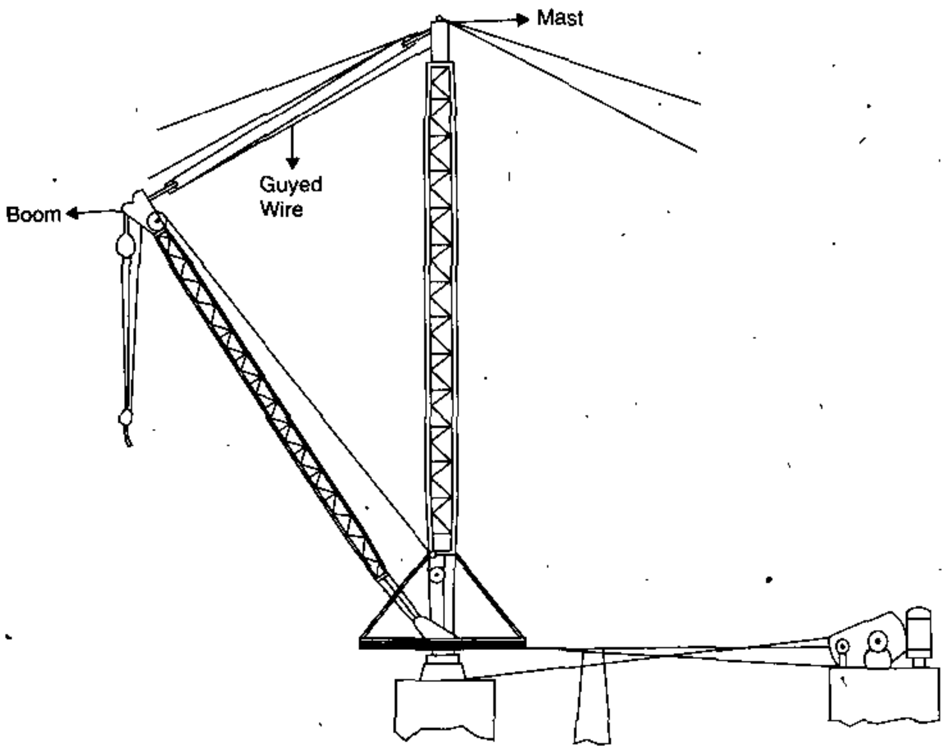


Fig. 6.38. Guyed derrick.

It is supported at its lower end by a ball and socket or antifriction bearing fitting. The boom has rope supported at its outer end and pinned to lower portion of the mast at its inner end. A bull wheel is attached to the lower end of the mast, with sway

NOTES

rods running to each side of the boom, for swinging derrick. Ropes are led to an operating winch through sheaves at the base of the derrick. The bull wheel ropes are tied through guide sheaves to an independent swinger or a swinger attached to the winch.

5. **Travelling Cantilever Wall Crane** which are arranged to travel over tracks secured to a side wall of the building. To obtain a controlled reach, the crane is provided with a trolley or an electric hoist capable of moving along a horizontal jib. In some installations, the jib itself can pivot about a vertical axis, simplifying thus the crane control. Cranes of this kind provide coverage for all the floor area extending along the track and are employed in assembly shops and machine tool shops as a means of transferring the work from station to station.

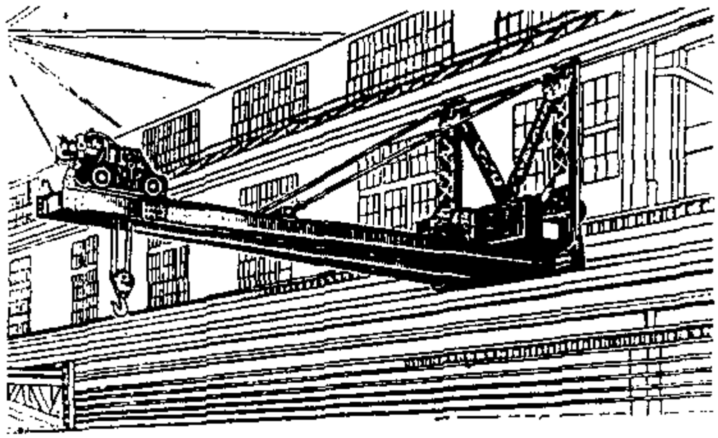


Fig. 6.39. Travelling cantilever wall crane.

6. **Electric Overhead Bridge Crane.** This consists essentially of a bridge 11 travelling on wheels 3 fitted to end carriages 4 and supported by tracks rails 2 which,

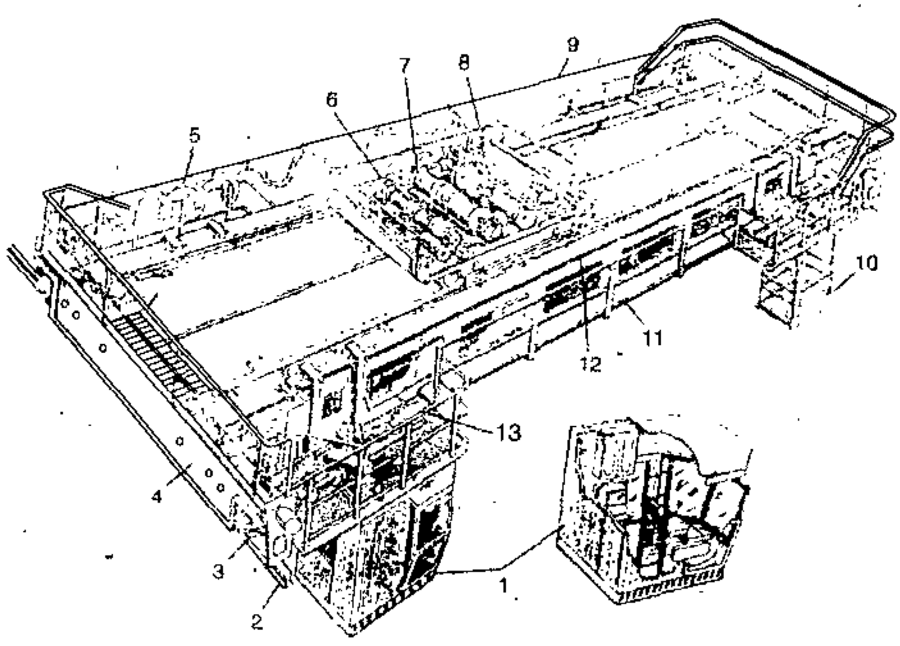


Fig. 6.40. Electric overhead bridge crane.

in their turn, are fixed to a rail supports provided either at the top of the shop walls or columns. A trolley or crab 8 equipped with a hoisting mechanism 7 which hoists or lowers a hook or grip of some kind travels along the top flanges of the bridge girders (in some installations the trolley is arranged to travel over the bottom flanges).

NOTES

Depending on the purpose the crane is intended to serve, the trolley can be fitted with one hoist or it can carry two hoists of different kind, one of them referred to as the main 7 and the other as the auxiliary hoist 6 of lower capacity. A travel mechanism 13 imparting motion to the bridge is installed directly on it and a cross traverse mechanism 12 is fitted to the trolley. All crane motions are controlled from a cab 1 attached to the bridge.

The power to drive the motors is commonly supplied over down-shop conductor rails which, as a rule, are rolled angles attached to walls of the building. Shoe collectors attached to the bridge slide along the conductor rails when the bridge is in motion. A special platform 10 is provided on the crane for the maintenance of conductor rails.

Current is applied to the trolley and hoist motors by way of cross-crane wiring made of round or angle bars. To dispense with support brackets commonly provided along toeboards topping the main girder, in recent designs of overhead bridge cranes the power is supplied over a flexible cable 5 suspended from a catenary wire 9 stretched between two brackets fitted next to the end carriages. This arrangement enables the flexible cable to coil when the trolley is hard over and to stretch (with some amount of slack) when the trolley arrives at the opposite end. The use of a flexible power cable has simplified crane construction, improved operational reliability and reduced the mass of the crane, the latter factor being attributed to the elimination of brackets and toeboards.

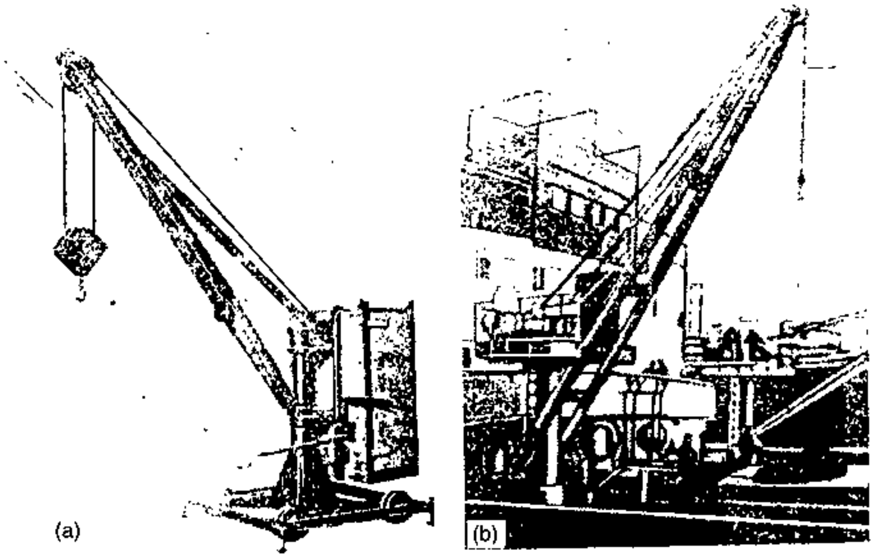


Fig. 6.41. Crane derricks

(*a*) permanent-reach type ; (*b*) controllable-reach type

NOTES

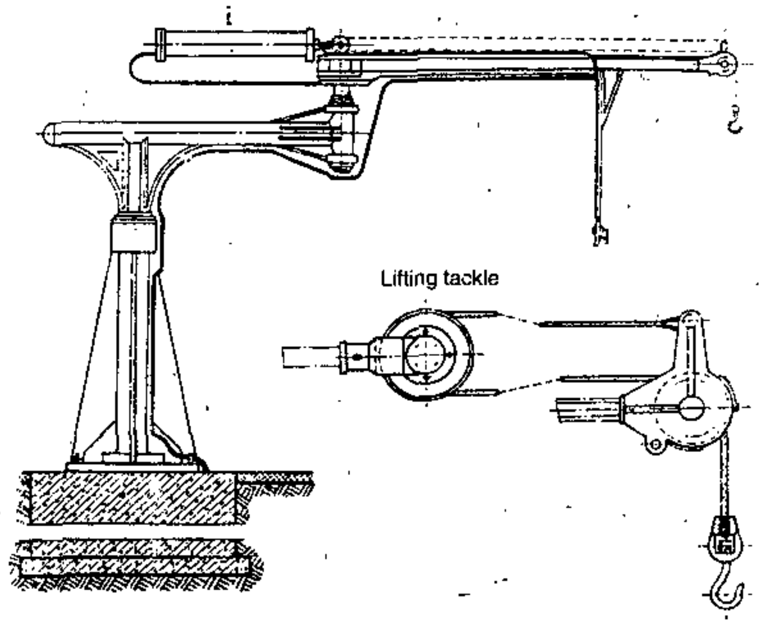


Fig. 6.42. Pillar-mounted revolving crane with articulated boom.

The trolley of a 20.5-tonne capacity overhead bridge crane is accommodated on the trolley frame 11 are the main and auxiliary hoists along with the cross-traverse mechanism. The main hoist consists of an electric motor 9 linked to a reducer 19 by means of a cross-shaft. The coupling half connecting the input shaft of the reducer 19 to the cross-shaft serves as the pulley of a block brake 1 fitted with an electro-hydraulic release. The reducer output shaft is connected to a drum 10 with the aid of a jaw coupling. The bearings of the upper blocks 3 top the frame and so do compensating sheaves 2, this arrangement facilitating maintenance and adding up the lift. A limit switch 12 of the screw type provided for hoisting breaks the supply circuit when the bottom block reaches its topmost or lowermost position. The auxiliary hoist is of the same setup. Comprising an electric motor 15 a reducer 18 a drum 17 and a limit switch 13. Both hoists are equipped with hook blocks main hoist and auxiliary point 16.

7. **Revolving Crane**, both fixed and travelling. The travelling revolving crane is mounted either on wheels which enable it to be moved to the site unloaded and then installed in the working position by means of outriggers or on flat cars travelling over shop floor track. The fixed revolving crane of the pillar-mounted kind has a permanent boom reach, *i.e.*, the distance between the load's centre of gravity and the axis about which the boom can swing remains always unchanged. It is referred to as the *crane derrick*. Cranes of this type can lift up the load and transfer it to any point of a circle with the radius equal to the reach, being thus suitable for the loading of railroad flat cars and lorries, for handling workpieces at machine tool shops, for construction site work, etc.

When there is a need to extend crane coverage, use is made of crane derricks with a controllable reach capable of providing floor coverage inside an area bounded by two circles whose radii are the minimum and maximum reaches, respectively. Such derricks are used in numerous industrial applications. One is exemplified in Fig. 6.43 which illustrates a cargo derrick used for handling cargo on board the ship. It will be noted that the reach is controlled by lifting the boom which is pivotally attached to the rotatable part of the crane. The derrick jib apart from swinging about the pillar axis, is provided with a centralloy-located pivotal joint, enabling the pivoting of a portion of the jib in the horizontal plane so as to change the reach. In the self-swinging crane derrick of the reach is changed form L_1 to L with the aid of a trolley travelling along the jib. Employed as the forge crane and in load-handling operations, this derrick features a swinging jib rotating about a pillar which tops a stationary tower of latticed construction. The derrick is equipped with three mechanisms : a hoisting mechanism 1, a swinging mechanism 2 and a trolley cross-traverse mechanism 3. The angle through which the jib can swing so as to meet certain service requirements is controlled by limit switches fitted to the top platform. Derricks of this type are widely used in machine tool shops as work positioners. When the load to be handled is light, they use an electric hoist pushed along the jib by hand or are fitted with a cross-traverse electric drive.

NOTES

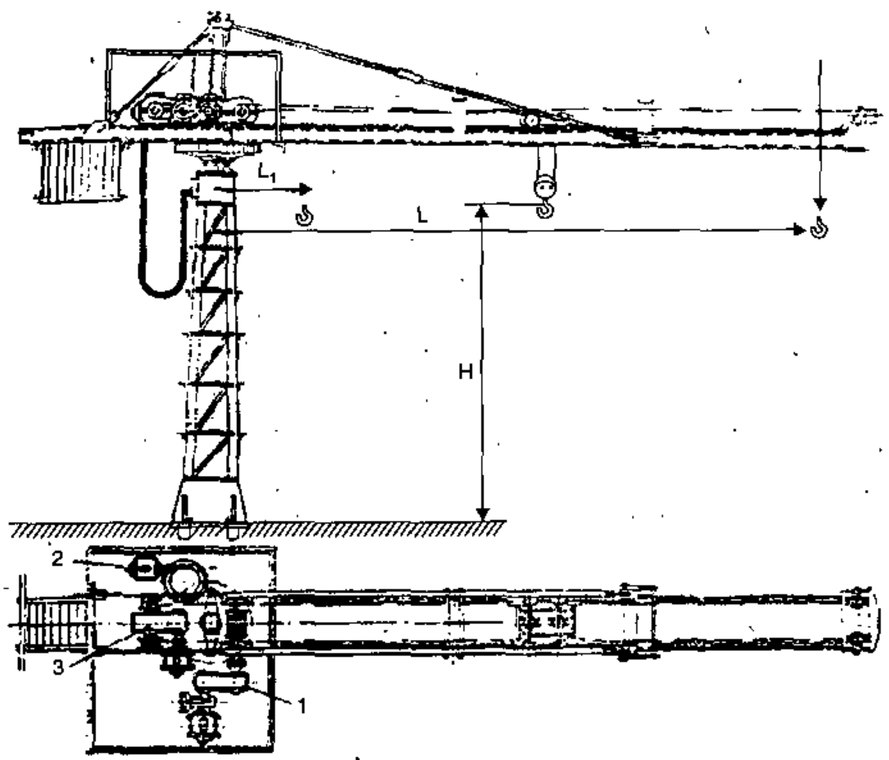


Fig. 6.43. Pillar-mounted crane with reach controlled by a rope-operated trolley.

8. **Tower crane** used at construction sites come in a variety of configurations which are all arranged to travel outside the walls of the building erected. The reach is changed by displacing the trolley along a single-rail track attached to the crane jib by luffing the jib in the vertical plane the tower crane incorporates live rollers or trucks 1 and a turntable 2 which enables a tower 4 to rotate integrally with a jib 5 about the vertical axis. The live rollers or trucks and the turntable are interlinked by some means of support and rotation. Accommodated on the turntable are a hoisting mechanism 9, a swinging mechanism 10, a mechanism 8 serving to lift and fold the jib into the transport position, a counterweight 7, and a lower operator's cab 3. The upper operator's cab 6 is attached to the crane head. The tubular crane, used in erecting buildings ten to twelve stories high, provides for a hoisting height of 42 m and a reach ranging between 10 and 20 m. The moment of load of this crane is 1600 kN m.

NOTES

9. **Crawler, Truck and Railroad Crane**

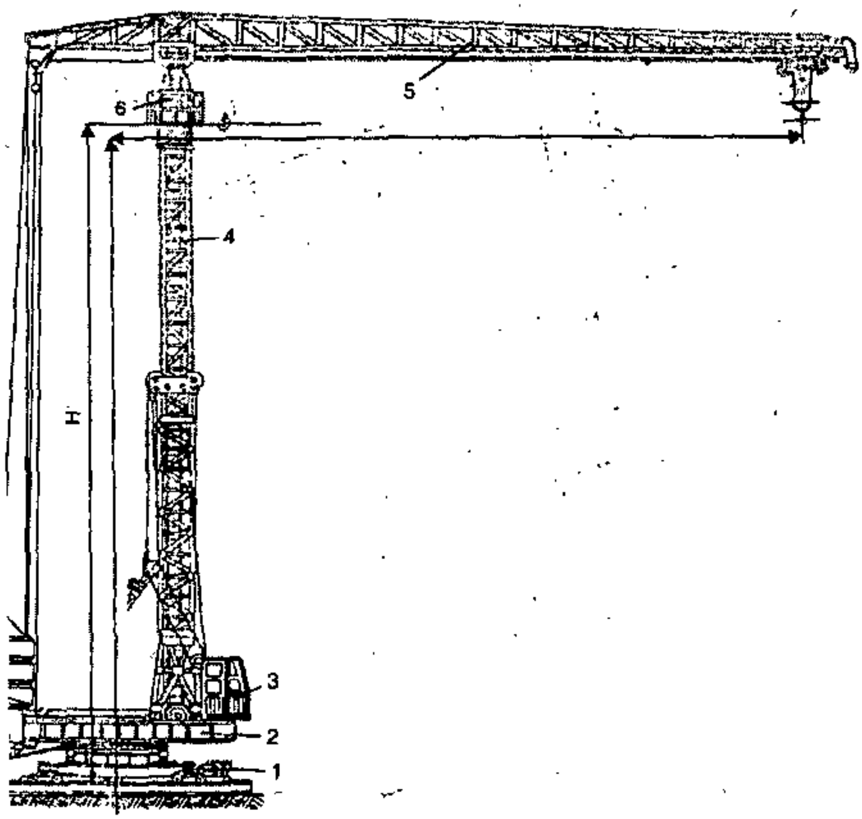


Fig. 6.44. Telescopic tower crane.

Crawler cranes manufactured have a capacity of up to 50 tonnes. The crawler mounting represents a frame supported by tracklaying assemblies which obtain the drive from an engine mounted on a rotating part of the crane. Since the travelling speed of the crawler crane is never exceeding 6 km/h, special tractor-drawn trailers are used to deliver crawler cranes over long distances. Tracks permit operation on ground of various hardness and density.

Truck cranes are mounted on chassis of standard design, on heavy-duty chassis (when the capacity is up to 7.5 tonnes) or on special purpose chassis with tired wheels.

Truck cranes are classed into *general-purpose cranes* adapted to operate with the hook only, *dual-purpose cranes* using both the hook and grab bucket, and *multi-purpose cranes* which can operate with any load-handling or earth-moving attachment.

Hydraulically-operated truck crane mounted on a standard chassis of the truck and fitted with a standard jib or one of the lengthened type. Consequently, its capacity is 6.3 tonnes at a 3-metre reach or 0.615 tonne at a 10.8-metre reach. The speed of lifting and lowering the load ranges between 2 and 12 m/min and the pressure in the hydraulic system is maintained at 100 daN/cm^2 (9.81 × 10^6 Pa). The crane turntable can be swung at the rate of 3 rev/min, and the controls are of the revolving type, *i.e.*, arranged on the turntable 6. A hydraulic pump 10 obtains the drive from the truck gearbox through a double-reduction distribution box 11. The crane employs hydraulic cylinders as linear actuators and hydraulic motors as rotary ones.

NOTES

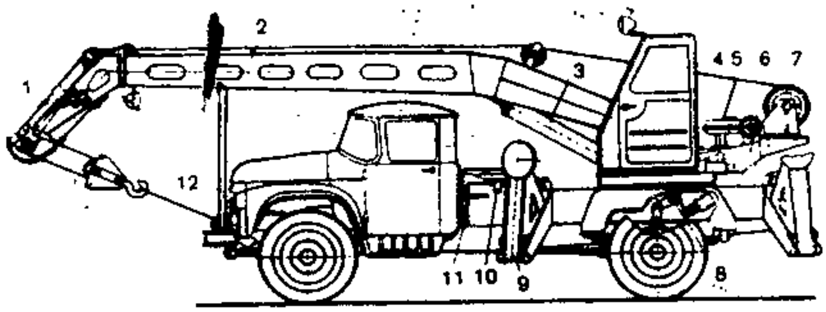


Fig. 6.45. Hydraulically-operated truck crane.

10. **Ship Building Travelling Gantry Crane**

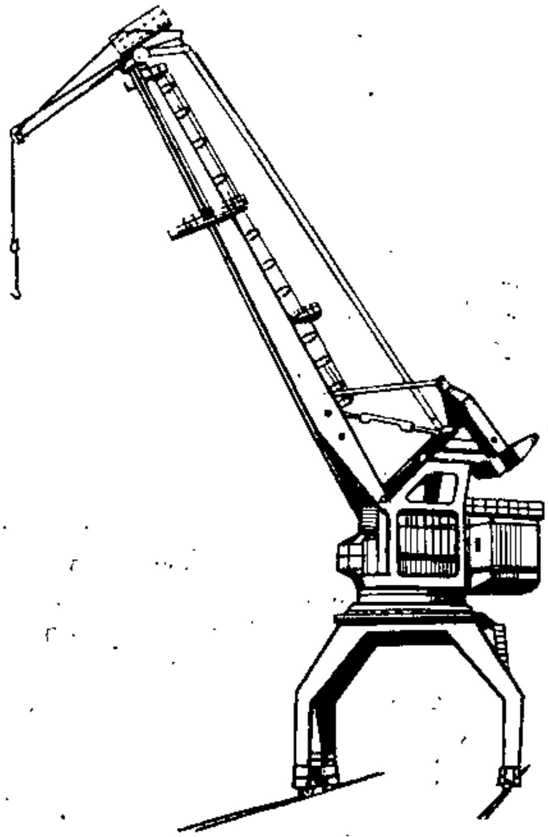


Fig. 6.46. Shipbuilding travelling gantry crane.

6.19. AERIAL TRANSPORT

Aerial rope way is generally used for transporting material end passenger traffic in mountaneous areas. Rope way and cable way are very cheap in mountains and used as aerial transport, whereas cable way is a single span over head conveying system, rope way having two or more spans. The rope ways are becoming very popular in the construction of irrigation, power projects, mining etc.

NOTES

(*a*) **Cable Ways.** (Fig. 6.47). In cable way while traversing the load can be lowered or raised at any point. This is very useful in elevation work in dams, work pits, quarries etc. where loads are hoisted and moved horizontally. These are also used for transporting and then placing the concrete in concrete structure.

Storage and production areas of considerable extent are served by tautline cableways which also find application at building sites. The tautline cableway consists of two towers 1 and 7 suspended between which is a track cable 3 of the locked-coil construction serving as a bridge structure. A carriage 2 with a handling attachment travels on the track cable with the aid of a haul rope 5 and a winch 8. The haul rope is reeved through sheaves provided at both towers and passes over a drum of the winch 8, forming a closed loop attached to which is the carriage. For hoisting and lowering the load at any point along the span, use is made of a hoisting rope 6 attached to the drum of a hoisting winch 9 with one end. The other end of the rope is fastened to the carriage or the tower free of the winch. To minimize the slack in the haul and hoisting ropes, use is made of rope hangers 4.

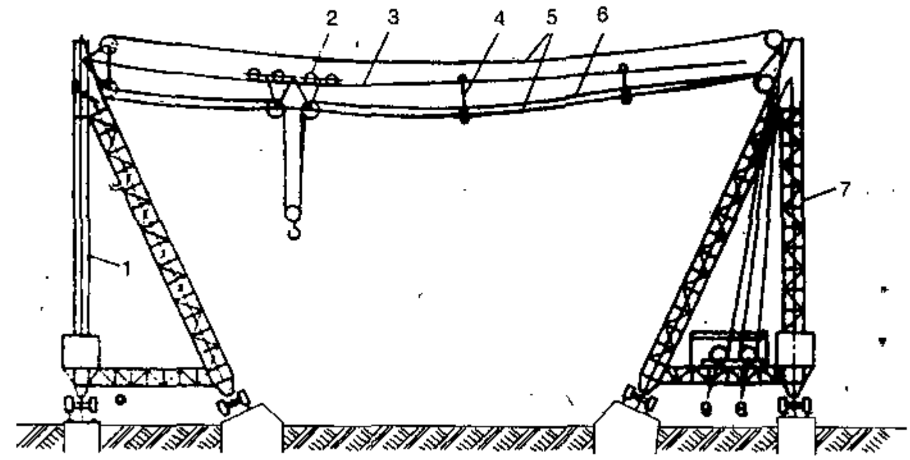


Fig. 6.47. Tautline cableway.

Tautline cableway towers can be either fixed structures or travelling ones moving over parallel tracks. In the radial cableway installation, one tower is a stationary structure and the other can move over a track which is a part of a circle covering a sector-shaped area. Spans range between 150 and 600 m but 1-km spans are also met wittonne. Standard capacity is 1 to 25 t while cableways rated at 150-tonne capacity are also in use. The load hoisting speed is 1.5 to 3 m/s depending on the height, and the conveying speed varies between 8 and 10 m/s. Towers are spotted into the working position at a rate of 6 to 20 m/min.

(*b*) **Rope ways.** These are used for long distances. Ropeways have two end towers and rest intermediate towers, the number depends on the distance. Ropeways are of following two types :

(*i*) In first type endless rope runs over pulleys or horizontal sheaves at the two on towers and is supported along its length on a series of pulleys mounted an intermediate towers. These are rotated by diesel engine or electric motor at a speed of 5 to 6 km/hr. In this system the same rope is acting as a supported as well as hauling rape for the carriers.

(*ii*) In this type separate hauling and support ropes are provided some times two support ropes with one hauling rope care also provided so that one carries can be drawn in one direction on one supporting rope, while another carrier as drawn in opposite direction on second supporting rope. Though this system is expensive in initial cost but due to large carrying capacities higher speeds and lesser wear the system is economical and hence widely used as compared to that of first type.

NOTES

6.20. JACKS

Jacks are used to lift a part of equipment by either mechanical or hydraulic means to a sufficient height to enable the removal of the flat tyred wheel and put on a spare wheel or for servicing. These work on the principle of the lever. These are classified as :

1. With respect to method of operation/mechanical or hydraulic.
2. With respect to the lifting mechanism—Ratchet, friction, screw scissors, geared.

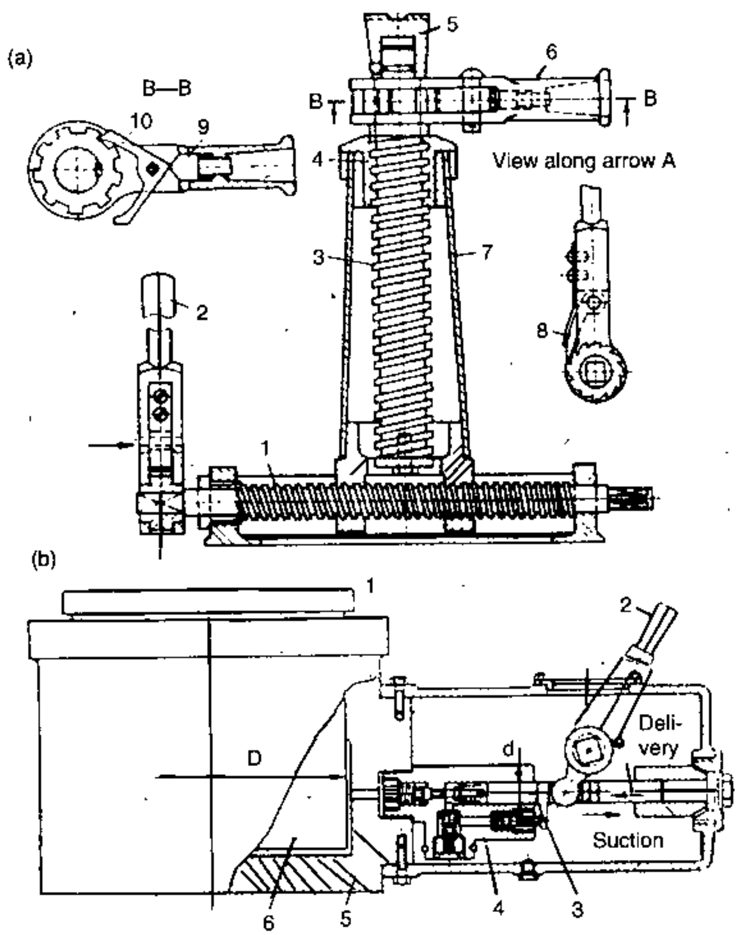


Fig. 6.48. Jacks.

Mechanical Jack. These may be ratchet type, screw type, acessir type or geared type. Geared types are generally used for construction equipment whereas others mentioned are used for lifting works.

NOTES

The geared mechanical jack is operated by a lever having a pawl and ratchet and which is attached to the level gears.

Hydraulic Jack. These work on the principle that the pressure exerted by a liquid on a surface is proportional to the area of the surface. Due to this principle these jacks are capable of lifting great weight. Surface pressure exerted by a liquid depends on the ratio of face areas of the ram and plunger.

6.21. LIFTING AND LOWERING DEVICES (HOISTING EQUIPMENTS)

Hoisting is the operation of lifting a load handling them in suspension and lowering and placing then at required locations.

(*a*) **Lifting tackle.** Fig. 6.49 illustrates a schematic diagram of a lifting tackle featuring the single-reeving setup. In the absence of any resistance, which is the case when the system is at rest, the tension at any point of the rope can be determined from

$$S_o = \frac{G_{load}}{a}$$

where G_{load} = weight of load ; a = number of rope parts cut by plane K-K.

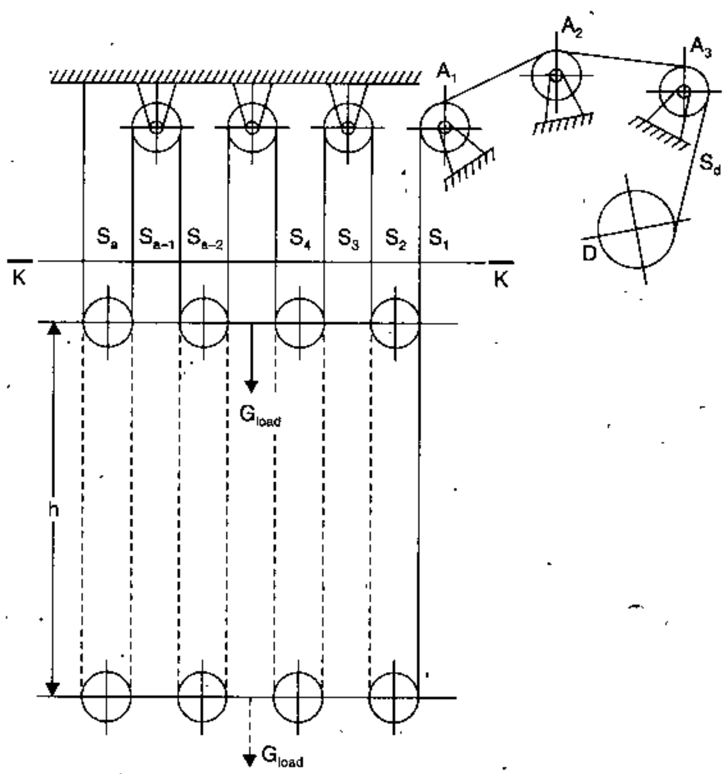


Fig. 6.49. Schematic diagram of a lifting tackle.

When the load is either hoisted or lowered, the tension in rope parts will be different owing to sheave resistance brought about by rope stiffness and friction in sheave bearings. Let the tension in that part of rope which passes over a deflection sheave A_1 be S_1, that in the next part, S_2 and so on. Then, if the number of rope parts is a, the tension in the last immovably attached part will be S_a. The sum of the projections of all tensions on the line of action of the force of gravity of the load produces an equation

NOTES

$$S_1 + S_2 + S_3 + ... + S_{a-1} + S_a = G_{load}$$

The relations between the individual tensions in the rope while hoisting the load are given by

$$S_2 = S_1 \eta \; ; S_3 = S_2 \eta = S_1 \eta^2 \; ; S_4 = S_1 \eta^3 ..., S_{a-1} = S_1 \eta^{a-2} \; ; S_a = S_1 \eta^{a-1}$$

where η is the sheave efficiency.

From the above we can write

$$G_{load} = S_1 (1 + \eta + \eta^2 + ... + \eta^{a-2} + \eta^{a-1})$$

On determining the sum of the geometric progression (the expression in the parentheses), we can find the relation between the weight of the load and the tension S_1 :

$$S_1 = G_{load} \frac{1-\eta}{1-\eta^a} \qquad ...(1)$$

The tension S_d in the rope wound around the drum D is greater than the tension S_1, apparently due to the resistance of the deflection sheaves A. When the number of these sheaves is t, then the maximum tension in the rope while hoisting the load will be

$$S_d = S_{max} = \frac{S_1}{\eta^t} = G_{load} \frac{1-\eta}{\eta^t (1-\eta^a)}$$

In lowering the load, the maximum tension will be applied to the parts S_a

$$S_a = G_{load} \frac{1-\eta}{1-\eta^a}$$

The efficiency of a $1-\eta$ lifting tackle with an a-part reeving is the effective work done on the load Q in hoisting it to the height h divided by the work $S_d ah$ done by the effort S_d :

$$\eta_{l.t.} = \frac{G_{load} h}{S_d ah} = \frac{(1-\eta^a)\eta^t}{(1-\eta) a} \qquad ...(2)$$

Consequently, the maximum tension the lifting-tackle system is experiencing in *hoisting* the load will be given by

$$S_{max} = \frac{G_{load}}{a\eta_{l.t.}} \qquad ...(3)$$

and in *lowering* the load, the maximum tension applied to the a part will be

$$S'_{max} = S_a' = \frac{G_{load}}{a\eta_{l.t.}}$$

The minimum tension in the rope while *lowering* the load will be in the part entering the drum

$$S_{min} = S_d' = \frac{G_{load}}{a\eta_{l.t.}} \eta^{a+t-1}$$

(*b*) **Winch.** This is used to lift loads vertically by winding the rope or cable on a drum. Here it is possible to use man power to get a much greater mechanical advantage than with a block and tackle. It is frequently used in loading heavy equipment into ships, construction of buildings and in similar jobs.

NOTES

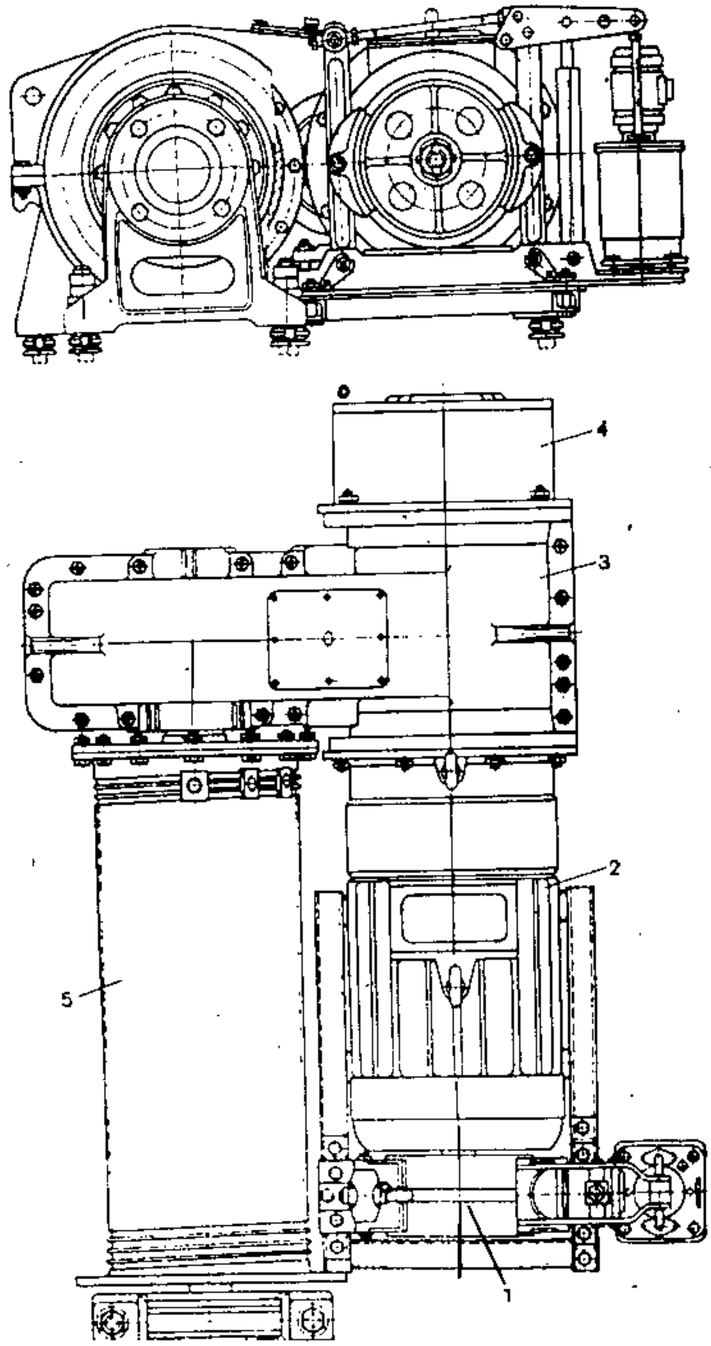


Fig. 6.50. Electric winch.

Capacity of a winch can be increased by increasing the number of gear-trains. These are very useful simple and law cost equipment for lifting heavy loads. Ratchet brakes may be fitted on the winch to hold a suspended load and to prevent reverse travel of gears and thus avoid accidental dropping of load.

1. The winch illustrated in Fig. 6.50 is driven by a flanged a.c. motor.
2. Attached to the housing of a reducer.

3. The reducer input shaft is linked to the motor shaft through a jaw coupling built the reducer. Mounted at the end of the motor shaft is a pulley. 1 of a block brake actuated by a thruster. A drum S attached to which is the rope end 1. fitted to an extended portion of the reducer output shaft. An eddy current brake 4 fitted to the other end of the reducer input shaft controls the rate of descent in a gradual way.

NOTES

(c) **Hoist.** This is often operated between fixed guide rails for lifting things vertically. Hoists are hand, electric, air powered installed.

Chain hoist. *Which is operated by hand. (Fig. 6.51)*

Hand Powered Hoist is suspended from a hook 3 need to secure hoist in an operating position Fig. 6.52.

It is operated with the aid of an endless welded chain 7 engaging a drive chain sheave 4 and the hook is suspended from a roller chain for a welded tested chain. The load can be sustained in a lifted position with the aid of a disc brake 5 aclivaled under the weight of load. To the end the hub of the drive chain sheaves made in the form of a nut which clamps a brake ratch ring 6. A brake pawl 25 is attached to the hoist housing.

Fig. 6.51. Chain hoist.

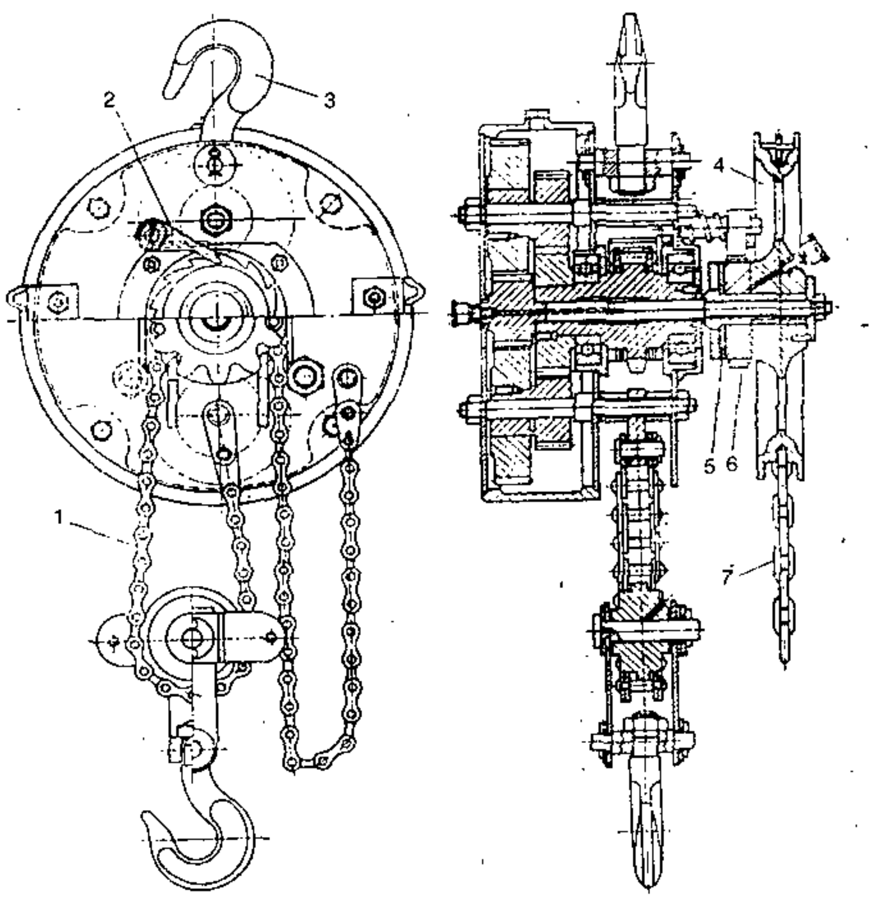


Fig. 6.52. Hand powered hoist with coaxial gear drive.

Hoists used for short distance horizontal haul are suspended from trolley in carriers Fig. 6.52 travelling over an overhead single rail track commonly a rolled I beam. Trolleys are of the pusher type being pushed by hand in installations with capacity under tonne or they out fitted with hand or mechanically operated drives.

NOTES

Electric hoist. (Fig. 6.54) Capable of hoisting speeds between 5425 m/min. are available in capacities ranging between 0.25 and is T. The speed of their travel over a single rail track varies depending on the distance.

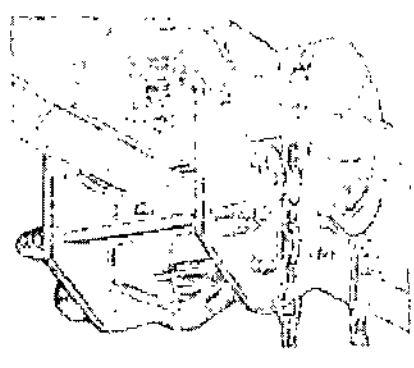


Fig. 6.53. Hand powered monorail hoist.

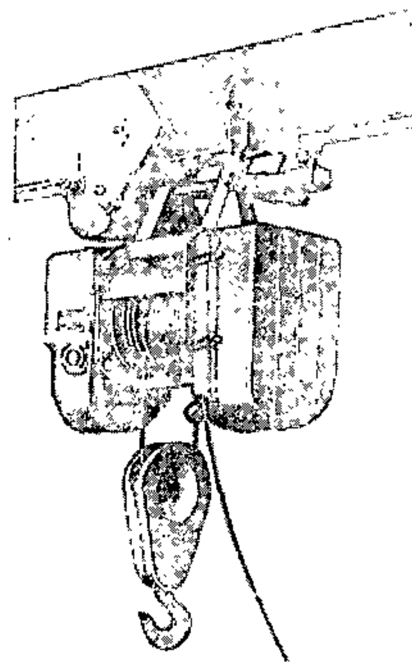


Fig. 6.54. Electric hoist.

Pneumatic hoists are gainling a wide spreed in industry those designed to operate in explosive surrounding are equipped.

With chains in steel of the spark proof grade and bronze hooks. The cylinder is arranged either vertically or horizontally, the air pressure varies between 2 and 12 da N/cm^2, the capacity is between 10 kg and 5t, the cylinder bore is 30 to 300 mm, and the lift varies between 50 and 2000 mm.

The air hoist illustrated in Fig. 6.55 (*a*) consists of a double acting cylinder operated by the air admitted over two air hoses with the aid of a twin-push button control. The hoisting speed is changed steplessly, and the hook can be stopped in any position. Such air hoists operate at a speed between 0.1 and 0.3 m/s depending on the capacity and diameter of the air hose.

Hoists with cantilever handling attachment [Fig. 6.55 (*b*)] are designed to stand to bending and tilting moments. The handling attachment is rigidly secured to a full-swing guide sleeve which can travel along the outside surface of the air cylinder and is linked with the piston rod. The hoist is suspended from a trolley travelling over a pair of rails.

A **pneumatic hoist** with deflecting sheaves is illustrated in Fig. 6.55 (*c*). The lift this setup is capable of providing is, consequently, twice the piston stroke. An appreciable lift combined with compactness of the hoisting mechanism can be obtained by arranging the cylinder horizontally [Fig. 6.55 (*d*)]. Then, the deflecting sheaves transform the horizontal piston stroke into vertical hook travel. The efficiency of pneumatic hoists is as high as 0.9 to 0.93, provided the cylinder bore and piston are finished to a high-degree accuracy and effective seals are used. Such hoists with a built-in lifting tackle can give 9-metre lifts.

NOTES

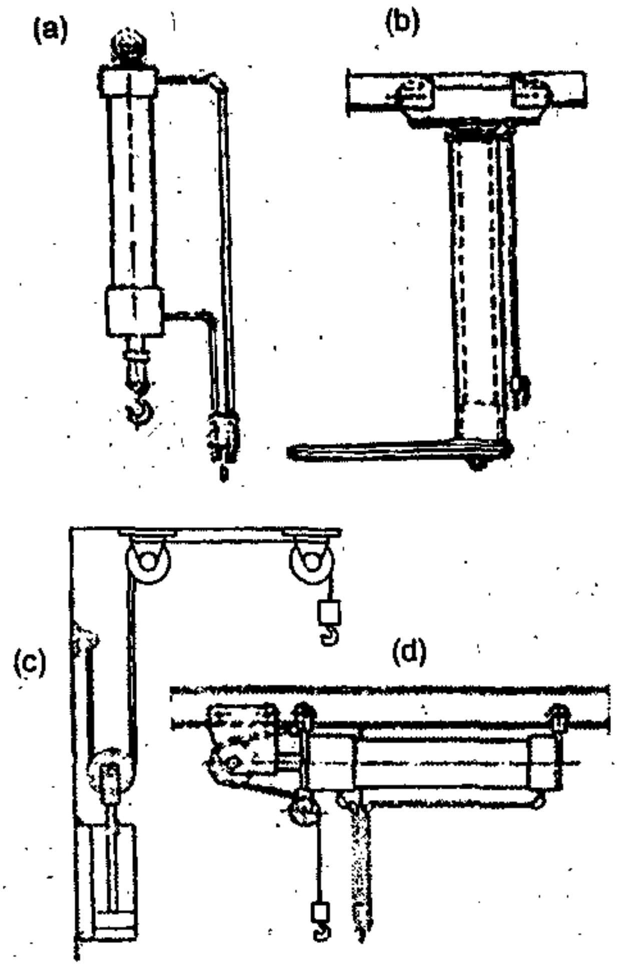


Fig. 6.55. Pneumatic hosting mechanisms.

6.22. LIFT

Hoisting equipment adopted to lift load vertically is called a lift lifts are used in storehouse handling mines, construction sites : Goods lift.

Passanger lift. Essentially consisting a car 6 travelling over a set of rigid guide rails 5 which keep the car restrained latterly and provide support for it with the aid of special safety devices 10 should the hoisting rope 3 rupture. A hoisting m/c is arranged at the topor both of hoist way with the top arrangement preferred in passanger installation. To reduce the load on hoisting m/c counter weights 7 is commonly employed. Running along a separate set of guide rails 4 it offsets the car mass and half the duty

NOTES

load. A governor 2 operated from a separate rope 9 being provided in the m/c room for the purpose of regulating the speed. Buffers 8 are arranged as the bottom of the hoist way and lift control are found in a coubice next to the hoisting m/c.

Skip Hoist. Hoisting equipment for the handling of bulk materials in self dumping buckets or skips is called bucket or skip hoist. They are used to charge blast furnaces, cupolas, etc.

Skip hoists fall into three types differing by the way the skip is balanced. The type is provided with a counterweight offsetting the mass of the empty skip plus half the duty load. The power requirement of this hoist are the same whether the skip is hoisted or lowered, amounting to what is needed to lift half the duty load. Skip hoists of this kind are employed in installations of medium and high lifting capacity and a medium effective handling capacity.

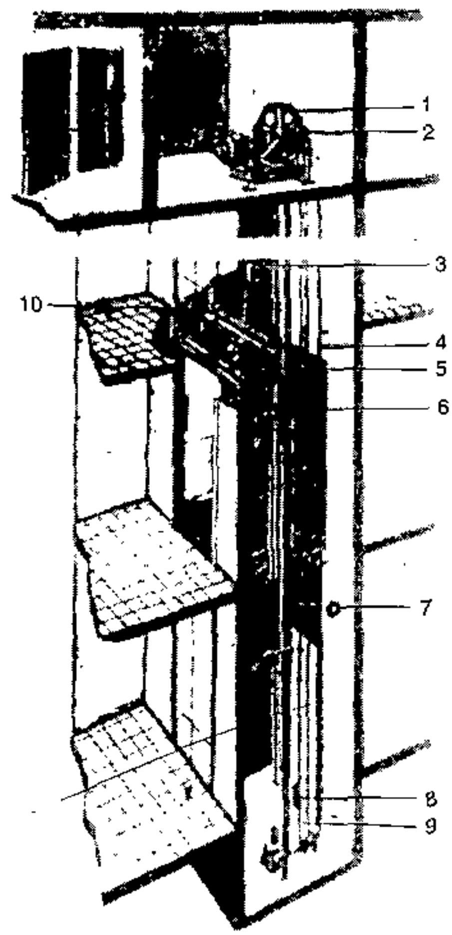


Fig. 6.56. Passanger lift.

Another typical arrangement of skip hoists is one with two skips moving in opposite direction. The winding machine provided only the force required to handle the duty load in just one of the skips. This equipment is used when high effective handling capacities are required and the height of the lifts is also high.

NOTES

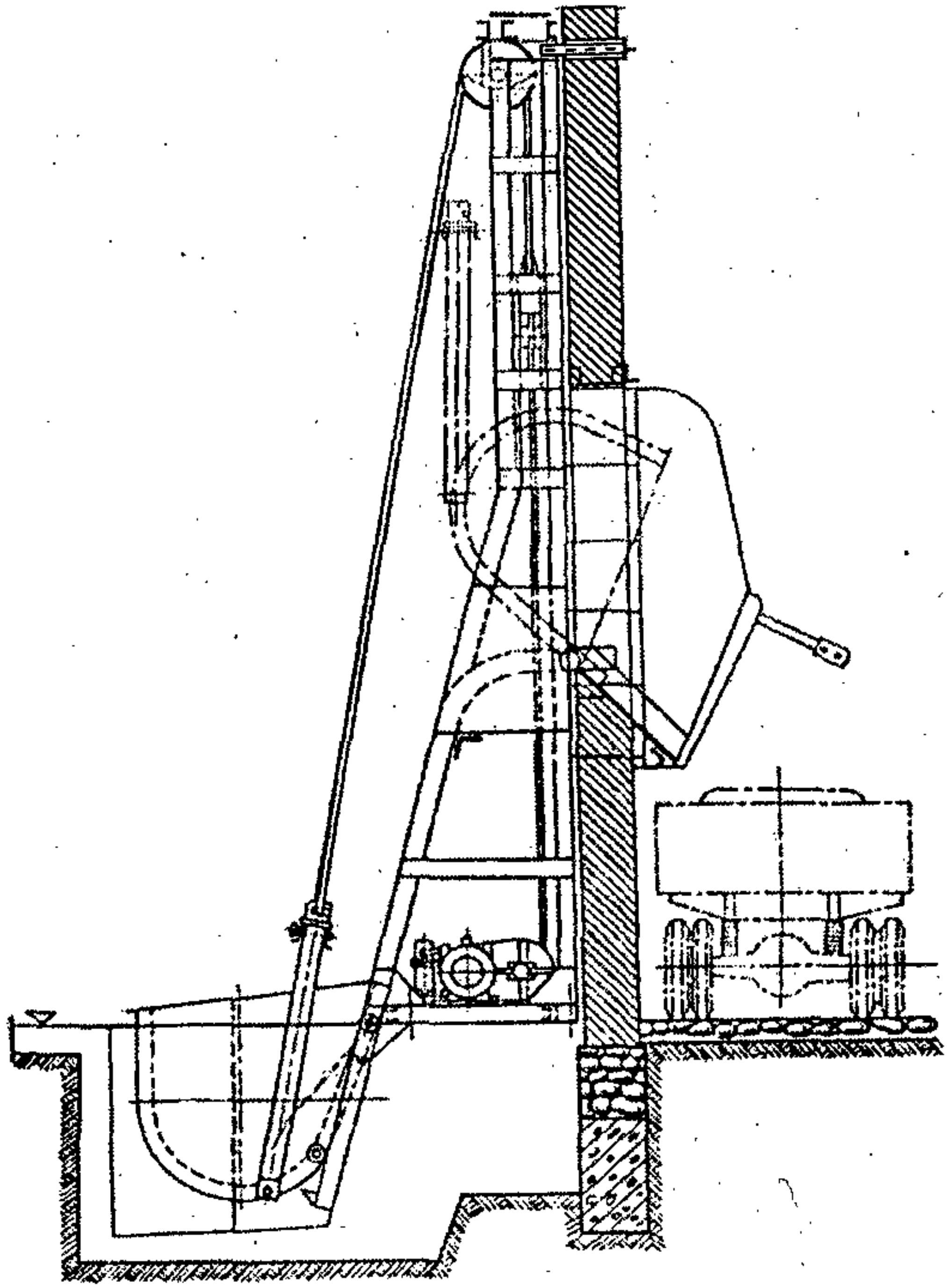


Fig. 6.57. Skip hoist.

STUDENT ACTIVITY

1. Do you have MH equipments in your organization ? If yes.
   write name
   its function
   its description.

2. In your drganization MH system has got defects, name them. How these defects can be elimineted ?

NOTES

SUMMARY

1. Materials handling devices should be able to give maximum efficiency, economy, life and reliability of service. Under *utilization and faulty selection of* the materials handling equipment is an responsive luxury, which gives rise to increase in *operating* costs.
2. Materials handling should never be treated as an ancilliary, and materials handling should always be integrated with the production processes.
3. Material movements should be synchronised with the production processes. Effective production results from planned processes coordinate and synchronised and if possible integrated with planned movement.
4. Belt conveyor is one of the most common form of material handling system used in mining industries and in construction projects.

TEST YOURSELF

1. Define materials handling. What are the advantages of materials handling ?
2. What are functions and principles of materials handling ?
3. What is relationship of materials handling and plant layout ?
4. Write about types of materials handling equipment/devices.
5. Write about design of materials handling system.
6. What are objectives of materials handling ?
7. What are features or characteristics of good materials handling *system* ?
8. What are materials handling jobs ?
9. What are basic materials handling system ?
10. What factors are considered for selecting materials handling equipment ?
11. Why materials handling important ?
12. Why materials handling is necessary ?
13. What are the advantages of materials handling ?
14. Why fixed cranes are important ?
15. Write about revolving pillar *jib crane, swinging pillar jib crane.*
16. Write about fixed gantry crane, industrial mobile crane.
17. Write about full *swing turn table truck crane and* wagon crane.
18. Write about gantry floor crane.
19. Write about crane *ship kearsagge, full revolving floating* crane with rope ruffed strurt boom.
20. Write about guied derrick.
21. Write about monorail conveyors, belt conveyor, wire conveyor, roller conveyor, potabu wheel conveyor V bucket conveyor, flight conveyor, push bar conveyor, lowering devices, drag chain conveyor, trolley conveyor, screw conveyor, vibrating conveyor, light weight heavy duty conveyor, heavy duty drag conveyor, feed conveyor, slides, chute.
22. Write about wheels, caster, roller, crate lifting devices, wheeled devices.

23. Where chutes, conveyor, crane, fork lift trucks, trails, pallet trucks, rolle conveyor, trolleys, skids are used ?

24. State the difference between elevator and crane.

NOTES

OBJECTIVE TYPE QUESTIONS

1. The proper use of materials handling equipments resulted in
(*a*) Improvement in quality standards
(*b*) Increase in the efficiency of plant
(*c*) Increases in the wages of workers
(*d*) Better coordination among different sections.

2. Principle of materials handling suggest that the best way of handling where ever applicable.
(*a*) To eliminate it (*b*) To be as flexible as possible
(*c*) To involve standard equipment (*d*) To involve minimum effort.

3. While selecting a materials handling system, the essential criteria are
(*i*) Flexibility (*ii*) Space requirement
(*iii*) Path of the movement (*iv*) Scrap value of equipment.
(*a*) (*i*), (*ii*), (*iii*) (*b*) (*iii*), (*iii*), (*iv*)
(*c*) (*iii*), (*iv*), (*i*) (*d*) (*iv*), (*i*), (*ii*).

4. In which of the following situations are lifting trucks used for materials handling
(*a*) Gravity handling (*b*) Mass movement of products
(*c*) Limited travel on heavy shops (*d*) Systematic piling of the packages.

5. Different parts are to be assembled on an engine block of a cylinder 10 HP automobile of different work stations in sequence which one of the following materials handling equipment will be most suitable
(*a*) Fork lift trucks (*b*) Overhead crane
(*c*) Mono rails (*d*) Roller conveyors.

6. Identify a material handling equipment which suits even if there is any flexibility in path, size and weight
(*a*) Mono rail (*b*) Skids
(*c*) Conveyors (*d*) Fork lift trucks.

7. Which one of the following is an important characteristics of efficient materials handling equipment
(*a*) Easy to handle (*b*) Low terminal time
(*c*) High capacity (*d*) Comfortable to operator.

8. In an automobile industry where different operations are to be performed on a Cylinder block, which of the following equipment is recommended for movement of cylinder block through assembly stations.
(*a*) Belt conveyors (*b*) Chain conveyors
(*c*) Bucket conveyors (*d*) Roller conveyors.

9. When transportation of heavy materials require true movement in both horizontal and vertical planes within a limited area, the best materials handling equipment for the purpose is

(*a*) Chute (*b*) Power trucks
(*c*) Elevators (*d*) Overhead crane.

10. The assembly shop of small part consists of four departments, assembly, storage, inspection and shipping the best sequence of departments having minimum handling no back tracking is
(*a*) Assembly, storage, shipping, inspection
(*b*) Assembly, inspection, storage, shipping
(*c*) Assembly, storage, shipping
(*d*) Inspection, assembly, shipping.

11. In a thermal power plant, coal is to be continuously moved into the boiler-bunker from the coal crushing plant. Which of one of the following materials handling equipment will be most suitable
(*a*) Conveyor (*b*) Elevator
(*c*) Overhead crane (*d*) Rope trolley.

12. Apple (1977) has classified the handling equipment into
(*a*) Conveyance (*b*) Cranes and hoists
(*c*) Trucks and Auxiliary equipment (*d*) All of the above.

NOTES

Fill in the blank

1. Materials handling does not add .... to a product, but it is usually a significant element of ....

2. There are varying estimates is to how much materials handling actually costs : these range from .... % to .... % of the costs of the product.

3. The least total cost of materials handling is the ultimate objective of the .... materials handling.

4. Working airless should permit easy passage of materials handling ....

5. The angle of repose (for bulk materials) is the angle formed by ....

True or False

1. A rubber—covered belt conveyor can be used to carry hot forgings.

2. A single phase/10 V AC 60 cycles power supply is sufficient for most bridge crane.

NOTES

CHAPTER

7

PRODUCTION PLANNING AND CONTROL

LEARNING OBJECTIVES

- Introduction to Production Planning and Control
- Pre-planning
- Production Planning
- Production Planning in Detail
- Types of Production
- Materials Planning
- Process Planning
- Inventory Control

7.1. INTRODUCTION TO PRODUCTION PLANNING AND CONTROL

PPC means a complete manufacturing plan. Production is carried in the best manner which is possible by planning of production. Management sets the exact route or path of individual item or part or assembly, fixes the starting and finishing data for each item, assembly or finished product, releases the necessary orders and initiate the required follow up to ensure the smooth functioning.

PPC is needed :

(*i*) For minimising (*a*) idleness of men and machines (*b*) setups of machines

(*ii*) Keeping in process inventories minimum

(*iii*) Reducing material handling cost

(*iv*) Reducing storage cost

(*v*) Meeting changes in demand

(*vi*) Meeting emergencies such as breakdown, material shortage etc.

Effects of PPC

(*a*) Material factors, quality of output, plant utilization, utilities users, process efficiency, safe and clean working conditions. (*b*) Human factors

NOTES

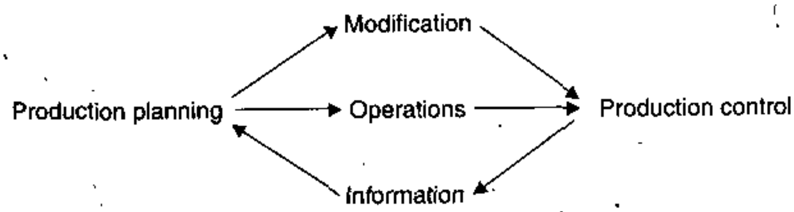


Fig. 7.1

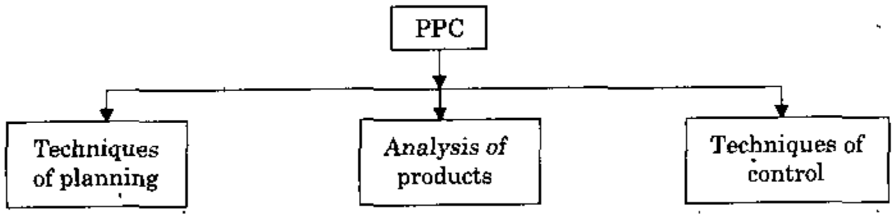


Fig. 7.2

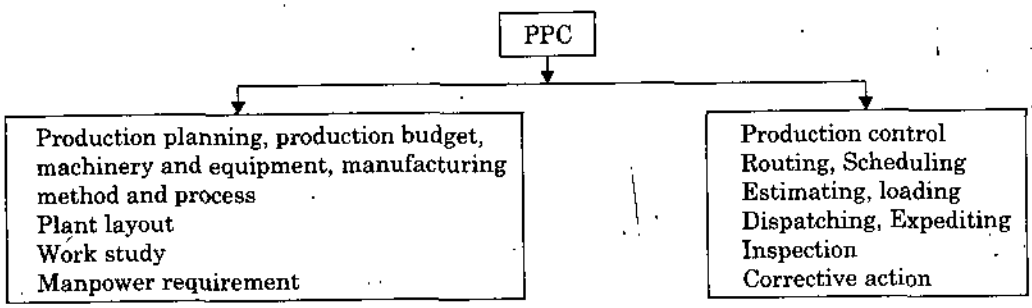


Fig. 7.3

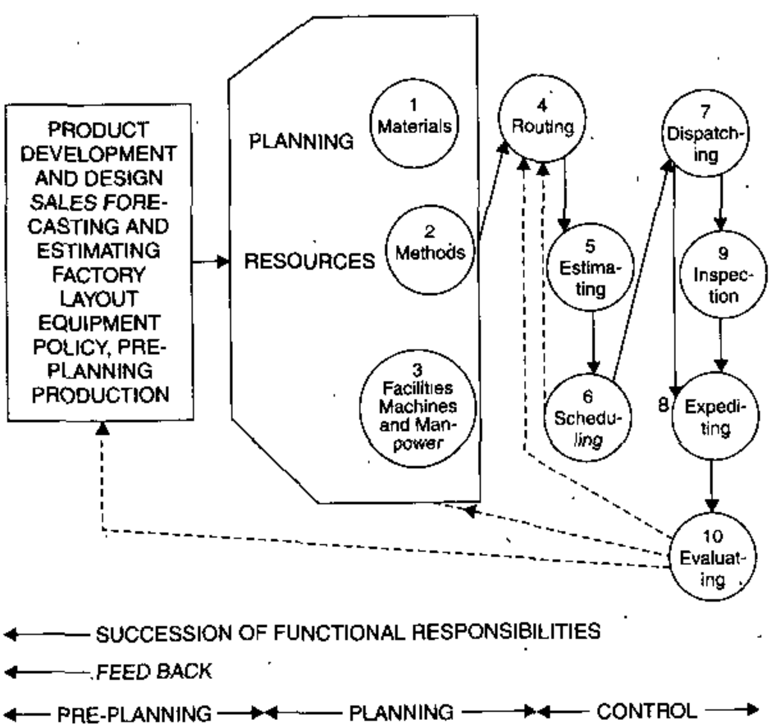


Fig. 7.4. Ten functions of PPC cycle.

NOTES

Action Planning

Process Planning and routing, material control, Tool control, loading, scheduling.

I. Action Phase

Starting the actual work, Dispatching.

II. Follow up or control phase

Progress reporting, Data processing, Expediting, corrective action, replan.

Objectives of PPC

(*a*) To determine the sequence of operations, which will continue production.

(*b*) To issue coordinated work schedule of production to the Foremen of various shops.

(*c*) To plan plant capacity that will provide sufficient facilities for future production programmes.

(*d*) To maintain sufficient inventories of material to support the continuous flow of production.

(*e*) To maintain production and employment level that are relatively stable and constant with the volume of production.

(*f*) To follow up production schedule to ensure that delivery promises are kept.

(*g*) To evaluate the performance of various shops and individuals.

Advantages of PPC. These are :

(*a*) Efficient uses of resources

(*b*) Economy

(*c*) Coordination

(*d*) Avoid bottlenecks

(*e*) Inventory control

(*f*) Public image improves.

Limitations of PPC. These are :

(*a*) It may bring rigidity in the behaviour of employees

(*b*) It is a time consuming process

(*c*) It is a costly procedure

(*d*) Its effectiveness is reduced due to external factors *e.g.* power, government control, natural havoc, technology change, change in fashion etc.

The planning and control process consist of

(*i*) Measuring historical performance

(*ii*) Examining the future environment and develop the environment in which the company will be operating

(*iii*) Developing objectives

(*iv*) Formulating strategy to achieve objectives

(*v*) Translating the strategy into operating plans

(*vi*) Implemention of plan motivating people to achieve those plans and budgets

(*vii*) Continuous comparison of actual with planned one.

NOTES

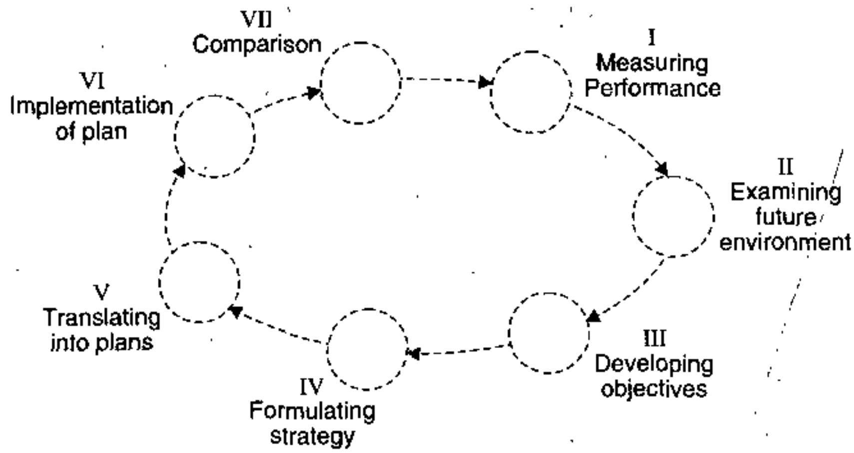


Fig. 7.5

PPC Department. It consists of :

(*a*) Production planning section
(*b*) Production control section
(*c*) Inventory control section
(*d*) Work study section
(*e*) Transportation section
(*f*) Standards section.

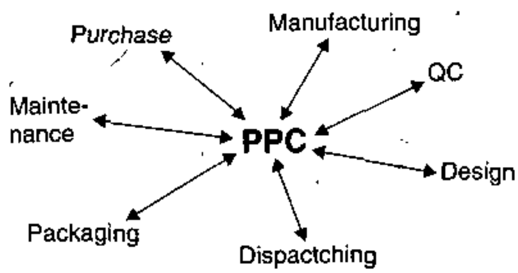


Fig. 7.6

7.2. PRE-PLANNING

Sales forecasting and estimating, market research, Product development and design, Factory layout, Equipment policy and replacement, pre-planning production.

7.3. PRODUCTION PLANNING

It consists of mainly the evaluation and determination of production inputs such as labour, machinery and equipment, material and utilities to achieve the desired goods.

It involves management decisions on the resources that the organisation will require for its manufacturing operations and the selection of these resources to produce the desired goods at the appropriate time and at the least possible cost.

NOTES

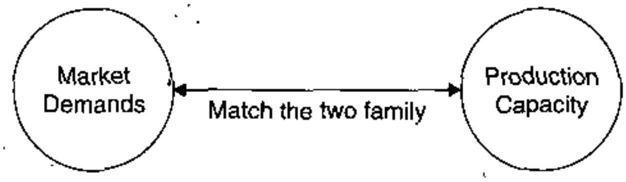


Fig. 7.7. Production Planning.

Functions of P.P.

(*a*) Investigation about products. Product design, assemblies
(*b*) Quality of products
(*c*) Quantity to be manufactured
(*d*) Quality and quantity of materials used
(*e*) Sequence of operations
(*f*) Capacity of equipments/machines/tools
(*g*) Internal transportation
(*h*) Factory design
(*i*) Manpower planning
(*j*) Stores
(*k*) Standard time for operations.

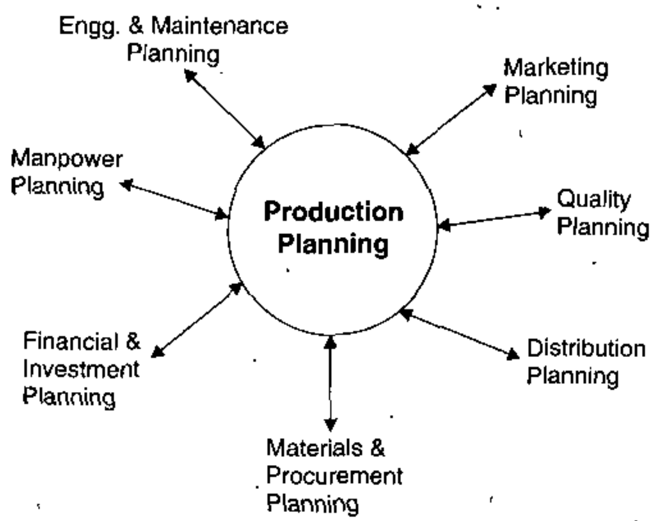


Fig. 7.8. Production Planning and other plannings.

Steps of P.P. These are :

(*a*) Demand forecasts, (*b*) Specifications of product requirements, (*c*) Setting the production rates, (*d*) Controlling production.

Objectives of P.P. These are :

(*a*) Future expansion possibilities
(*b*) Establish routing, dispatching
(*c*) Establish time schedule
(*d*) Establish budgetary plan
(*e*) Forecast manpower requirements
(*f*) Value analysis

NOTES

(*g*) Get a prescribed level of profit

(*h*) Capture desired share of the market demand

(*i*) Operate the plant at a predetermined level of efficiency

(*j*) Utilise plant facility.

Necessity of P.P. It is due to :

(*a*) The increased complexity of production and distribution system

(*b*) Adjusting timings of interrelated activities

(*c*) Forecasting future change and trends and accordingly reactions to them

(*d*) *Obtain economical combination of resources by eliminating waste in all di*rections and making the necessary adjustments.

Planning may for :

(*a*) **Long-term/strategic**—One year or to more

(*b*) **Intermediate term**—One month to a year

(*c*) **Short-term**—A day to a month

(*a*) **Long-term**—Technology, Location of facilities, capital investment, Personnel selection, Raw materials, environment.

(*b*) **Intermediate term**—Physical arrangements of machines, raw materials, personnel, Environmental, time, Aggregate Plan.

(*c*) **Short-term**—Sequence, batch size, etc.

Product Planning

Information obtained from product design for planning production processes and procure materials.

When any product drawings reaches to production planning section, the whole assembly of the product is broken down into sub-assemblies and components. Later on each component, the tolerances are established and a bill of material is prepared. The technique of value analysis is applied to decide whether the component should be purchased or made.

Production Planning Components and Stages

Components	*Stages*
(*a*) Process Planning	(*a*) Adoption of a policy and strategy of production.
(*b*) Work Planning	(*b*) Determination of design and development of products and services
(*c*) Raw materials and machines	(*c*) Forecasting and assignment of men
(*d*) Cost and Quality	(*d*) Materials and resources allocation and scheduling of financial,, technical and human resources. Preparation of procedures and patterns of work and activities
(*e*) Planning	(*e*) Fixation of costs of manufacturing operations and their economic evaluation.

NOTES

7.4. PRODUCTION PLANNING IN DETAIL

(A) **Planning resources allocation**

The marshalling of all the resources of production which will be required to perform the task is called allocation. This division is concerned with the provision of space, the supply of labour, availability of machines and equipments and the provision of materials and space. Allocation of resources is done taking all the other limitations in to consideration and the priorities allotted to various products.

(B) **Routing and Sequencing**

The specification of the flow or sequence of operation and the process to be followed in producing a particular manufacturing lot.

Following factors are involved in routing :

(*a*) A study of the product for determining, the possible method of processing and choosing the best method.

(*b*) A study of method to find out of any special equipment which would be needed for carrying them out.

(*c*) The capacity of the equipment/machine must be analysed.

(*d*) The sequence of operation must be determined—Operation and Route sheet.

(*e*) The standard time of each operation must be known.

(*f*) The grouping of route sheets into sub-assemblies and a major assembly must be done.

Sequencing is the order in which tasks waiting at a work can be as to be performed. Sequencing problem arises when we are concerned with situation where there is a choice as to the order in which a number of tasks can be performed. To determine the sequence in which two or more jobs should be proceeded on one or more machine, in order to optimize some measure of effectiveness. Some constraints may be placed, due date for each job, processing order of each job on each machine or variable processing time. Measure of effectiveness could be the total elapsed time between the start of the first job on machine and the completion of the last job on the last machine or it could be maximum tardiness or total tardiness.

Uses of route sheets

(*a*) It specifies the exact sequence of each operation along with the allowed time and operation instruction.

(*b*) It serves as a progress report of the part in the entire cycle of operation for stock to completion and delivery to stores

Operation and route sheet

No. ....

Part No. .... Drawing ....

Name ....

Material specification .... Quantity .... To be finished on ....

NOTES

Routing Dept.	Machine	Operation	Description	Tools	Jigs and Fixtures	Time		
						Set up	Operation time	Total

(*c*) It is used to check the subsequent steps and procedure.

(C) Scheduling

It relates to time-table of production function.

Objectives of scheduling are :

(*a*) Ensures completion of orders
(*b*) Ensures utilization of facilities and manpower
(*c*) Reduce stockouts
(*d*) Minimizes in process inventory
(*e*) Minimizes over time
(*f*) Eliminates idle capacity
(*g*) To meet the established lead time

(I) **Scheduling in Intermittent Production System**

It is difficult because

(*a*) A variation in the order specification
(*b*) Requirements of the different types of materials
(*c*) Change in the machine setups
(*d*) Varying sequencing of the production processes
(*e*) Economic lot size of the production
(*f*) Increased degree of inspection

(II) **Scheduling in Continuous Production System**

It is simple because

(*a*) Standardise m/c setups
(*b*) Standard m/c loading and line balancing during assembly
(*c*) The number of operations and the sequence of operations are same
(*d*) The raw materials and components of standard specifications are used.

(D) Estimating

Once the overall method and sequence of operations is fixed and process sheet for each operation is available, then the operation times are estimated. This function is carried our using extensive analysis of operation along with method and routing and a standard time for operation are established using work measurement techniques.

(E) **Dispatching**

It deals with the release of resources along with the necessary instruction for the production function. The routine of setting production activities in motion through release of orders and instruction and in accordance with previously planned items and sequence as embodied in route sheet and load schedule.

(F) **Follow up/expediting/progress and reporting**

Expediting maintain execution of production plans and see them through successful completion.

The person who is assigned this function is known as follow up man, expeditor, stock chaser.

Follow up is the branch of production control procedure which require the progress of materials and parts through the production process.

(G) **Inspection**

It is a major control tool. Though the quality control is the separate function this is important to PPC both for the execution of the current plans and its scope for future planning. This form the basis for knowing the limitation with respect to methods, process is writing, very much useful for evaluation phase.

(H) **Evaluating**

It is done after entire production cycle is completed.

7.5. TYPES OF PRODUCTION

1. Continuous flow technology—Mass scale production
2. Project technology
3. Intermittent flow process job, batch
4. Assembly line technology
5. Processing industries

1. **Continuous Flow Technology.** When goods are produced by performing same activities in specified sequence repetitively we call it a flow shop or mass production system.

Materials and products are produced in continuous endless flows. The product is highly standardised as are all of manufacturing procedures.

Continuous flow technology affords high volume around the clock operation with capital intensive specialized automation.

All outputs are treated alike in this form of processing. The production process is therefore geared to produce one output. Arranging the facilities in the sequence in which they are required for the output.

Characteristics of Continuous Process

Relatively standardized outputs consequently fixed inputs. Fixed sequence of operations. Fixed processing time.

I. High Volumes. Special purpose, customer built production facilities, initial costs are high. They can produce output at a low variable cost.

The least cost processing form.

II. Easier Planning and Control. All operations are standardized with standard operation times. No waiting between operations.

Volumes are high, special purpose fixed position material handling equipment like chutes, conveyor etc. which have low space requirements and operate at low variable costs.

III. Linear Work Flow. The material moves from one facility to another with no back- tracking. The material moves on a conveyor and workers remove one unit from the conveyor for processing and pulling it back on the conveyor at the end of the operations.

Advantages of Continuous Flow Technology

(*i*) **Low unit cost.** Cost saving is possible due to low manufacturing cost, bulk purchasing of materials efficient facility utilization, low in process inventories, low material handling costs.

(*ii*) **Lower operator skills.** Machines operations are simpler, few set ups. Improves the availability of workers with requisite skills. Lower labour costs.

Because machines are special purpose, their maintenance is difficult. Higher maintenance skills are required. Times taken for diagnosis and repair is longer. Spare-parts availability may be difficult.

(*iii*) **Simpler managerial control.** Planning and control of production is simple. Predictability of operations is higher. Performance on meeting delivery dates is better.

Disadvantages of Continuous Flow Technology

(*i*) Balancing of production/assembly lines is difficult.

(*ii*) Balancing of raw materials supply is difficult.

Difficult to adopt. Changes in the output characteristics, the product design and the rate of output, are difficult.

Possibility of stoppage of line. If there is no demand, breakdown of any workstation, breakdown in the material handling equipment there is possibility of stoppage of line.

Balancing the line. Output rate is governed by the slowest work station, there will be always idle time at some workstations.

Low worker morale. Worker's task is (*i*) highly repetitive (*ii*) insignificant (*iii*) unchallenging.

Causes boredom, monotony, lower morale of the workers.

High initial cost. Special purpose machines and equipments vary high initial cost. Costly to service and maintain. Susceptible to obsolescence. Not easy to find a buyer for such machines or equipments. It is difficult to modify these for other users.

New technology for continuous flow process :

(*i*) CNC/DNC

(*ii*) Robotics

(*iii*) CAD/CAM/CAE

(*iv*) Flexible manufacturing.

2. Project technology deals with one of a kind products that are tailored to the unique requirements of each customer.

NOTES

3. Intermittent flow processes. Production process starts after receiving the sales order in quantities dictated by each order.

Each output takes a different route through the organisation.

Each output uses different inputs.

Each output requires different operations.

Each output takes a different amount of time and sequence.

The facilities are organised around similar operations functions.

The intermittent process is especially suited for service organisation because each service is often customized and so each one requires a different set of operations in a different sequence.

Combination of continuous and intermittent processes.

Component and sub-assemblies produced to stock.

Final assembly on order.

Characteristics of the intermittent form

(*i*) **Flexibility.** When an organisation wants to produce a variety of outputs using common facilities, it wants to have flexibility in its operations. This is achieved by employing general purpose machines and equipment as well as having staff with a wide range of skills, process layout used. The facilities are laid out in accordance with the general flow and for specific outputs, there may be a lot of movement as well as backtracking depending on the sequence of operations required. Not only the processing, even the inputs required for different outputs could be quite different.

Even if the final product does not have excessive variety, the intermittent form is still used for the manufacture of components. This is because a large number of components are assembled into a product and the same facilities could be used in making many different components in batches. One batch of 1000 components could be produced this week and the next batch may have to be produced only after one month. By splitting into batches in this manner, a large number of different components can be produced on a common set of machines. All this is possible because the intermittent form of processing is flexible.

(*ii*) **Around Standard Operations.** The transformation processes are organised around standard operations in the intermittent form. In a bank, this would result in departments like cash, advances, deposits, savings bank accounts and so on. Any customer who wants to deposit or withdraw cash, has to go to the cash department for this purpose.

In such a scheme, each functional group is a specialised group and performs all tasks connected with that specialisation. That is why the workers need to have a width of skills so that they can perform a range of tasks—of course within the specialisation. A machine operator in a grinding shop will not be producing the same output everyday and thus besides skills in operating different types of grinding machines needs the ability to read and interpret blueprints, drawings and perhaps also the ability to 'set up' grinding machines to perform different jobs.

The amount of specialisation achieved by organising around standard operations enables the organisation to solve complex and specialised problems. Thus, a difficult grinding job is more likely to be carried out by an organisation having a grinding shop than by another having project operations or even continuous flow processing where grinding operations are also being performed.

NOTES

(*iii*) **Material Handling and In-process Inventory.** As the grouping of facilities is around standard operations, the partly processed output is to be transported *from one standard operation to another.* The amount of material handling for an output or a batch of output depends on the number of standard operations to be performed and also the distance between the locations where the operations are performed. For all the outputs of the organisation, therefore, the amount of material handling would depend on the output mix and the layout of different facilities. A great deal of effort is made to design the facilities layout so that the material handling is reduced for a targeted output mix.

Again, as the same facilities are being used for the processing of many outputs, the flow of materials through the facilities is not smooth, but interrupted. After one operation, the partly processed output or batch of outputs may have to wait if the facilities required for the next operation are busy on the processing of another output on batch. Such material is referred to as work-in-process and the consequent in-process inventory is typical in intermittent flow processing.

(*iv*) **Difficult in Management of Resources.** Since each output or batch of outputs is different, the planning and control of the operations function is very difficult under intermittent flow processing. Elaborate planning and control procedures are used so that the movement of each output or batch of outputs can be tracked and all the inputs required for a particular output or batch be made available in time. The planning and control becomes more difficult in the absence of accurate time standards as the outputs may not be repetitive.

Advantages of the Intermittent Form

(*i*) **Variety at Low Cost.** The intermittent form of processing is appropriate when we want to respond to demands of small volume and high variety. The primary advantage of this form of processing is, therefore, the ability to produce a wide variety of outputs at a reasonable cost.

The choice of machines and equipment, the skill of the staff, the layout of the facilities and all related decisions emphasise the need to have flexible operations which are also not very costly. In intermittent flow processing, general purpose machines are generally used as these are cheaper than special purpose machines, since they are in greater demand and generally available from more suppliers. Also, they are easier and cheaper to maintain and dispose of thus reducing the cost of obsolescence. Because of the diversity in outputs, all the equipment does not have hundred per cent utilisation. The cost of unutilised equipment is low, as the equipment is simple general purpose and not very costly.

(*ii*) **High Capacity Utilisation.** As facilities are grouped around standard operations, all the outputs requiring a particular operation will have to be sent to the section carrying out that operation. Thus, there will be a high capacity utilisation for equipment grouped around that operation. The cost involved in providing special environmental conditions for some operations *e.g.*, air-conditioning, dehumidifying, dust proofing etc., is also minimised as all such equipment is physically close to each other when the organisation is laid out for intermittent form of processing.

(*iii*) **Staff Advantages.** Each worker performs a complete operation under intermittent processing—*e.g.*, completing an analysis on a form, painting a component or product etc. This, complemented by the fact that the task itself is not repetitive, provides the workers pride of workmanship and increased responsibility. There is usually a high morale in the group when all the group members are similarly skilled and work in the same location.

Disadvantages of the Intermittent Form

(*i*) **More Costly for High Volumes.** The initial cost for general purpose machines, which are mostly used in intermittent processing, is low. But they are usually slower than special purpose machines and also give lower quality of outputs. The skilled operators are paid more than the semi-skilled or the unskilled. The end result being that although the fixed costs are lower for general purpose machines, the variable costs per unit of output are higher. For low output volumes, therefore, the general purpose equipment could be the cheapest as well. However, as output volumes rise, the advantage in terms of a lower fixed cost is more than compensated by a higher component of variable cost and thus the special purpose machines may offer the least cost alternative.

(*ii*) **Complex Operations Planning and Control.** The planning and control of operations is very complex for the intermittent form. When the number of jobs on the shop floor rises to high levels, it becomes almost impossible to keep track of individual jobs. Over and above the paper work involved, "expediters" are employed to reorder priorities and track down specific jobs.

The requirement of each output being different, in the absence of such detailed planning and control there may be production bottlenecks on some facilities whereas resources may remain idle at some other facilities. It is easy to see that there may be a host of reasons causing such idling of resources—*e.g.*, machine breakdown, raw material non-availability, delay in a previous operation, absent worker, non-availability of tools etc. It is the job of operations planning and control to ensure that all the inputs required for a particular operation are made available when the operation is planned.

(*iii*) **Large In-process Inventory.** Intermittent processing would always have some in-process inventory. However, as the variety of outputs and the scale of operations increase, the in-process inventory becomes large. On top of it, there will be a fast build-up of in-process inventory if there is any laxity in the operations planning and control function. This increases the space requirement of operations and also disturbs the appearance of the operations area at times making it even unsafe.

The material handling equipment used in intermittent operations is generally mobile and is more expensive than the fixed position handling equipment like chutes and conveyor belts. It also requires more space for movement thus adding to the space requirement.

New Technology for Intermittent Flow Operations

(*i*) **Computerised Production and Inventory Control Systems.** Many different types of computer packages are available which can link the input and output requirements, check with the inventory at hand and automatically raise purchase orders and also prepare different types of statements for planning and control purposes. Given a schedule of output requirements, the computer can work out the requirements of raw materials and other bought out items and can plan the procurement and production of these so that there is no hold up of production due to non-availability of materials.

(*ii*) **Integrated Computer-Aided Manufacturing.** These computer packages tie up the previous systems with mechanical systems that control machinery and material handling equipment. These packages do not carry out manufacturing of parts alone but also process planning, costing, *tool design, production planning, material* ordering etc. The rate of development in this area is extremely rapid and is also accelerating. Computers are used for both planning as well as execution of the plans.

NOTES

(iii) ***Manufacturing Resource Planning* (MRP II).** If the computerised production and inventory control systems could be linked with other planning and accounting systems of the organisation, it would result in comprehensive computer packages on manufacturing resource planning. Such a system would integrate marketing, finance, personnel, payroll and other systems and can prepare statements on funds requirement, promotional need, capacity planning and so on.

(iv) **Group Technology**

Group technology has developed over the years to become a complete philosophy rather than a single technique. The common thread running through all these techniques is the attempt to find groups which can be used in organising the transformation process. The purpose of grouping is to overcome some of the disadvantages of intermittent flow processing as outlined in previous pages and the grouping can be of component parts, machines, equipment and people.

In general, component parts are grouped into families so that the processing required for members of a family is similar. The machines and equipment are also grouped into cells so that the volumes through a cell are higher and the variety smaller. Therefore, the principles used in continuous *flow processing can be used for each of* these groups.

3A. Job Shop Technology. Multiproduct small batch production is appropriate for manufactures *of small batches of many different products each of* which customer designed and consequently requires its own unique set of processing steps or routing through. the production process. This is the manufacture of products to meet specific requirement of special orders of outside conditions.

Characteristics of Jobshop Technology. Uncertained variety of product items, variety of production process, complexity of productive capacity.

Productivity improvement by

(i) Maintaining valued job order priorities.

(ii) Reducing inventories to planned levels.

(iii) Reducing lead times.

(iv) Projecting work centre loads for capacity planning.

(v) Production planning is done in standard times. Difficulty of production planning and *scheduling.*

(vi) Useful for make to order

(vii) Assemble to order production

(viii) Long planning horizon (one year or more).

If the volume is very low, production will be done on a jobbing or slow moving basis.

A factory or m/c shop that deals with this type of *production is called a job shop.*

To overcome the difficulties involved in multiproduct small batch production in the job shop, several effective techniques have been developed. These are :

(i) Industrial Engg. (IE) emphasises the following standardization, simplification, specialization.

(ii) Group Technology

NOTES

(*iii*) Part Oriented Production (System)
(*iv*) MRP
(*v*) Lot Scheduling.
(*vi*) Modular Production
(*vii*) Flexible automation
(*viii*) Flexible Manufacture
(*ix*) On-line Production Management
(*x*) JIT.

3B. Batch technology is a setup from job shop technology in term of product standardization, yet it is not as standard as assembly line technology. Within the wide range of products in the batch facility, several are demanded repeatedly in large volumes.

The demand for a commodity is small compared with the production capacity. The product is then manufactured periodically in a quantity which will meet the demand for some time period in the interval between production runs. The production facilities may be utilized for other works in similar fashion.

Characteristics of Batch Technology

(*i*) Machines are of general purpose.
(*ii*) Material flow is complex.
(*iii*) Production planning and control is difficult.

Problems of Batch Technology

(*i*) Optimum layout planning is difficult.
(*ii*) Aggregate Production Planning

Features of Batch Production

Unlike mass production systems which tend to be organised as product layouts with machines or equipments arranged according to the product flow, batch production normally is done employing a process layout. Here similar machines or equipments are grouped in departments and different jobs will follow their own route depending on requirement. Apart from the greater flexibility afforded by process layouts as compared to product layouts some of the advantages and disadvantages of batch production are summarised below :

Advantages of Batch Production

(*i*) Better utilisation of machines is possible, consequently, fewer machines are required.
(*ii*) A high degree of flexibility exists *vis-a-vis* equipment or man power allocation for specific tasks.
(*iii*) Comparatively low investment in machines is needed.
(*iv*) There is generally greater job satisfaction for the operator owing to the diversity of jobs handled.
(*v*) Specialised supervision is possible.

Disadvantages of Batch Production

(*i*) Since longer and irregular flow lines results, material handling is more expensive.
(*ii*) Production planning and control systems are more difficult.

NOTES

(*iii*) Total production time is usually longer.

(*iv*) Comparatively large amounts of in-process inventory result.

(*v*) Space and capital are tied up by work-in-process.

(*vi*) Because of the diversity of job in specialised departments, higher grades of skill are required.

Problem and prospects of batch production

In batch production systems, the in-process inventories and the lead time tend to be large. As we have seen MRP is a vehicle to control the discrete parts production planning and also to reduce work-in process inventory. However, the drawback of MRP is that it is expensive to implement as it requires the capability of a main frame computer, technical support professionals, and MRP software. Instead of designing production control tools for a complex production system, attempts have been made to simplify the system itself. One example of this is Kanban developed in Japan and being implemented at Takahama plant of Toyota. Kanban emphasises the reduction in production lead time and in-process inventory by specifying shorter production runs of any single product. Kanban is characterised by quick change tooling to reduce set up times. Production control is decentralised. Production activity is regulated by Kanban cards. Conflicts are handled by management and supervisory intervention on the shop floor.

Another major development with respect to the complicated problems of batch manufacturing been the development of flexible manufacturing systems (FMS) in an attempts to apply computer controls to production scheduling, the control of machines and the movement of materials in a discrete parts manufacturing environment.

4. Assembly Line Technology is for facilities that produce a narrow range of standardized products.

Since product design are relatively stable, specialized equipment, human skills and management systems can be developed and dedicated to the limited range of products and volume.

A product layout often is called a production line or an assembly line.

5. Processing Industries. The processing industries *e.g.*, fertiliser, petrochemicals, petroleum, milk, drugs, etc. also use continuous processing. However, they deserve a special mention as they differ from organisations producing either discrete products or services. In general, the operations in these organisations are highly automated with very sophisticated controls, often electronic or computerised. The labour requirements are generally low and the role of the production workers is limited to monitoring and taking some corrective action if necessary. However, maintenance of equipment is very critical and the skills required in maintenance are of high order.

7.6. MATERIALS PLANNING

The process of planning, procuring, storing, handling and distribution of required materials within the organisation is termed as Materials Management.

Issues in Materials Management

As per major activity groups involved in materials management in any manufacturing organisation, several issues emerge, which need to be considered while discharging its functions ;

NOTES

(a) Issues Relating to Materials Planning

(i) **Materials Identification.** Materials management department closely and continuously coordinates with the engineering and design, production and process to help identify the materials, sub-assembly, spare parts, tool and equipments needed in the process and manufacture of end products. It provides information with respect to various options, alternative materials available/or could be made available to meet the needs of production. The engineering and design, production and process departments assess these alternatives for suitability to the design from functional point of view, from processing point of view, *i.e.*, whether it will help in easier/faster/more efficient performance of process operations ? Through meticulous assessment each of the material, component etc., is identified. This assessment is a continuous process depending on new materials, substitutes, supply conditions or internal changes in the products, process methods, designs or schedules.

(ii) **Standardisation.** Basic purpose of standardisation is to achieve interchangeability of parts/components internally in the organisation or even across industry. Second purpose is to reduce the number of varieties of parts/components uses in the production process of the organisation.

(iii) **Make or buy.** Large organisations, (even small organisations) usually are not in a position of manufacture all parts or components required to be used in the product manufactured by them.

This is because :

(a) It may not be economical to manufacture internally.

(b) In house, expertise/technical skill may not be available.

(c) Additional capital required to set up facilities for the manufacture of the component may not be available.

(d) Specialized manufacturers—suppliers of the specialized components may be operating in the market, the components of the right quality may be available at competitive rates.

From time to time it needs to be reviewed whether certain items may be more advantageously manufactured in house or to be brought from outside. Materials management activity helps the organisation in taking this decision from time to time. Engineering and design, production, finance departments etc. also join together to help to take this decision. A decision to make an item in house has long term implications because the company's funds are to be invested into fixed assets to create the manufacturing facilities. Such a decision is very difficult to reverse later on.

(iv) **Coding and Classification.** A system of classification and codification for all items/parts/components, needs to be devised and implemented. So that detailed descriptions need not be referred to every time. The code assigned to an item is uniquely identified. It should be uniformly understood by all concerned in the organisation.

(v) **Quality Specification.** Materials department, engineering and design department, production department, collectively decide on required quality standards for every item : so as to achieve the desired quality of the end product at the same time meeting the cost target to the end product. Agreed upon quality is precisely specified and becomes part of the item description and also integral part of the code used to identify the item. Usually, it is in the form of physical, chemical or performance specifications. Where Engineering Drawing or Blue prints are provided for the part, the quality specifications become integral part of such Drawing or Blue print.

NOTES

Material Requirement Planning

After inventory control concepts in 1960, a systematic comprehensive manufacturing and controlling technique. MRP-I (Material Requirement Planning) is an inventory control process carried out with the aid of computer to determine time phased requirements of components that are used for manufacturing product on assembly line principles.

If the delivery schedule for end products is known, the size and timing of the requirements of work in process items and raw materials can be planned.

MRP system—control of inventory levels

Assignments of priorities for components and determination of capacity requirements.

The master production schedule is the basis of an MRP system. Most MRPs are computerised because of the large amount of data processing that must be done.

The formulation of an MRP begins with an annual sales forecast, which is used to get an initial idea of the demand for the company's products. Each of these products is "exploded" to determine the materials and parts that will be needed to produce it.

The amount of inventory on hand is than subtracted from the total inventory that will be needed to produce it. The amount of inventory, to arrive at the amount that has to be ordered. Then the time between the placement of an order and the expected delivery date is calculated along with lead time necessary to ensure that materials and parts are received on time for production.

The forecast and the materials requirement plan often have to be revised on the basis of actual sales so that demand and supply can be kept in balance.

When system works properly, the firm can avoid costly ripple effects from either a sharp, unexpected drop in sales or delivery problem created by suppliers.

Given a master schedule of end product, MRP computes the timing of all subassemblies components and raw materials production and purchasing activities required over the specified production horizon to meet the master schedule of the end product.

When do we want to make ? How many of this end product ?

What components/sub-assemblies/raw materials are required ? How many of each of these are already on hand ? When should these be ordered ?

A master plan stating, what is to be made ? How many are needed ? and when items are needed for product ? must be developed called the master production schedule, 1960.

Limitations of manual data handling precluded applying time, net time phased MRP, explosion chart are planning tools.

MRP inputs—Master production schedule, inventory status file, production structure file, bill of materials, gross requirements.

Parts explosion requirements. Requirements for purchased and manufactured products and sub-assemblies must be determined from master schedule. This is parts explosion.

NOTES

Mfg. code				Date
Component		Quantity required	Source	Remark
Number	Description			

Approved

Fig. 7.9

Bill of Materials

Bill of materials matrix

MRP approach requires computerized data information system based on the relationship between end product and its components.

MRP Based Planning System

MRP-I (1960). It is an inventory control system, which releases manufacturing and purchase orders at the right time to support the master schedule. This system launches orders to control work-in-process and raw materials inventories through proper timing of order placement. MRP-I doesn't include capacity planning. Henceforth the terminology MRP-I and MRP will be used interchangeably.

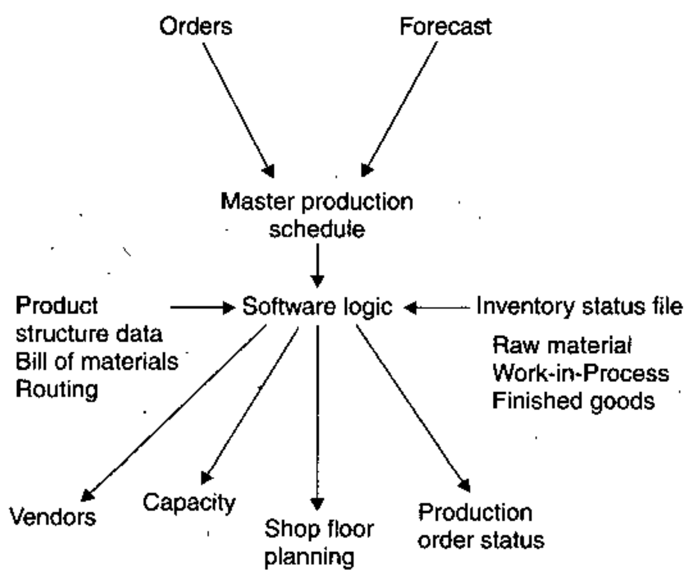


Fig. 7.10

7.7. PROCESS PLANNING

Process planning consists of

(1) Process Selection

(2) Operation Process Planning.

1. Process Selection

Unit cost of manufacturing

Quality and uniformity of the product

Quantity of manufacturing envisaged.

Large number of manufacturing processes are available :

(*a*) CAD Computer Aided Drafting and Designing/CAM/CAE

(*b*) CNC/DNC, Group Technology

(*c*) Computer Integrated Manufacturing (CIM)

(*d*) Flexible manufacturing system

(*e*) Automation robotics.

Selected process should be based on

(*a*) Quantity and quality of men *i.e.,* skills

(*b*) Investment cost, operating cost

(*c*) Production quantities, capacity

(*d*) Flexibility change in product design

(*e*) Lead time

(*f*) Efficiency—utilization of equipments, jigs, fixtures.

Process selection is an adaptation.

The transformation process selection is a complex decision because of the existence of so many tradeoffs, many of which are interdependent.

Process selection and the environment

(*i*) New materials

(*ii*) New technology—Group technology, Autonomous working

(*iii*) Competitors.

Process planning establishes the methods and means of co
material to a finished part.

The subsystem responsible for the conversion c

The function within a manufacturing facilit
rameters to be used in order to convert a piece-pa
that is predetermined on a detailed engineering

NOTES

Drawings and specifications of what to make
↓
Assembly charts and flow charts
↓
Make or Buy decision
↓
Make
↓
Process decision
↓
Route sheet and operation sheet
↓
Work place and tool design

Fig. 7.11

For each part a detailed routing a developed.

Requirements of Process Planning

The following principal data and information are required to plan a manufacturing process :

1. A brief description of the job to be manufactured which clearly and comprehensively defines its service function.
2. Specification and standards that stipulate the service function.
3. Working drawing of the job with complete specification.
4. Drawing of the blank.
5. Data on the quantity of parts to be manufactured in a period.
6. Total quantity of spare parts required for each unit.
7. Equipment data that includes specifications and capacity data of machine tools, and other, available equipments, the data concerning the arrangement and loading of equipment in the shop.
8. Conditions under which production engineering and manufacturing are to be organised and accomplished *i.e.,* whether a new or existing plant, available equipment in the plant, possibility of obtaining new equipment etc.
9. Location of the plant.
10. Availability of manpower to staff the plant.
11. Date of starting the work and date of delivery.

Process Plannin... tion

It is ... constitute a department or may have subgroup.

S... The purpose of process planning is to determine ... to produce a part. In order to accomplish these ... followed :

takes in the drawings.

5. To determine what parts to be purchased with their complete identification and required quantity.
6. To prepare a list of raw materials of right quality and quantity to be purchased from outside giving their shape, size and special property.
7. To select the most economical process for obtaining the blanks, and to determine the quantities to be produced for the purpose of costing.
8. To determine the most economical process for manufacturing the parts keeping in view the current production commitments, delivery date, quantity to be produced and the quality standard.
9. To determine the best sequence of operation to be performed on each parts in a particular process.
10. To select the machine tools that will perform the operations with required accuracies.
11. To select the any other accessories and equipments like jigs, fixtures, dies, gauges etc. that may be required to give higher production rate.
12. To layout the equipment and workpieces, calculate machine loads and make necessary corrections in the process.
13. To revise the process to correct all mistakes and shortcoming that where discovered when the process was realised in actual production.
14. To determine the stages of inspection, inspection procedure and limit gauges required for different stages of manufacture to inspect accurately and at a faster rate.
15. To determine the set up time and standard time for each operation and fix up the rate of payment.
16. To determine the kind of labour of successful execution of the job.
17. To determine the estimated cost of the product to see whether or not that will complete in the sales market.

It is worthwhile to mention that process planning is a dynamic process and the planners are continuously engaged in making their product more and more useful and economical to their customers by reducing material cost, tooling cost, labour cost or any other cost that may involved in the process.

Important Steps

1. Manufacturing specifications. The chief documents in which manufacturing specifications are listed is the detail drawing. The drawing specifies :

(*i*) dimensions and machining accuracy with permissible deviation from the proper geometrical form.

(*ii*) accuracy in the co-ordination of various surface with permissible deviation.

(*iii*) Places subject to heat treatment and type of heat treatment required.

(*iv*) Surface quality.

(*v*) Machining method required to obtain the specified surface finish, if necessary.

(*vi*) Places of protective coating with the type and thickness of this coating.

(*vii*) Locating place for measurement of dimensions on finished part.

(*viii*) Special inspection procedure such as X-rays, hydraulic tests, when required.

2. Determination of the blank size. Process planning actually starts with the selection of blanks. The blank or basic parts may be obtained by processing raw mate-

NOTES

rials by casting, forging, welding, rolling, extrusion, etc. which are called primary operations. The size, shapes and weights of parts, its material, the scale of production, how frequently repeated batches are to be manufactured, the amount of machining allowances and the accuracy determine the method of manufacturing the blank.

3. Selection of machine tools. The selection of machine tools is largely determined by the choice of the method or process of a machining part. Even though it is difficult to formulate a definite rule for selecting the machine tools for any case of machining, the following factors must be considered in selecting a machine tool for a particular operations :

1. Size, shape and material of the workpiece.
2. Accuracy and surface finished required.
3. Required output and production capacity of the machine tool.
4. Power of the machine tool to know whether it is sufficient for performing the operation or not.
5. Performance of the operation to know whether it is economical or not.
6. Ease and convenience in operating the machine tool.

For small quantities, general purpose machine tools are more economical, while for greater quantity, special purpose machine tools are preferable as they can reduce the manufacturing costs considerably.

The power of machine tool is also a decisive factor in its selection. A machine tool of small horsepower is unsuitable for doing a heavy job which calls for a machine tool of large horse power.

The economic consideration is perhaps the most important factor in the selection of machine tools. As a rule, the number of machine tools performing a single operation in a continuous flow mass production should not exceed two or three.

Availability charts. The availability chart is a list of machine tools arranged according to their classes *e.g.*, engine lathes ; Turret lathes, automatics and the like giving their identification and model number, location, general condition, tooling available, cutting speeds and feeds etc. This availability chart is necessary in selecting machine tools for a new product in an existing plant.

Machine load charts. It shows which machine is remaining idle and which one is loaded. Accordingly, the process planner will select the particular machine tool which may be used to perform the machining operation. Process planner is not so much concerned with machine load chart as the production planner is.

Capability charts. The capability may be defined as a chart which shows the ability of a machine tool of doing the work. A machine tool, like any other machine, do not remain in the same condition as purchased due to wear and tear in use, and they loose their accuracy in the long run. The capability chart which shows the present condition of the machine is a guide to the process planner in making his choice of the proper machine.

4. Planning the operation sequence. Both product cost and product quality are closely related to operation sequence. A different sequence of operations performed will result in different operational times, different transportation time to the work centre, different tooling in view of different locating and clamping surface.

If a new plant is set up for a product, the process planner has much more freedom in determining the sequence of operation that may be best suited for purpose. In case of an existing plant the operation sequence for a new product is to be determined on the basis of available equipment and loading condition of the equipments. In the latter case the process planner must be provided with the following information :

1. List of available machines.
2. List of available general purpose tooling.
3. Capability of equipments.
4. Machine load charts.
5. Standard data.

However, in any case, there are certain fundamental principles which must be followed in planning the optimum operation sequence. These are :

(*i*) First the datum surfaces should be selected with due attention. The selection of datum influences all subsequent machining operations and inspections. A surface which is to remain unmachined should be selected as the first setting up datum surface only in the case of first machining operation.

(*ii*) Surface, whose machining will not reduce the rigidity of the work to any appreciable extent, should be machined earlier in the sequence.

(*iii*) Internal operations are performed in advance of external operations. The principal reason for performing internal operations early is that internal surfaces are less likely to be damaged in material handling and subsequent processes so their surfaces can be completed more early in the sequence. Another reason is that internal surfaces frequently provide a better means of holding the work and thus help to ensure concentricity between inside and outside diameter.

(*iv*) The operation in the sequence should begin with removing largest layer of metal. Removing thick layers by heavy cuts will reveal internal defects in the raw materials much more readily than light cuts. The workpiece is also relieved of internal stresses which eliminate the danger of warping in subsequent operations. The large cutting and clamping forces that may be associated with heavy cut affect the accuracy of finished surfaces of another part of the same workpiece call for those machines which are intended for roughing operations. Further more, heavy cuts involving coarse or rough finishes are usually faster with less expensive workmen than fine finishes.

(*v*) Operations, in which an increased number of reject is to be expected due to revealing of defects as stated above, should be performed as near as possible to the beginning of the machine sequence.

(*vi*) Finishing operations should be performed at the end of the operation sequence to reduce danger of damaging finished surfaces, of changing their dimension and co-ordination in reference to other surfaces of the part.

(*vii*) Roughing and finishing operations should be done on separate machines so that accuracy of machines intended for finishing is not disturbed by heavy loads in roughing works.

(*viii*) Inspection stages should be introduced (*a*) after roughing (*b*) before operation which are to be performed in other shops and departments (*c*) before laborious and important operation (for example, before preparing datum surfaces) and after them, and (*d*) after the last machined operation.

(*ix*) The sequence of machining operation should be co-ordinated with heat treating operations which are of vital importance in the manufacture of the machine parts.

NOTES

5. Process Planning Sheet. Process planning sheet is a detail record where all information relating to different operations needed to manufacture a part are listed in tabular form. This is also known as analysis sheet, instruction sheet, operation sheet or process design sheet. An example of a process sheet is given in Fig. 7.13.

The description of the operations and their elements indicated in the process sheet should give extremely concise but comprehensive information on what is to be done and why. The data should clearly indicate how and with what the job is to be done and if possible, the time expenditure it will require.

The form of such sheet may vary for different production conditions. The character of a process sheet will depend mainly on the scale of production and the degree of importance of the product being manufactured. Further more, different types of sheet are used in manufacturing concerns which are already in operation and in organisation designing new plants.

Information available on process sheet

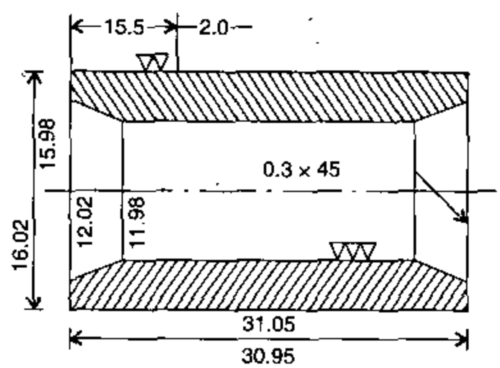
In majority of cases, however, the following informations are listed in process sheet :

1. Information concerning the workpiece which includes name, drawing and service function if possible.
2. Information concerning the blank which includes material, size of stock when used as a blank character etc.
3. Description and number of operations and those of their elements.
4. Information concerning the manufacturing equipment such as machine tools, auxiliary equipments, attachments and accessories etc.
5. Data on jigs, fixtures and tools such as description, sizes or code numbers.
6. Elements of standard time such as setting time, handling time and machining time etc.
7. Job rating of the worker for each operation.

Process sheet example for machining a bush bearing

Example. Prepare a process sheet for machining a bush bearing.

In planning manufacturing processes for machining operations frequently operation sketches are drawn for various operation as shown in Fig. 7.12. The surfaces that are to be machined are indicated on the sketch together with dimensions giving tolerance desired.



(a)

NOTES

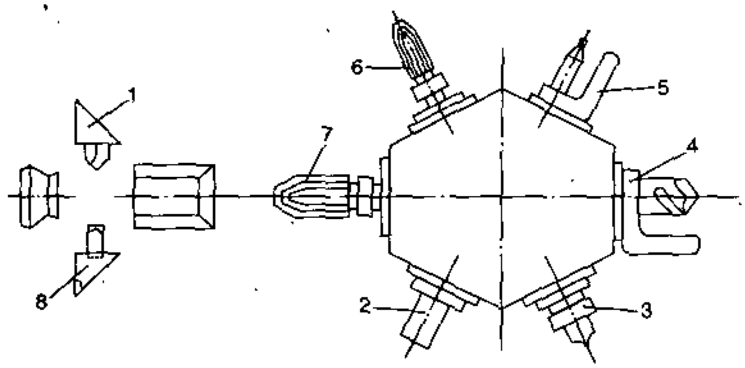


Fig. 7.12

Typical Process Sheet

Plant......									Department......
Program No.	Party Name							Issue Dates	Part No. Release sheet of
For models	Material				Wt/kg RGH FIN				
Oper. No.	Operation description	Tool-M/C Equip Description	M/Cs required	Net hourly capacity	Est. minutes	Facility tool	Durable cost	Special tool cost	Expense cost
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
10	Drill (3) locator holes 10ϕ, 30 deep	Single spindle drill press locating fixture required	1	16	3.75				
Total									
Remarks									
	Process Engineering	Plant layout	Design	Material Engineering	Daily service	Required per vehicle	Next Ass.	Oper No.	
	Ind. Engineer	QC Contr.	Plant Engineer	Production	Daily Plant planning volume	Req. mts PC/hr	Supersedes		

T—*Total* +T—Total
B—Basic D—Design
F—Freight BL—Build
I—Installation IT—Inst. tryout

Fig. 7.13. Typical Process Sheet.

7.8. INVENTORY CONTROL

NOTES

Inventory is simply a stock of physical assets having some economic value, which can be either in the form of material, money or labour.

This can be in the form of physical resource such as raw materials, semi finished goods, bought out products used in the production and assembling operations.

Finished products ready for delivery to consume human resources such as unutilised labour, financial resources such as working capital etc.

The present concept of inventories has necessitated the use of scientific techniques in the management of inventories known as inventory control.

Inventory control is the technique of maintaining stock-items at desired levels.

Inventory control is the means by which material of the correct quality and quantity is made available as and when it is required with due regard to economy in the storage costs, setup costs, manufacturing costs, purchase prices and working capital.

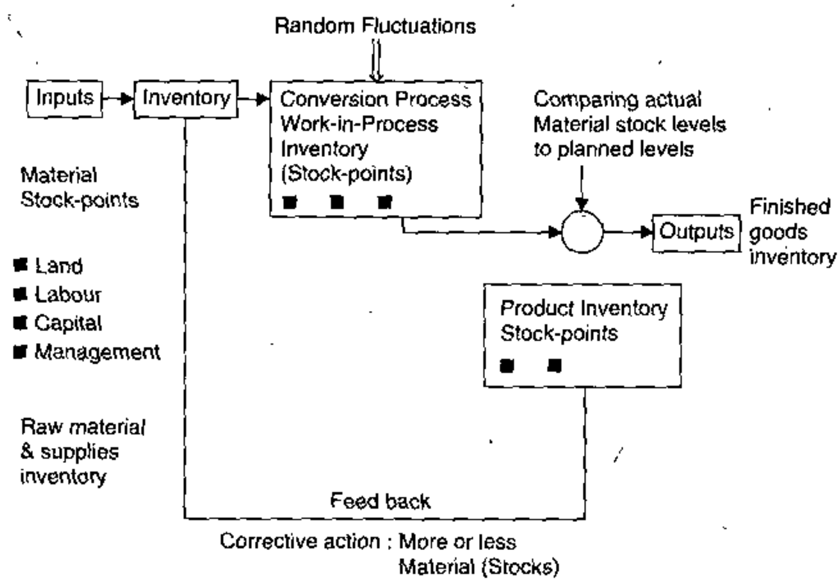


Fig. 7.14. The materials conversion process.

As inventory is an essential part of any organisation, it consists of many items running into thousands. Systematic management and control of inventory for all the items is a challenging job. Main advantages of inventory control are :

— To maintain the overall investment in inventory at the lowest level, consistent with operating requirements.

— To supply the product, raw material, sub-assemblies, semi-finished goods, etc. to its users as per their requirements at right time and at right price.

— To keep inactive, waste, surplus, scrap and obsolete items at the minimum level.

— To minimize holding, replacement and shortage costs of inventories and maximize the efficiency in production and distribution.

— To treat inventory as investment which is risky. For some items, investment may lead to higher returns and for others less returns.

STUDENT ACTIVITY

1. Write the process of manufacturing in your organisation ? This is mass scale production/job production/batch production.

2. Write about production planning.

3. Write about process planning.

4. How inventories are controlled in your organisation ?

SUMMARY

1. This chapter deals with production planning and control. What is Production ? What is Production Planning ? What is Production Control ? What is Action Planning ? What is Preplaning ? What is Product Planning ? What is routing, sequencing, scheduling, estimating, dispatching, follow up, reporting, inspection, evaluating. There are production system—mass scale, intermittent job and batch, project, assembly line, process industries. For any industry raw materials an needed. Before starting production we must decide make or buy. Continuous supply of raw materials of correct quality and quantity at proper time is necessary. Storage of materials is necessary. Quantity of material storage is important decision. Now software an available manufacturing resource planning MRP-II, material requirements planning MRP-I. Process planning is necessary for intermittent industries. For purchasing materials economic order quantity concept is available. Large number of EOQ models an available. Running an industry proper planning and control is necessary.

TEST YOURSELF

1. What is PPC ? What are objectives of PPC ? What is the scope of PPC ? Why PPC is significant ? What are advantages of PPC ? What are limitations of PPC ?
2. Write about PPC department.
3. Write about Product planning.
4. Write about Routing and sequencing.
5. Write about scheduling, estimating, dispatching follow up, inspection, evaluating.
6. Write about Mass Production, Job production, Batch production.
7. What is Materials Management ? What are issues in Materials Management ?
8. Write about Materials planning.
9. Write about MRP-I Software.
10. Write about Process Planning Sheet.
11. What is inventory ? What is Inventory Control ? What are its advantages ?

OBJECTIVE TYPE QUESTION

1. The production system whose facilities are arranged according to sequence of operations and the whole system is cascaded is known
   (*a*) Mass production or flow line production system
   (*b*) Batch production
   (*c*) Job shop
   (*d*) Unit Manufacturing.
2. In produce to order type of transformation process
   (*a*) Production process starts after receiving the sales orders in quantity
   (*b*) Production process starts much before the sales order
   (*c*) The quantities are already in stock before receiving the order
   (*d*) None of the above.

NOTES

3. Material flow is must smooth in
   (a) Job shops (b) Projects
   (c) Batch production (d) Mass production.
4. Mass production is suitable for
   (a) Low volume of production (b) Large volume of an production
   (c) Job shop production (d) Ship building.
5. Which of the following processes is generally characterised by high volume and low unit costs
   (a) Intermittent flow process (b) Continuous flow process
   (c) Project form (d) All of the above.
6. Batch Production requires
   (a) More investment in machines (b) More number of workers
   (c) Less investment in machines (d) Less production time.
7. Henry Ford introduced the nation of mass production in year
   (a) 1903 (b) 1907
   (c) 1913 (d) 1879.
8. Inventory control answer
   (a) Where to order (b) How much to order
   (c) When to order (d) Both (b) and (c).
9. The main objective of inventory control is
   (a) To keep inactive item at maximum level
   (b) To maximise inventory holding cost
   (c) To maintain investment in inventory at lowest level
   (d) To maintain inventory at zero level.
10. The following function is a compulsory function of PPC department
   (a) Manufacturing (b) Recruitment
   (c) Inspection (d) Routing.
11. The objectives of PPC is
   (a) To assist the production manager to achieve the target efficiently
   (b) To formulate industry's organised policies
   (c) To keep strict quality control
   (d) To advise managing committee to decide about means of financing the engineering enterprise.
12. The major factor in preproduction planning function is
   (a) Determination of plant design
   (b) Selection and recruitment of employees
   (c) Raising capital
   (d) Selection of factory site.
13. Long range planning is usually for a period
   (a) 6 months (b) 1 year
   (c) 2 years (d) More than 2 years.
14. A PPC department is meant
   (a) To make the desired part
   (b) To assemble the various parts into a product
   (c) To help make up master production schedule.

15. Which section of PPC department needs feedback for making remedial action
(a) Scheduling (b) Evaluating
(c) Estimating (d) Expediting.

16. Preplanning stage is concerned with
(a) Forecasting and product design
(b) Process planning and routing
(c) Determination of requirements and control of equipment and manpower
(d) Determination of when work is to be done.

17. Routing refers to
(a) Sequence of operations (b) Flow of work in the plant
(c) Layout (d) None of the above.

18. Loading is defined as
(a) Assignment of work to a facility
(b) Assignment of work to facility and the specification of the time and the sequence in which the work is to be done
(c) Transfer of goods load from one work station to the other work station
(d) None of the above.

19. Scheduling is
(a) Time phasing of loading (b) Execution of the planning functions
(c) Flow of work is the plant (d) None of the above.

20. The following function of PPC is a control function
(a) Estimating (b) Cost control
(c) Forecasting (d) Expediting.

21. Progress reporting as PPC function refers to
(a) Transmission of the information of accomplishments by the operating facility to the planning group and the interpretation for necessary corrective action
(b) Transmission of the information of sales achievement and increase or decrease in the sales of the product to the planning group and necessary corrective action
(c) Preparation of report of progress made by the industry during previous year and preparation of forecast on its basis
(d) None of the above.

22. Dispatching function of PPC refers to
(a) Dispatch of finished goods in order
(b) Movement of in-process material from shop to shop
(c) Authorizing a production work order to be launched
(d) Dispatch of bills and invoice to the customer.

23. Evaluating function of PPC refers to
(a) Value analysis of the product
(b) Evaluation of past experiences with a view to improve utilization of methods and facility
(c) Estimation of unit cost of the product
(d) Evaluating the performance rating of the workers.

24. Inspection refers to
(a) Control of Quality (b) Control of manual machine

NOTES

(c) Inspection of schedules

(d) Inspection and preventive maintenance of machines and equipments.

Yes/No Type Questions

NOTES

1. Master schedules provides detailed job information.
2. Machine load records tell how fast the machine can run and what size of products to run on them.
3. Once production has been scheduled it is visually impossible to add rush order jobs.
4. Dispatching is the act of giving production instructions to the factory.
5. Stock chasers are sometimes substituted for progress reports.
6. Production control's plans are made out as if nothing will go wrong but the total production time is not scheduled.
7. One of the main job of production control is to expedite orders.
8. Order control is the production control method used in the continuous type of manufacture.
9. Manufacturing capacity of a plant does not affect the schedule

Fill in the blank

1. *Scheduling means* .... *and in* .... sequence and given task will be performed.

True and False Type Questions

1. The continuous form of processing is the most economical when the system requires flexibility.
2. Special purpose equipments are more likely to be affected by obsolescence than general purpose equipments.

CHAPTER

8

INSPECTION AND QUALITY CONTROL

LEARNING OBJECTIVES

- Introduction to Inspection
- Need of Inspection
- Inspection Stages
- *Systems of Inspection*
- Operator Inspection
- Inspector Inspection
- Inspection Planning
- Introduction to Quality
- Quality Control (1920)
- Statistical Quality Control
- Quality Assurance (1960)
- Total Quality Management
- Acceptance Sampling
- Process Control
- Process Capability

8.1. INTRODUCTION TO INSPECTION

Inspection means checking and measuring of all materials, products at various stags during production and after production is completed.

Inspection is the act of comparing with some established standard.

Inspection is defined as to examine carefully especially for flaws.

Inspection falls into—visual human eye

Scale measurement

Microscope examination

Testing of materials and components

Metallurgical examination

Chemical examination

Sensory (touch, smell, taste) etc.

Inspection evaluate the product to see whether it fulfills the quality requirements and then decide to accept, reject or, rework.

NOTES

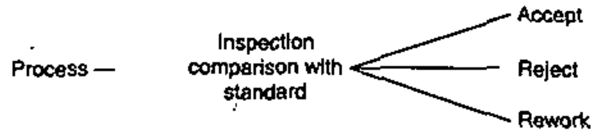


Fig. 8.1

Benefits—

— To evaluate the degree of conformance to specifications.

— To report deficiencies in the production process.

8.2. NEED OF INSPECTION

Is to ensure that the parts conform to the established standard-accepted.

To meet the interchangeability of manufacture.

To satisfy regulatory requirements.

8.3. INSPECTION STAGES

(*i*) **Incoming materials**/Bought out parts/Semi finished products.

(*ii*) Stage inspection during manufacturing—to prevent defective product flowing down the succession operation and prevent loss of yield.

(*iii*) At the completion of processing of parts.

(*iv*) Before shipping the find assembled product to the customer—to meet customer requirements in case of final inspection.

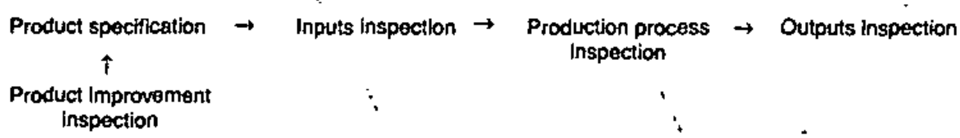


Fig. 8.2

Process inspection — First piece inspection

— Periodic inspection

— Last piece inspections

8.4. SYSTEMS OF INSPECTION

1. **Floor inspection.** The inspection of product when it is coming out of the production line. Inspection is carried out at the manufacturing site/place.

Advantages of floor inspection

(*i*) Production error are detected at the start.

(*ii*) Waiting for inspection is reduced.

(*iii*) Reduces material handling of parts.

NOTES

Disadvantages of floor inspection

(*i*) Inspection of high accuracy is not possible.

(*ii*) Inspection has to carry his own kit for inspection.

(*iii*) Shop conditions distract inspection work.

(*iv*) Inspection can be influenced by workers.

(*v*) Supervision of inspectors difficult.

2. **Petrol inspection.** Petrol inspector walks around on the shop floor from one machine to another machine and checks the parts made by the machine operators. If parts are defective then defective machines are stopped for adjustment. Negligence on the part of worker also comes in light.

3. **Centralised inspection.** Inspection is carried out in separate cabin. The components are brought to cabin. Highly precesion instruments can be used.

Inspection results are more accurate. The Inspector works in a free atmosphere and is not disturbed by the interference of the workers.

Advantage

(*i*) Accurate results

(*ii*) Species type of tests can be performed.

Disadvantages

(*i*) The material handling is increased.

(*ii*) The report from inspection room will take some time to reach the manufacturing department.

(*iii*) Unsuitable for heavy parts.

4. **Combined Method.** The generalised inspection is done at the floor itself. Heavy parts can also be inspected at the floor.

Thorough Inspection can be done at centralised inspection.

8.5. OPERATOR INSPECTION

Operator himself carries out the inspection during manufacturing. It helps in taking corrective action rapidly. This results in the reduction of defects occuring. Operator inspection can also make the operator job more interesting. Operator feel proud of the work which he knows and those processes he is familiar with besides giving a sense of ownership it also gives him a sense of fulfillment.

Training includes attitude change, technical class room training and on the job practical training. Workman understand the test procedures and perform these tests regularly and accurately.

8.6. INSPECTOR INSPECTION

Inspection done by inspector depends on.

(*i*) **Inspector's personal character.** Technical aptitude, eye sight, colour discrimination, intelligence, inspection attitude etc.

NOTES

(*ii*) Nature of the inspection task and the environment in which inspection is carried out—Nature of inspection work, fraction defective–inspector accuracy increases with fraction defective. The alloted inspection time, inspection equipment, lighting and inspection procedure.

(*iii*) Responsibility and behaviour at the inspection place.

Inspectors relation with supervisor, operators.

(*iv*) Working conditions.

(*v*) Selection and training of inspection person.

Selection Criteria for Inspector

(*i*) Expereience (*ii*) Skill/knowledge (*iii*) Communication (*iv*) Interest in growth and learning (*v*) attitude (*vi*) Restriction (*vii*) Education (*viii*) Tact fullness. (*ix*) Training required (*x*) consistency of goals (*xi*) Reliability.

8.7. INSPECTION PLANNING

Inspection requirement

Selection of type of inspection for different stages in the production flow

Inspection operation in detail

Inspection work place

Processing inspection equipments

Frequency of inspection

Inspection quality

Disposition of inspected parts.

8.8. INTRODUCTION TO QUALITY

You all must have come across the word **quality** in different contexts. All of us look for good quality in goods and services. We all realise the fact that the major achievement of industrial revolution has been the ability to mass produce a variety of goods of uniform quality, the classic example being the automobile. You will agree that the characteristic which sets apart Japanese goods as a superior class, is precisely their quality.

Even though we all talk of quality, it is not easily defined. Before we give definition, it will be a good idea to give your own definition.

(*i*) One of the accepted definitions of quality is **fitness for use,** (*ii*) An equally good definition is **conformance to requirements.** Not that in both the definitions quality is defined relative to use, rather than as a general characteristic that may be intangible. By this simple, yet practical definition, if a product lives up to expectations, it is of high quality. On the other hand, extra fine finish or using materials that are far stronger than required does NOT add quality to an item unless it somehow causes the item to conform to its requirements better. To appreciate the definition of quality, try the following activity.

You will notice that the same item may be perceived to be of quite different quality based on individual perception of end users. You should always keep this point in mind.

8.9. QUALITY CONTROL (1920)

NOTES

Is defined as that Industrial management technique by means of which products of uniform acceptable quality are manufactured.

Quality control is the technique of management for achieving required standard of products.

Quality control begins with assessment and includes action taken to eliminate unacceptable quality. The typical quality control programme is based on periodic inspection followed by feedback of the results and changes or adjustments whenever necessary.

Objects of QC

(*i*) To decide about the standard of quality of a product.

(*ii*) To take steps so that goods below standard may not reach to the customers.

(*iii*) To take measures to improve the standard of quality of product.

(*iv*) In case of deviation of quality, various steps to be taken to check the deviation.

Advantages of QC

(*i*) Quality of product is improved.

(*ii*) Uniformity in quality can be achieved.

(*iii*) Efforts are made for reducing the wastage and scraps etc.

(*iv*) Inspection cost is reduced to a certain extent.

8.10. STATISTICAL QUALITY CONTROL

When statistical techniques are used to control quality it is known as statistical quality control.

The fundamental basis of SQC is the theory of probability.

Application of statistics and sampling theory in an productive environment.

The techniques of applying statistical methods based upon the theory of probability to quality control problems with the purpose of establishing quality standard and maintaining adherence to those standard in the most economical manner.

Why SQC ?

(*i*) Fractional output inspection is Sampling inspection.

(*ii*) Cost of Inspection reduced.

(*iii*) It requires less time and less boredom.

(*iv*) Specifications can be predicted for future.

(*v*) Can be used where destructive testing is needed.

(*vi*) Early detection of faults.

Advantages

(*i*) It gives an early warning of defects.

(*ii*) Rework and scrap minimized.

(*iii*) Cost of inspection reduced.

(*iv*) Less boring activity.

(*v*) Give accurate prediction.

Techniques used in SQC
(i) Sampling inspection
(ii) Control charts

NOTES

8.11. QUALITY ASSURANCE (1960)

Includes Quality control.

It also refers to emphasis on quality in the design of products, processes and jobs and in personal selection and Training.

It means assuring conformity of quality to be required specification.

The benefits that accure from the application of quality assurance Engg. are

(i) Lower unit costs
(ii) Better quality of product
(iii) Better moral of employees
(iv) Higher productivity.

The main purpose of QA is to assume that the product is fit for use.

A QA system is an effective method of attaining and maintaining the desired quality standard. QA system can be broken down in to 10 subsystems.

1. Management of the quality system 2. Product quality and reliability development 3. Product and process quality planning 4. Supplier quality assurance 5. Product and process quality evaluation and control 6. Special quality studies 7. Quality information feedback 8. Quality measurement equipment 9. Quality training and manpower development 10. Field quality evaluation and control.

8.12. TOTAL QUALITY MANAGEMENT

The term total quality control was coined by AV Feignbaum in 1983 Japan.

TQC—An effective system to integrate the quality development, quality maintenance and quality improvement efforts of various groups so as to enable production most economical for greater customer satisfaction.

The quality of a product extends over its entire life. We purchase a product. It continues right up to the time the product has served its useful life and scraped. This complete span of product life is covered by total quality. Total quality accomplish the business goals by designing, manufacturing and supplying products to achieve customer satisfaction at an economical level.

TQC was latter become TQM

TQM is a building, housing QA system. The foundation of this building is quality consciousness of employees walls of this building are employees involvement and Commitment, roof of this building in quality policy of the top Management.

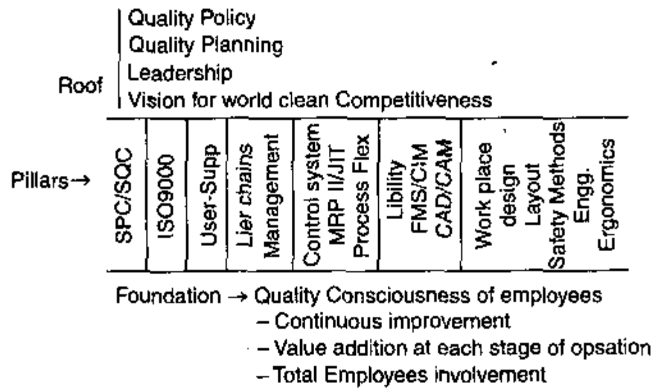


Fig. 8.3

TQM involve consideration of all major areas of production activities such as Engg. design developement, sales marketing information system, purchasing, service *distribution etc.*

TQM approach—**Process improvement**—Process ownership, team work—Participative Management, Quality orientation → Profit orientation, eliminate failure mode.

Ideas encouraged by employees, trained. Employees involvement, empowerment, Management is to guide coach integrate—encourage people to take initiare, worker job is to think plan and Implementing cooperation. Top management committment, vandors partnership, continuous quality improvement—Quality planning.

Total Quality Management (TQM)

Total = Quality involves everyone and all activities in process

Quality = Conformance to requirements (Meeting Customer requirements

Management = Quality can and must be managed.

TQM = A process for managing quality; it must be a improvement in *everything we do.*

TQM Compared to ISO 9001

ISO 9000 is a Quality System Management Standard. The ISO Quality standard sets in place a system to develop; implementation is a basis for a Total Quality Manage system, about 75 percent of the steps are in place for considered ISO plus. Customer satisfaction implementing (2000). TQM is being proactive concerning quality.

TQM as a Foundation

TQM is the foundation for activities which include;

- Meeting Customer Requirements
- Reducing Development Cycle Times
- Just In Time/Demand Flow Manufacturing
- Improvement Teams
- Reducing Product and Service Costs
- Improving Administrative Systems Training

Ten Steps to Total Quality Management (TQM)

1. Pursue New Strategic Thinking
2. Know your Customers
3. Set True Customer Requirements

NOTES

4. Concentrate on Prevention, Not Correction
5. Reduce chronic waste
6. Pursue a Continuous Improvement Strategy
7. Use Structured Methodology for Process Improvement
8. Reduce Variation
9. Use a Balanced Approach
10. Apply to All Functions

Principles of TQM

The Principles of TQM are as follows :

1. Quality can and must be managed.
2. Everyone has a customer and is a supplier.
3. Processes, not people are the problem.
4. Every employee is responsible for quality.
5. Problems must be prevented, not just fixed.
6. Quality must be measured.
7. Quality improvements must be continuous.
8. The quality standard is defect free.
9. Goals are based on requirements, not negotiated.
10. Life cycle costs, not front end costs.
11. Management must be involved and lead.
12. Plan and organize for quality improvement.

Processes must be managed and improved! This involves

- Defining the process
- Measuring process performance (metrics)
- Reviewing process performance
- Identifying process shortcomings
- Analyzing process problems
- Making a process change
- Measuring the effects of the process change
- Communicating both ways between supervisor and operator

Key to Quality

The key to improving quality is to improve processes

All people work in processes.

People

- Get processes "in control"
- Work with other employees and managers. Managers and/or Supervisors Work on Processes
- Provide training and tool resources
- Measure and review process performance (metrics.)
- Improve process performance

NOTES

TQM Process Improvement a **PLAN** (PLAN A CHANGE)		
DEFINE THE PROBLEM	**IDENTIFY POSSIBLE CAUSES**	**EVALUATE POSSIBLE CAUSES**
1. Recognize that What you are doing is a "PROCESS" 2. Identify the commodity being processed. - Process Inference 3. Define some measurable characteristics of value to the commodity. 4. Describe the "PROCESS" • Process Flow Analysis's • Flow charts • List of steps 5. Identify the "Big" problem • Brainstorming • Checklists • Pareto analysis	6. "BRAINSTROM" What is causing the problem. 7. Determine what past data shows. • Frequency distribution • Pareto charts • Control charts — sampling	8. Determine the relationship between cause and effect • Scatter diagrams • Regression analysis 9. Determine what the process is doing now • Control charts — sampling

8.13. ACCEPTANCE SAMPLING

One of the powerful statistical techniques of quality control is Acceptance Sampling. This technique is generally used in those situations where items are inspected in batches, generally known as **lots.** For example, you may receive a shipment of 10,000 electric bulbs and you may have to decide whether to accept the shipment or return it back to the supplier. The acceptability will depend on the acceptable quality of the lot,

NOTES

which in turn depends on the use and the price you are willing to pay for this quality. Suppose you decide to accept if the average fraction defective is less than 5 percent. Then to ascertain the actual quality you may decide to inspect each and every bulb. Such a strategy of **100 percent inspection,** however, may often be expensive and impractical. In such cases a more intelligent way is to use the concept of **Sampling Inspection.** Sampling means drawing a small number of components for inspection out of a large size batch.

The idea of **sampling inspection** is to inspect only a small portion of the lot and **infer** the quality of the lot, based on the quality of the sample. Acceptance is based on the inference made from the sample and hence the technique is known as Acceptance Sampling. Typically a lot is specified by its size (N) and the fraction (f) of defectives that are expected to be present (at the most) in the lot. The principles of statistics are used in the inference process.

Interestingly the concept of acceptance sampling is not different from the strategy adopted by a typical housewife who decides whether or not a pot-ful of rice is cooked by inspecting just a spoonful of grains.

Two things must be kept in mind. In order that sampling inspection might work, the sample must be **representative** of the lot. Typically this is ensured by choosing the sample at random so that every portion of the lot has equal representation in the sample. Such a sampling is known as **Random Sampling.** Second, a sample is only representative and not identical (in characteristic) with the lot. In the inference process, therefore, a few good lots will be rejected and a few bad lots will be accepted. We can control such **sampling errors,** but they cannot be eliminated. In fact in the design of **sampling plans** we will ensure that the errors are kept below certain acceptable levels.

Sampling Plans

We will first consider a **single sampling plan** in which accept/reject decisions are based on the results of a single sample of n items from the lost n items. Each of the n sample items is inspected and categorised as either **acceptable or defective.** Such a plan is known as **Sampling by Attributes.** If the number of defective items in the sample exceeds a pre-specified cut off level, c, the entire batch is rejected. (Depending on costs, a rejected lot may be scrapped, 100 percent inspected or returned back to the manufacturer). Since a finding of c or fewer defective items in the sample implies accepting the batch, c is often referred to as the **acceptance level.** A Sampling Plan is specified by the values of n and c.

The sampling plan is supposed to separate good lots from bad lots. As mentioned earlier there are bound to be sampling errors. We will now study the probabilities of such error graphically, using an **Operating Characteristics Curve.**

It is useful to have a simple picture that allows us to compare sampling plans as to how they will react to different lots with **unknown, varying** fraction defective. Such a comparison is provided by the **operating characteristic curve** (OCC) which displays the probability *of accepting a lot with any fraction defective.*

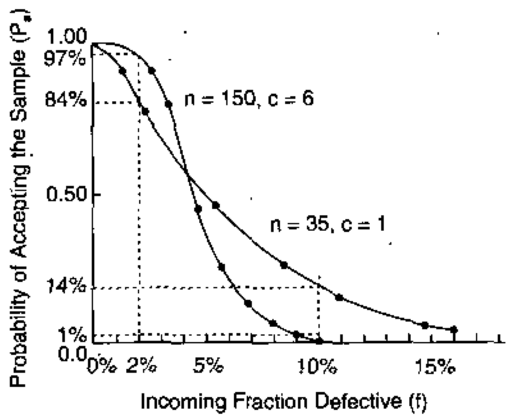


Fig. 8.4. *Operating Characteristics Curve*

Figure 8.4 shows OCC for two single sampling plans A and B with $n = 35$, $c = 1$ and $n = 150$, $c = 6$, respectively. *For example, suppose that a lot with F = 10 percent* defectives is considered to be a bad lot and a lot with $f = 2$ percent defectives is considered to be a good lot. From Figure 8.4, it is clear that sampling plan A would stand a 14 percent chance of accepting a bad lot. The same unfortunate error can occur with the sampling plan B, with larger sample size also, but the probability of error is much smaller: In fact it is only 1 percent. The sampling plan B is also better at not rejecting good lots ($f = 2$ percent). Sampling plan A has 16 percent chance of rejecting a good lot whereas sampling plan B has only 3 percent chance of rejecting *a good lot.*

It is not surprising that a larger sample does a better job of discriminating between good and bad lots. *It has more information.* However, the price for increased accuracy is higher inspection costs. The design of a sampling plan has to optimally **trade off** cost with discrimination.

The values of the ordinates of the Operating Characteristics Curve are determined from the Poisson Distribution.

I. Design of Single Sampling Plan

You have to design a sampling plan (n, c) that has an OCC that meets certain pre-specified requirements. Generally the design is based on the following criteria that are related to the probability of making either of the following errors: accepting a bad lot (β) and rejecting a good lot (α). The criteria are established *subjectively and ultimately* should reflect the cost of accepting a bad lot or rejecting a good lot.

Needless to say before α and β values can be specified, one has to decided what is a good lot and what is bad lot. Invariably this is done by specifying the lower/upper limits of fraction defective (f), as illustrated below:

AQL (Acceptable Quality Level) the fraction defective (f) that the user considers acceptable. Thus if a batch were known to have a fraction defective equal to AQL, it should not be rejected.

LTPD (Lot Tolerance Percent Defective) the fraction defective that defines a bad lot or one that should be rejected. Of course AQL must be less than LTPD.

NOTES

Producers Risk (α) the largest allowable probability of rejecting a good lot (due to statistical error). Note that a good lot has fraction defective less than or equal to AQL (generally 5 percent).

Consumers Risk (β) the largest allowable probability of accepting a bad lot (due to statistical error). Note that a bad lot as fraction defective greater than or equal to LTPD (generally 10 percent).

Example 1

Consider a manufacturing situation with the following values:

$$AQL = 0.02, \qquad \alpha = 0.05$$
$$LTPD = 0.10, \qquad \beta = 0.01$$

From Figure 8.4 you can verify that sampling plan A (n = 35, c = 1) has a probability of acceptance of 84 percent for a fraction defective of 0.02 (AQL). In other words this plan has a 16 percent chance of rejecting a good lot. Similarly, it has a probability of 0.14 of rejecting a bad lot with f = 0.10 (LTPD). Since both the values are higher than the allowed values of 0.05 and 0.01, respectively, this sampling plan is not acceptable. Only larger values of n can yield better discriminating power.

The sampling plan B(n = 150, c = 6) has the probability of accepting a good lot by 97 percent and probability of rejecting a bad lot by 1 percent. In other words it has a α value of 0.03 and β value of 0.01. This discriminating power is even more than what is needed. The plan is acceptable but it may be possible to get the required discrimination with smaller sample size and in turn with a lower inspection cost.

One way to decide the optimal **sampling** plan is to search through several sampling plans with n values between 35 and 150 and select the one that matches α and β value more closely. An easier way is to use **Thorndike Chart** (Table 8.1). This chart can be used for

(*a*) Plotting OCC; and

(*b*) Designing a Sampling Plan.

We will illustrate the design of sampling plan using this chart. Before we move to this topic, ensure that plan A does not meet the requirement and Plan B meets more than the requirements, by following the arguments given earlier.

To design the sampling plan follow the instruction at the bottom of the chart. Note that we have to read off β = 0.01 and $(1 - \alpha)$ = 0.95 rows only. We first need to find a c value for which $\mu_\beta/\mu_\alpha \leq$ LTPD/AQL. For this problem LTPD/AQL = 0.10/0.02 = 5. Starting with c = 0, we read off μ_β = 4. 6052 and μ_∞ = 0.0513 and so $\mu_\beta/\mu_\alpha \leq 5$ is not satisfied. Continuing with C = 1, 2, 3, 4, 5 we find that for C = 6,

μ_β/μ_α = 14.5706/3.2853 $\leq$ 5. Hence we choose c = 6.

To get the value of n, the limits are $n_\beta = \mu_\beta$/LTPDL and n_α = $\mu\alpha$/AQL. Reading off the table we get.

$$n_\beta = 14.5706/0.10 = 146$$
$$n_\alpha = 3.2853/0.02 = 165$$

NOTES

Table 8.1 Thorndike Chart for Single Sampling Plans

	Acceptance Number C											
		0	1	2	3	4	5	6	7	8	9	10
Acceptance Probability P_a		$\mu = nf$ = expected number defective in the sample										
	0.010	4.6052	6.6383	8.4059	10.0450	11.6046	13.1085	14.5706	16,0000	17.4027	18.7831	20.1447
β rows,	0.025	3.6889	5.5716	7.2247	8.7672	10.2416	11.6683	13.0595	14.4227	15.7632	17.0848	18.3904
entries	0.050	2.9957	4.7439	6.2958	7.7537	9.1535	10.5130	11.8424	13.1481	14.4346	15.7052	16.9622
denoted	0.100	2.3026	3.8897	5.3223	6.6808	7.9936	9.2747	10.5321	11.7709	12.9947	14.2060	15.4066
μ_β	0.200	1.6094	2.9943	4.2790	5.5150	6.7210	7.9060	9.0754	10.2325	11.3798	12.5188	13.6507
	0.500	0.6931	1.6783	2.6741	3.6721	4.6709	5.6702	6.6696	7.6692	8.6690	9.6687	10.6685
$(1-\alpha)$	0.800	0.2231	0.8244	1.5360	2.2966	3.0895	3.9037	4.7337	5.5761	6.4285	7.2892	8.1570
rows,	0.900	0.1054	0.5318	1.1021	1.7448	2.4326	3.1519	3.8948	4.6561	5.4325	6.2213	7.0208
entries	0.950	0.0513	0.3554	0.8177	1.3663	1.9701	2.6130	3.2853	3.9808	4.6952	5.4254	6.1690
denoted	0.975	0.0253	0.2422	0.6187	1.0899	1.6235	2.2019	2.8144	3.4538	4.1154	4.7954	5.4912
$\mu/_\alpha$	0.990	0.0101	0.1486	0.4360	0.8233	1.2791	1.7853	2.3302	2.9061	3.5075	4.1302	4.7712

1. To plot an OC curve for a given sample plan (n, c): (*a*) Find the column for your c value. (*b*) Divide each number in that column by n. The results are the f values for the horizontal axis. (*c*) The P_a values, for the vertical axis, are in the far left column.
2. To find a single sampling plan:
   (*a*) Find c for which $\mu_\beta/\mu_\alpha \leq$ LTPD/AQL.
   (*b*) Then choose any n between $n_\beta = \mu_\beta$/LTPD and $n_\alpha = \mu_\alpha$/AQL.
3. To find the acceptance probability for a given n, c, and f : (*a*) Multiply (n) (f) (*b*) In the appropriate c column, find values above and below nf. (*c*) In the P_a column read upper and lower limits for p_a in two rows from step (*b*) (interpolate, if you wish).

Hence sampling plans with size in the range of 146 to 165 will satisfy the requirement. The exact values of α and β for any sampling plan can be determined using Thorndike Chart again. The exercise at the end of the unit will give you an opportunity to design many other sampling plans and decide the exact values of Consumer's Risk and producer's Risk.

Average Outgoing Quality

The inspection process rejects lots with high fraction defectives. After rejection either you may stop, or you may continue the inspection of all the items in the rejected lot and all defective items are replaced with good items. Such a policy is known as **Rectifying Inspection.**

In rectifying inspection, all outgoing lots consists of N items either accepted ones or rejected ones. Suppose a lot has incoming fraction defective f. If it is accepted $(N - n)$ items remain uninspected. We, therefore, expect $f(N - n)$ defectives in the accepted lots (assuming that the defectives found in the sample are replaced with good ones). In contrast, if it is rejected and hence (100 percent rectified and inspected) there are no defectives. Thus is P_a is the probability that the sampling plan will accept the lot,

$$\textit{Outgoing fraction defective} = \frac{(P_a)(f)(N-n) + (1-P_a)(0)}{N}$$

$$= (P_a)(f)\left(\frac{N-n}{N}\right) \simeq (P_a)(f)$$

NOTES

A plot of outgoing fraction defective against incoming fraction defective (f) is generally called the **Average Outgoing Quality** (AOQ) curve. Figure 8.5 shows the curve for sampling plan B (n = 150, C = 6) of the earlier example. This curve has a surprising property that, as f increases, there comes a point at which the outgoing fraction defective actually begins to improve. The reason being that the sampling plan rejects most bad lots and they are rectified through 100 percent inspection.

The most critical incoming fraction defective f gives the worst outgoing quality. On the average, the value of that critical f is not important but the corresponding outgoing fraction defective generally known as **average outgoing quality limit** (AOQL) is extremely useful. No matter what the incoming fraction defective is, the long-run average outgoing fraction defective will not be worse than AOQL.

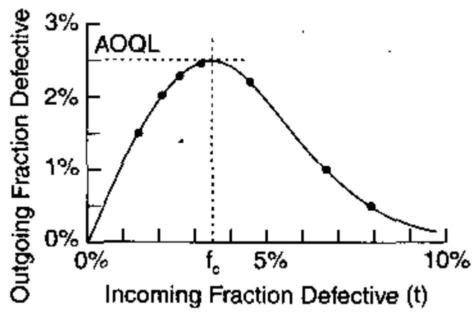


Fig. 8.5. AOQ Curve for Sampling Plan B(N = 10,000)

You do not have to determine AOQL by plotting the AOQ. One can use the following AOQL factor table 8.2. To get the AOQL simply use the formula,

$$\text{AOQL} = (\text{AOQL factor})\left(\frac{1}{n}-\frac{1}{\text{N}}\right)$$

Table 8.2. AOQL Factor

Acceptance Number (C)	AOQL factor (Y)
0	0.3679
1	0.8400
2	1.3711
3	1.9424
4	2.5435
5	3.1680
6	3.8120
7	4.4720
8	5.1457
9	5.8314
10	6.5277

Convince yourself that you understand the mechanism of determining AOQL by doing the following exercise.

Many managers prefer to use the AOQL as a criterion for designing a sampling plan rather than trying to decide on values of AQL, LTPD, α and β. Dodge and Romig (1959) present tables that are designed for this purpose. In fact these tables meet the requirement of a specified AOQL and minimise the expected number of items inspected per lot.

The OCC approach and AOQL based approach are but two of the many other approaches that can be used to design a sampling plan. Choice among them is a match of personal experience, the exact situation and the objectives of the organisation. Regardless of the approach, all sampling plans have both an OC curve and an AOQ curve, so the principles discussed in this unit can be used to evaluated any sampling plan.

II. Sequential Sampling Plan

One takes a sequence of samples from lot. It is a plan in which sample size is increased by one piece at a time.

In sequential sampling a lot is accepted.

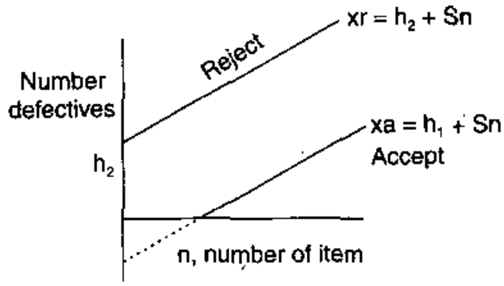


Fig. 8.6

The cumulative observed number of defectives is plotted. Accepting a bad lot β. Rejecting a good lot α.

III. Double and Multiple Sampling

Extensions of the single sampling plans to double and multiple sampling plans are also available. In a double sampling plan, after the first n_1 samples have been inspected there are three choices depending on the number of defectives found:

1. reject the lot
2. accept the lot, and
3. draw a second sample of n_2 items.

If choice (3) is made the final accept/reject decision is made on combined sample of $n_1 + n_2$ items. A multiple sampling plan operates in the same way, but with more than two samples. Double and multiple sampling plans reduce inspection costs because many accept/reject decisions are made based on the first sample which is smaller than that of the single sampling plan. However, single sampling plan is more common and easy to use.

8.14. PROCESS CONTROL

Variability

All products and services have a certain amount of natural variability because of variations in the input as well as imperfections in the process. For example, different quality of raw materials could have been used and different quantities of chemicals could have been used in the process. This **process variability** may be measured by the process standard deviation σ, which indicates how much the products will vary even if the process is in control.

Product have to meet **specified tolerances** imposed by their intended use. Accordingly the natural variability must be substantially smaller than the specified tolerance. This is explained in Figure 8.7 in which the central line is the desired average of the process and the dashed lines are the '3-Sigma limits' representing the natural process variability.

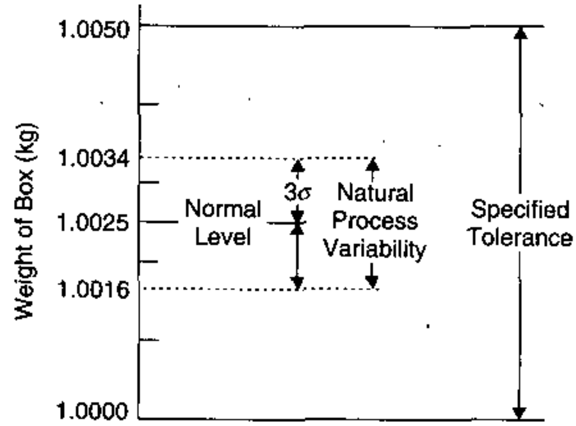


Fig. 8.7. Process Variability

It can be shown that variations of more than 3σ from the process average are very unlikely. In fact it is about 0.25 percent if the process follows the normal distribution and definitely less than 5% for most processes. The solid lines represent the tolerances specified by the intended use of the product.

Within the specified tolerances, a certain amount of process variability is to be expected. However it is the goal of the **statistical process control** to determine when the process variability is getting out of hand, so that corrective action can be taken, preferably before the required tolerances are violated. This is generally achieved by a **Control Chart**

Control Chart

In order to provide rapid feedback to an ongoing production process, methods somewhat different from acceptance sampling are appropriate. Samples are taken as soon as they are available, rather than waiting for the completion of a lot. This affords the opportunity to detect unplanned changes in the process, shortly after they occur and take a quick action, such as adjusting the machine.

The most common device used for this purpose is Shewart Control chart introduced in 1931. The **control chart** is a visual display of the result of an inspection process incorporating carefully derived limits to indicate unusual behaviour. A control chart can be based on categorical information or actual measurement. Accordingly, they are called **control chart for variables** and **control chart for attributes.** Since control chart for variables are more commonly used and more powerful, we will describe them first.

The control chart is based on the idea that the average of a sample of several items will tend to cancel out the normal process variability, so that undesirable changes in the process will be more visible. We will illustrate the idea through an example.

I. $\overline{X}$ and R Charts

Consider XYZ Company that uses an automatic machine to fill 1 kg. boxes of sugar. The tolerances are specified as 1.000 kg. on the lower side (legal requirement) and 1.005 kg. on the high side (no point wasting sugar). Since the spread is only 0.005

NOTES

they selected a machine that has a natural process variability of = 0.0003. The three sigma limits of the machine therefore are 3(.0003) = .0009 kg. above and below the mean. The spread is .0018 which is narrower than the specified tolerance of .005. They adjust the machine to fill boxes with an average 1.0025 kg. half way between the tolerance limits.

An $\overline{X}$ Chart (Average Control Chart) was set-up to detect when the machine goes out of control. In order to reduce the natural process variability, samples of $n = 5$ boxes were weighed, and the average weight per box, $\overline{X}$, was recorded for each sample.

Figure 8.8 shows the control chart used for this machine and the four points plotted on the chart represent the $\overline{X}$ values from four samples (a total of twenty 1 kg. boxes). We shall examine the details of the chart.

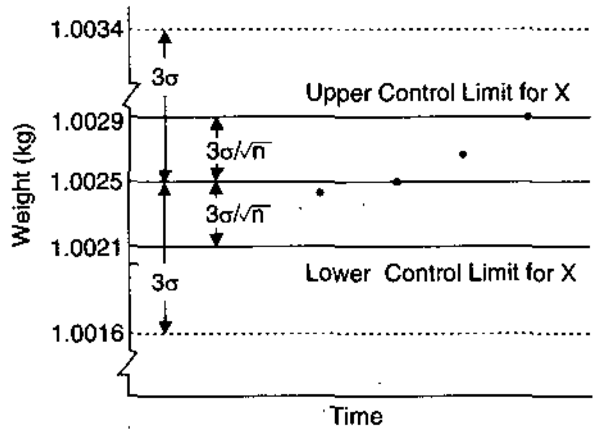


Fig. 8.8. $\overline{X}$ Chart

There is an apparent trend in $\overline{X}$. The samples seem to be getting progressively heavier. However, appearances notwithstanding, the trend in the Figure 8.8 may be $\overline{X}$ due to random fluctuations. It is for this reason that we must incorporate the concept of **statistical significance** in our discussion. The standard deviation of the sample average is expressed through the formula,

$$^{\sigma}\overline{X} = \sigma/\sqrt{n}$$

Therefore, the averages of $n = 5$ boxes of sugar should have a standard deviation of $^{\sigma}\overline{X} = 0.0003/\sqrt{5} = 0.000134$ kg. The control limits in Figure 8.8 represent 3 sigma limits and are therefore (3) (0.000134) = 0.0004 above and below the intended average of 1.0025. If a sample average falls outsides these control limits the deviation from the process average is **statistically significant.**

The fourth sample X is on the control limit and therefore there is a strong statistical evidence that more sugar is put into the boxes than what was intended and the machine needs adjustment.

The R Chart (Range Control Chart) is also used to control the processes. The range of a sample is the largest value minus the smallest. An R chart is appropriate if process sometimes goes out of control in such a way that there is inconsistency in the values, but no shift in the mean value of the process. For example, a worker who is basically good might produce an inconsistent set of sizes (of some manufactured product) when he is fatigued. The R chart used to plot the data XYZ Company appears in Figure 8.9.

NOTES

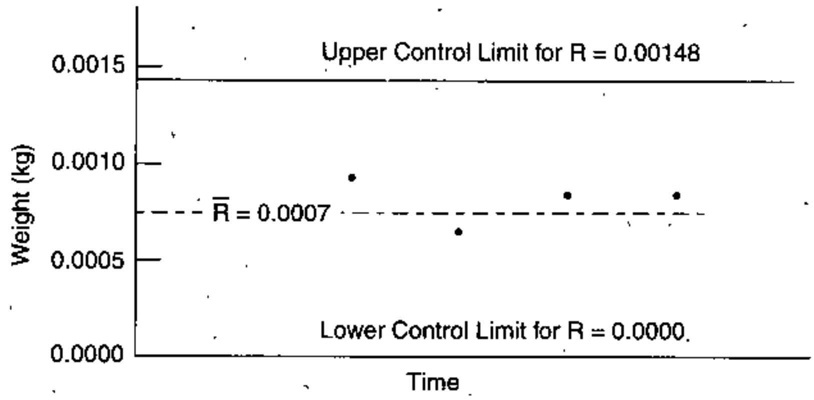


Fig. 8.9. R Chart

The control limits for R chart are determined differently. There is no need for lower control limit which is generally (for $n \leq 6$ it is zero) zero. Table 8.3 is used to set the upper control limit for an R chart and factor D_2 from the table is multiplied by the process standard deviation, σ. In the case of XYZ Company data, D_2 = 4.918 (for a sample size of 5) and hence upper control limit = (0.0003) (4.918) = 0.00148. As can be seen in Figure 8.8 no statistically significant shifts are present.

Table 8.3. R Chart Factor

Sample Size	D_2
2	3.686
3	4.358
4	4.698
5	4.918
6	5.078
7	5.203
8	5.307
9	5.394
10	5.469

Table 8.4. Weights of Twenty 1-kg. Boxes

Box	Sample 1	Sample 2	Sample 3	Sample 4
1	1.00218	1.00266	1.00266	1.00306
2	1.00298	1.00242	1.00290	1.00266
3	1.00210	1.00258	1.00223	1.00234
4	1.00226	1.00250	1.00250	1.00322
5	1.00258	1.00234	1.00301	1.00322
Average	1.00242	1.00250	1.00266	1.00290
Range	0.00088	0.00032	0.00078	0.00088

Determining the **sample size** is an important decision. It is common to use n = 4 or n = 5 in order to obtain low cost feedback. Large samples such as n = 15 or 20 are necessary if the process standard deviation is large. To a large extent this will depend on the rate of production, convenience and other considerations as well. Similarly, it is important to decide the **frequency** of sampling. It should be in general proportional to the average frequency of out-of-control conditions. It is a fairly complex decision to make if one were to look for some optimality. Generally, it is decided by convenience.

NOTES

II. p-Chart

The *p*-chart which is used to control the process when the measurement is by attributes. In other words the decision is only to decide whether or not the sample item is acceptable. No measurement is taken. For example in using the GO/NO GO gauges one gets only such a measurement.

The *p*-charts is based on the fraction defective, *p*, in a sample of *n* items. If p_0 represents the normal process defective (*i.e.* when the process is in control) then the 3 sigma control limits are,

This is based on the fact that the number of defectives has the binomial probability. The control chart is used just like an $\overline{X}$ chart, except that the fraction defective *p* is calculated rather than $\overline{X}$ for each sample of *n* items and a lower control limit is often omitted.

$$p_0 \pm 3 \sqrt{\frac{p_0\,(1-p_0)}{n}}$$

Sample sizes are typically larger for *p*-charts then for $\overline{X}$-charts. Since the information content of a yes/no measurement is much smaller than the actual variable measurement, it can only be expected. In fact, the required sample size can be computed approximately from the following formula.

$$n = \left[\frac{1.645\sqrt{p_1\,(1-p_1)} + 3\,p_0\,(1-p_0)}{p_1 - p_0}\right]^2$$

In this formula p_0 is the normal process fraction defective, p_1, is the specified fraction defective that is unacceptable. (p_0 like AQL and p_1 is like LTPD is acceptance sampling).

For example, consider ABC Company that makes ready-made shirts. It has been found that 4 percent of the shirts are defective when the process is under control. ABC Company wants to be able to detect a shirt to 12 percent defective on the basis of one sample of *n* items. The formula for *n* suggests a sample size of *n* = 197. The upper control limits will be

$$p_0 + 3\sqrt{p_0\,(1-p_0)/n} = 8.19 \text{ percent}$$

The *np* chart = Number defective

$$\text{UCL}_{np} = n\,\overline{p} + 3 \times \sqrt{n\overline{p}(1-\overline{p})} \quad \text{LCL}_{np} = n\,\overline{p} - 3 \times \sqrt{n\overline{p}(1-\overline{p})}$$

The *c* chart = Number of non-conformities with a constant sample size.

$$\overline{c} = \frac{\text{Total non - conformities}}{\text{Number of sub - groups}}$$

$$\text{UCL}_c = \overline{c} + 3 \times \sqrt{\overline{c}} \qquad \text{LCL}_c = \overline{c} - 3 \times \sqrt{\overline{c}}$$

The *u* chart = Number non-conformities with varying sample size.

$$\overline{u} = \frac{\text{Total non-conformities}}{\text{Total units inspected}}$$

NOTES

$$UCL_u^* = \bar{u} + 3 \times \frac{\sqrt{\bar{u}}}{\sqrt{n}} \qquad LCL_u^* = \bar{u} - 3 \times \frac{\sqrt{\bar{u}}}{\sqrt{n}}$$

*This formula creates changing control limits. To avoid this, use average sample sizes $\sqrt{\bar{n}}$ for those samples that are ± 20 % of the average sample size. Calculate individual limits for the samples exceeding ± 20 %.

8.15. PROCESS CAPABILITY

True improvement of a process comes from balancing repeatability and consistency with the capability of meeting your customer requirements otherwise known as process capability.

Formulas For Calculating process capability indices :

C_p is a simple process capability index that relates the allowable spread of the specification limits (*i.e.* the difference between the upper specification limit, USL, and the lower specification limits LSL) to the measure of actual, or natural variation of the process, represented by $6\hat{\sigma}$, where $\hat{\sigma}$ is the estimated process standard deviation.

$$C_p = \frac{USL - LSL}{6\hat{\sigma}}$$

If the process is in statistical control, then $\hat{\sigma}$ can be estimated from the control chart.

$$\hat{\sigma} = \frac{\bar{R}}{d_2}$$

Where $\bar{R}$ = the average of the subgroup ranges

d_2 = a tabled value based on the sub group sample size

Factor for estimating $\hat{\sigma}$:

n	d_2	n	d_2
2	1.128	6	2.534
3	1.693	7	2.704
4	2.059	8	2.847
5	2.326	9	2.970
		10	3.078

If C_p < 1 then the process variation exceed specification, so defectives are made.

If C_p = 1 then the process just meets the specification. Here a minimum of 0.3 % defectives will be made, and more if the process is not centered.

If C_p > 1 then the process variation is less than specification, however defectives can be made if the process is not centered on the target value.

While C_p relates the spread of the process relative to the specification width, it DOES NOT look at how well the process average $\bar{\bar{X}}$ is centred to the target value. C_p is often referred to as measure of process "potential".

The process capability indices C_{pl} and C_{pu} (for single sided specification limits) and C_{pk} (for two sided specification limits) measure not only the process variation with

NOTES

respect to the allowable specification, they also take into account the location of the process average. C_{pk} is considered a measured of the process "capability" and is taken as the smaller of either C_{pl} or C_{pu}.

$$C_{pl} = \frac{\overline{\overline{X}} - LSL}{3\hat{\sigma}}, \quad C_{pu} = \frac{USL - \overline{\overline{X}}}{3\hat{\sigma}}, \quad C_{pk} = \min\{C_{pl}, C_{pu}\}$$

If the process is near normal and in statistical control, C_{pk} can be used to estimate the expected percent of defective material.

Construction/Interpretation Tips on Process Capability

* C_p index is limited to two-sided specifications
* Some companies use the inverse of the C_p ratio

$$C_p = \frac{6\hat{\sigma}}{USL - LSL}$$

* Communicate with you customer as to which ratio he is using for interpretation
* The use of process capability indices assumes realistic and meaningful specifications. Be sure that you and your customer have agreed upon them.
* If the $C_{pl} = C_{pu}$, then the process is exactly centred.
* Many companies are establishing specific process capability targets, typically a C_{pk} of 1.33 for supplier qualification, with an expected achievement of a C_{pk} of 2.0 or higher term.

The process capability is kept into account at the time of production made by the machine. The following formulae is used

$$\text{Process capability} = \frac{6\sigma}{\text{Total Tolerance}} \times 100$$

If capacity is less than 67% it needs the use of new machine.

1. The *m/c* capacity is first determind.
2. Contry limits are calculated
   $UCLR = D_4R$
3. Upper and lower control limits are calculated
   $UCL = \overline{X} + A_2R$
   $LCL = \overline{X} - A_2R.$
4. CR is calculated by using the formula

$$CR = \frac{6\sigma}{\text{Total capacity}}$$

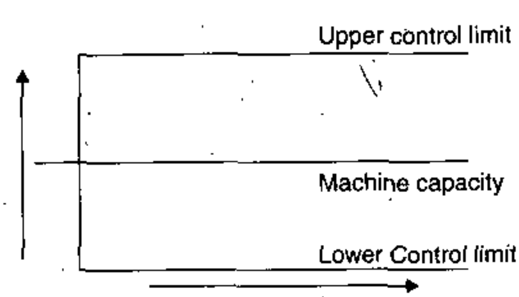


Fig. 8.10

STUDENT ACTIVITY

1. In your organization what is system of inspection ?

2. In the space provided, write down your definition of quality, in your own words. Also write down how quality can be measured ?

NOTES

SUMMARY

1. This chapter deals with inspection and quality control. Inspection is necessary in any industry different system of inspection are used in industry operator and inspection both can do inspection. Inspection planning is must quality is necessary for product. Quality control determins product acceptability. Statistical quality is becoming important day by day. To achieve quality QA is must total quality control become TQM. ISO 9000 is quality management system. 100% inspection costly and not effective. Acceptance sampling is used. Number of sampling plans are available. Control charts are used to control quality. Process capability is important.

KEY WORDS

Consumer's Risk: Probability of accepting a bad lot.

Producer's Risk: Probability of rejecting a good lot.

OCC: Operating Characteristic Curve.

AQL: Acceptable Quality Level.

LTPD: Lot Tolerance Percent Defective.

AOQ: Average Outgoing Quality.

AOQL: Average Outgoing Quality Limit.

Control Limits: Limits if exceeded imply that the process is out of control.

TEST YOURSELF

1. What is inspection ?
2. Why we need inspection ?
3. What are inspection stages ?
4. What are systems of inspection ?
5. What is operator inspection ?
6. What is inspector inspection ?
7. What is inspection planning ?
8. What is quality, quality control, Quality Assurance, SQC, Total Quality Control ?
9. What is TQM ? What are steps to TQM ? What are principles of TQM ?
10. What is ISO 9000 ? Compare ISO 9000 and TQM.
11. What is acceptance sampling ?
12. What is 100% inspection ? Why it is desirable ?
13. What is operating characteristics ? Explain its characteristics.
14. Write about single, double, multiple and sequential sampling.
15. Define average outgoing quality.
16. Write about $\overline{X} - R$ chart.
17. Write about p-chart, np chart, c chart, u-chart.

18. Write about process capability.
19. Why are averages of samples used in control charts rather than individual readings ?
20. It is important to inspect the inspector ?
21. Why range method is preferred for Process capability study.
22. For a single sampling plan N = 10000 sample size is 100 accepted number C = 2 Find $p_{0.95}p_{0.5}$ and $p_{0.1}$. Prepare an AOQ curve for the above sampling acceptance rectification plan and hence determine the value of AOQL.
23. In the example in the text, the sampling plan A with n = 35 and c = 1 has α = 0.16 and β = 0.14, both too large to be acceptable.
    (*a*) What would happen to α and β if c were increased but n remained at 35 ?
    (*b*) Why do we need to increase both n and c to lower both α and β ?
    (*c*) If a batch contains 8% defective items, what is the probability that it would be rejected by the plan n = 40 and c = 1.
    (*d*) Find a sampling plan for AQL = 0.008, LTPD = 0.01, α = 5%, β = 10 per cent.
24. A manufacturing company produces a small product in lots of 10,000. They want to be 90 percent sure of accepting the lot with fraction defective of 0.01 and 95 percent sure of rejecting a lot with a fraction defective of 0.08. They do not know anything about sampling plan design. They intuitively decide that they will take a sample size of 100 and accept if not more than 4 defective items are found. The reasoning is that it amounts to 4/100 = 0.04 fraction defective which is roughly the mid point of their acceptable and rejectable quality.
    (*a*) Does their plan achieve their goals ?
    (*b*) Suggest a better plan.
    (*c*) What are the AOQL values for these plans ?
25. One of the important functions of a hospital laboratory is the perform blood samples. The quality of this process is tested periodically be selecting five blood specimens and dividing each specimen into two equal parts. Approximately 30 minutes after the first batch of five has been processed, its twin are submitted and the result are compared. The following data are taken at four different times in an 8 hours shift.

Batch 1	Batch 2	Batch 3	Batch 4
1.2	0.6	0.6	2.1
1.8	0.3	1.5	0.6
1.5	0.3	1.0	0.6
0.9	0.0	1.0	2.7
0.3	0.6	0.9	2.7

    (*a*) Calculate the 3 sigma control limits for the process. Assume normal process, average to be 0.9 and the process standard deviation is 0.5.
    (*b*) What control limit will be used for range chart ?
    (*c*) Is the process in control ?
26. Using the data of Problem 25 calculate the mean and standard deviation of each of the batch data. Use the average of the means and the average of the standard

deviation as the estimate of the process average and process standard deviation (instead of 0.9 and 0.5, respectively).

Rework problems 25 (*b*) and 25 (*c*).

27. Judge the quality of the set of notes you are reading based on these definitions.

28. Ascertain from your organisation how the quality control function is set up. It may be a good idea to draw up an organisation chart.

29. Think of a common situation where 100 percent inspection is

(*a*) Impractical

(*b*) Impossible

30. (*a*) How will the OCC change shape as

(*i*) n is increased, keeping c constant.

(*ii*) c is increased, keeping n constant.

(*b*) What will be the limiting shape of the OCC.

(*c*) Can you interpret your answers to (*a*) and (*b*).

31. (*a*) Using OCC for sampling plan B draw the AOQ curve over the range of 0-10 percent fraction defective and determine AOQL.

(*b*) Verify your answer to (*a*) using AOQL factor in Table 8.2 and the formula.

32. Verify the control chart for the example given in Figure 8.8. The data regarding the samples is as in Table 8.4.

NOTES

CHAPTER

9

STANDARDS AND CODES

LEARNING OBJECTIVES

- Introduction to Standard
- Code
- Application of Standardisation
- National and International Standard
- Different Levels of Standardisation
- ISO 9000 Concept and its Evaluation and Implication
- ISO 9001 – 2000

9.1. INTRODUCTION TO STANDARD

A standard is defined as a model or general agreement or a rule established by authority, consensus or custom created and used by various levels of interest.

Standardisation is the orderly and systematic formulation adoption, application and review of Industrial standard which leads to simplification or variety reduction.

Standard

(*i*) Accurate authoritative.

(*ii*) Any established measure, a type of a model or example for comparision.

9.2. CODE

Any set of rule devised for the purpose of securing uniformity in work and for the maintaining of proper standards is usually called a code *e.g.*, building code in India.

9.3. APPLICATION OF STANDARDISATION

Standardisation is applied in industry:

I. Standardisation of products—their shape, dimensions, colour, physical and chemical properties.

II. Standardisation of business practices-of terms, procedures, systems, operating practices etc.

The process of standardisation can be conceived on three demensional plane :

Levels—Individual department, company, industry, national, international, universe.

Aspects—Firms, ethics, code of conduct, procedures, contracts, inspection, testing, sampling, agreement, reporting notes.

NOTES

Subjects—Industry, education, agriculture, communication, transport, mining, trade, commerce, energy, family planning, construction, administration etc.

9.4. NATIONAL AND INTERNATIONAL STANDARDS

The apex body of standards in India is the Bureau of Indian Standards. At the International level International Organisation for standard—Geneva.

9.5. DIFFERENT LEVELS OF STANDARDISATION

I. Individual level standards—Builder, *Corporate, Government Department*, private Co., lays down own specification to suit the special needs—house, dam, bridge, factory, furniture etc.

II. Industries wise standardisation

Directorate general of supplies and disposals.

Research designe and standards organisation-Railways, Lucknow

Directorate of standardisation-Defence.

Drug controller.

Chief inspector of factories/explosives

Textile commissioner

Food standards

Director general of mines safety

Export council of India.

Indian Road Congress etc.

III. National Level Standardisation—BIS

Department of weights and measures.

National physical laboratry.

IV. International Level Standardisation—ISO

- — Organisation for legal Metrology
- — Weights and measures.
- — Codex Alimentanous commission
- — Food standards.

V. Foreign standards

BSS—British Standard Specification.

ASA—American Standard Association.

ASTM—American Society of Test Materials.

SAE—Society of Automobile Engineer, Japan

API—American Petrolium Institute.

DIN—German Standards.

JIS—Japanese Standards.

NOTES

NF—French Standards.

CSN—Checholovak Standards.

UNI—Italian Standards.

GOST—USSR Standards.

CSA—Candian Standards

etc.

9.6. ISO 9000 CONCEPT AND ITS EVALUATION AND IMPLICATION

ISO started in 1947. ISO means International Ogranisation for Standards.

ISO 9000 is Quality Management System for Organisation. Organisation has to prepare Quality manual. Quality manual deals with organisational activities, procedures.

ISO 9000—1987

Revision—1994.

Now we have ISO 9001—2000

ISO 9000 is very popular quality management system and easy passport for export.

ISO 9000–1987 and 1994 were emphasising on documentation for implementing the system aimed at improving and sustaining customer satisfaction.

Upto 2000 we have got ISO 9001, 9002, 9003 and 9004.

ISO 9002 was for organisation who are not designing the product.

Organisation was divided into 20 parts, in ISO 9000–1994.

Introduction to Quality Management System

Customer satisfaction is the focus of any business. In the present day scenario, fierce competition in the market demands that the business organisations, in order to be successful, must provide products/services that :

- meet a well defined need, use or purpose
- satisfy customer's expectations
- comply with applicable standards and specifications
- comply with statutory and other requirements of society
- are made available at competitive prices, and
- are provided at a cost which yields a profit.

These issues play a very significant role in deciding the performance of an organisation. Most organisations produce a product or service intended to satisfy the user's requirements, which are often incorporated in the "specifications".

However, technical specifications in themselves may not guarantee that a customer's requirements will be met "consistently". There may be deficiencies in the specifications themselves or in the organisational system to design and produce the product or service.

For assuring consistency of operations in the supplier's premises, the establishment of a Quality System (standards and guidelines) that complements relevant product or service requirements given in the technical specifications is necessary.

The company should ensure that Quality is built into the products or services at all phases from initial identification to final satisfaction of customer requirements and expectations.

This leads to the concept of Total Quality Management, which stresses on "Doing right things right the first time every time". Doing right things means meeting customer requirements and doing them right the first time means customer satisfaction consistently at minimum cost.

Standard requirements of ISO 9001

(*i*) Customer satisfaction 8.4

(*ii*) Continual improvement of the organisation 8.5

(*iii*) Competence awareness and training requirements.

The objective is to provide people with knowledge and skills which, together with experience, improve their competence.

Education and training should emphasis the importance of meeting requirements and the needs and expectations of the customer and other interested parties. It should also include awareness of the consequences to the organisation and its people of failing to meet the requirements.

To support the achievement of the organisation's objectives and the development of its people, planning for education and training should consider:

- experience of people
- leadership and management skills,
- planning and improvement tools,
- team building,
- problem solving,
- communication skills,
- culture and social behaviour,
- knowledge of markets and the needs and expectations of customers, and
- creativity and innovation.

To facilitate the involvement of people, education and training should also include:

- the vision for the future of the organisation,
- the organisation's policies and objectives,
- organisational change and development,
- the initiation and implementation of improved processes,
- benefits from creativity and innovation,
- the organisation's impact on society,
- introductory programmes for new people, and
- periodic refresher programmes for people already trained.

Training plans should include:

- objectives,
- programmes and methods,
- resources needed,
- identification of necessary internal support,
- evaluation in terms of enhanced competence of people, and
- measurement of the effectiveness and the impact of the organisation.

NOTES

The education and training provided should be evaluated in terms of expectations and impact on the effectiveness and efficiency of the organisation as a means of improving future training plans.

(*iv*) **Analysis of data. (8.4.)** Decisions should be based on analysis of data obtained from measurements and information collected as described in ISO 9001 : 2000. The organisation should analyse date from its various sources to assess performance against plans, objectives and other defined goals, and to identify areas for improvement.

Decisions based on facts required effective and efficient actions such as :

- valid analysis methods,
- appropriate statistical techniques, and
- making decisions and taking actions based on results of logical analysis, as balanced with experience and intuition.

Analysis of data can help to determine the root cause of existing or potential problems, and therefore guide decisions about the corrective and preventive actions needed for improvement.

For an effective evaluation by management of the total performance of the organisation, data and information form all parts of the organisation should be integrated and analysed. The organisation's overall performance should be presented in a format that is suitable for different levels of the organisation. The results of this analysis can be used by the organisation to determine:

- trends,
- customer satisfaction,
- satisfaction of other interested parties,
- effectiveness and efficiency of its processes,
- supplier contribution,
- success of its performance improvement activities,
- economics of quality, financial and market-related performance,
- benchmarking of its performance, and
- competitiveness.

As a part of analysis of data, conceptual clarity on 7 QC tools of problem solving alongwith seven stop approach of solving is required.

9.7. ISO 9001 – 2000

Clause are :

1. Scope
2. Terms and Definition
3. Fundamentals of Quality Management System

4. GENERAL

4.1. General Requirements Concept of a Consistent Pair. The organisation shall establish, document and maintain a quality management system as a means of implementing the process necessary to ensure that product and services conform to specified requirements. The quality management system shall encompass all the applicable requirements of this International Standard.

4.2. General Documentation Requirements. Need to integrate clause content of ISO *9000 : 2000* and *9001 : 2000.*

Clause 4.2.1 of ISO 9001 states :

The quality management system documentation *shall include:*

(*a*) documented statements of a quality policy and quality objectives,

(*b*) a quality manual,

(*c*) documented procedures required by this international standard,

(*d*) documents needed by the organisation to ensure the effective planning, operation and control its processes, and

(*e*) records required by this international standard.

As is clear from the requirement, ISO 9001 does not lay down any fixed rule on how a quality system should be documented or in which media.

When a company decides to document its Quality System, it may find that it can put everything required by everyone into one document. Small companies often do this quite adequately and satisfactorily. Other companies find this would not be practicable for them and prefer to separate the levels in a way shown *in figure below*.

NOTES

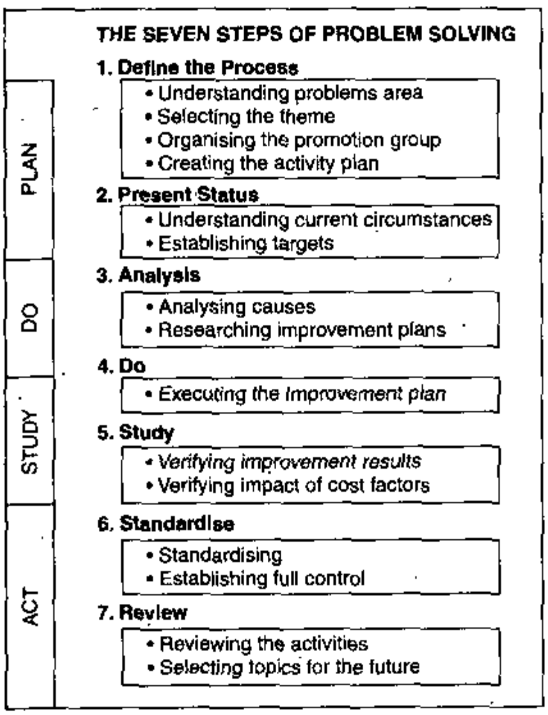


Fig. 9.1

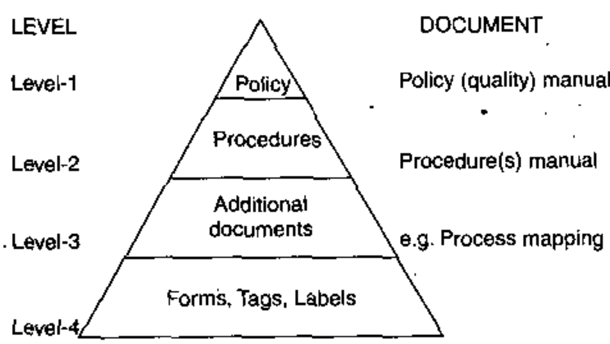


Fig. 9.2. Typical hierarchy of quality system documents.

NOTES

Very large companies such as BHEL (Bharat Heavy Electricals Ltd.) may have a need to have five or six levels of quality documents because of their organisational structure. Contents of the our level documents are as given below :

(*i*) **Policy (Quality) Manual.** It addresses all requirements of the applicable standard. This document covers policy, responsibility, organisation, scope of quality management system outlines the structure of the Quality System in the company, identifies the various processes needed for quality management system, their application throughout the organisation/the sequence and interaction of these processes. The manual may include or refer to the detailed procedures. This document can be used for external applications (*e.g.*, a potential customer) besides internal use. This manual, being a policy document, is approved by Chief Executive.

(*ii*) **Procedure(s) Manual.** There may be a document title as Procedure Manual containing all procedures documented in an organisation, or all procedures may be controlled separately as individual documents. Procedures give details of activities of a department or a function and highlight the way these activities are managed and controlled. Other than mandatory procedures, as required by the standard, organisation may require additional procedures. These are generally approved by Head of the Departments/Functional "incharges. Work Instructions are the detailed technical operating documents giving step-by-step approach. These instructions are very specific to an activity/operation and are generally approved by Department/Section incharges. Depending upon the skill, training, education and past-experience of the employees, there may be some activity for which no documented instruction is required. Thus instructions may be prepared as per the needs of the organisation.

(*iii*) **Additional Documents.** In order for an organisation to demonstrate the effectiveness of QMS, it may be necessary to develop documents other than documented procedures. There are several requirements of the standard where an organisation could add value to its QMS and demonstrate conformity by the preparation of other documents, even though standard does not specifically require them. Examples may include : Process map, Organisation chart, Internal communication, Production schedule, Approved supplier list, Quality plans.

(*iv*) **Forms and Records.** Are used for recording that activities were carried out as per specified procedures and results comply with specifications or not.

Structuring the documents in different levels is helpful because system for the document control, issue and maintenance of each of these levels of documentation may be different. But the whole system must be integrated and together it needs to confirm to the requirements of applicable standard. The organisations who are in the process of amending their documentation to 2000 version of standards should now focus on process rather than department.

DOCUMENTS PROVIDE REFERENCES

Documentation of an organisation explains the intentions of the management. Intentions of the management are indicated the following documents:

— Quality Policy

— Quality Manual (4.2.2)

— Procedures and Instructions.

Quality management system, requirements does not merely require intent to be defined and documented, but the same must be *implemented effectively.* Clause 4.1 of ISO 9001 States :

"The organisation shall establish, document, implement and maintain quality management system and continually improve its effectiveness in accordance with the requirements of this international standard".

NOTES

Clause 4.2 Note 1. Specifies, where the term "documented procedure" appears within this international standard, this means that procedure is established, documented implemented and maintained.

Implementation of the intent can be verified by going through various records which would provide evidence that the documented system is complied with.

Effectiveness can also be verified through records such as Customer complainst, corrective, and preventive action records, Management review records and internal audit records etc.

Mandatory procedures required by standard

1. Control of Documents (4.2.3)
2. Control of Records (4.2.4)
3. Internal Audit (8.2.2).
4. Control of non-coforming product (8.3)
5. Corrective Action (8.5.2)
6. Preventive Action (8.5.3)

Mandatory records required by standard

Records are special type of documents and are established and maintained to provide evidence of conformity to requirements and of effective operations of the quality management system. The list of mandatory records as per standard is :

- Results of management reviews (5.6.1) ;
- Records of education, experience, training and qualifications (6.2.2e) ;
- Records to provide evidence that realisation process and resulting product meet requirement (7.1 d) ;
- Results of customer requirement reviews and actions arising form reviews (7.2.2) ;
- Design and development input relation to product requirement (7.3.2) ;
- Records of design and development reviews (7.3.4) ;
- Results of design and development verification and any necessary actions (7.3.5) ;
- Results of design and development validation and necessary actions (7.3.6) ;
- Results of the review of design and development changes and any necessary actions (7.3.7) ;
- Results of evaluation of suppliers and any necessary actions arising from the evaluation (7.4.1) ;
- Evidence of validated processes (7.5.2d) ;
- Traceability (where it is requirement) (7.5.3) ;
- Records of customer property loss/damage/otherwise found unsuitable (7.5.4) ;
- Results of calibration and verification (7.6) ;
- Records of internal audit (8.2.2) ;
- Records of product conformity with acceptance criteria indicating authority responsible for release of product (8.2.4) ;

NOTES

- Records of the nature of non-conformities and any subsequent actions taken, including concessions obtained (8.3) ;
- Records of results of corrective actions taken (8.5.2e) ;
- Records of results of preventive actions taken (8.5.3d).

Documents and Records

To understand Document control, difference between a document and record must be clear, as explained in the following table.

	DOCUMENTS	*RECORDS*
What is gives	Document gives guidance on what, how, when, where to do ?	Record gives historical evidence how an activity was performed and what results were achieved ?
Possibility of change	Documents keep changing with as everyone tries to find better direction and better working methods	Records, being history can not be changed.
Examples	• Quality Policy • Responsibility • Organisation Chart • Quality Manual • Procedure • Work Instructions • Blank Record Formats • Drawings/specifications • Price List • Maintenance Schedule • Production Plan etc.	• Inspection and Test Records • Calibration Records • Management Review Records • Internal Quality Audit Records • Training Records • Design Verification Records • Design Review Records etc.
Control defined in	Clause 4.2.3. of ISO 9001 : 2000	Clause 4.2.4 of ISO 9001 : 2000

4.2.3 Control of Documents

4.2.4 Control of Quality records

4.2.4.1 Records Retention

4.3. Use of Quality Management Principles. (Eight in number, customer focused organisation leadership, involvement of people, process approach systems approach to management, factual approach to decision making, continual improvement, mutually beneficial supplier relationships).

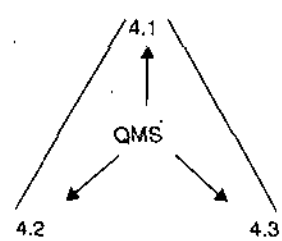


Fig. 9.3

4.4. Evaluation of the organisation's progression towards excellence. (Initially identify those elements, steps or processes which will define excellence for the organisation. Second, the appropriate steps or threshold in the movement towards excellence are to be determined and sufficiently described so as to permit management to evaluate improvement status).

4.5. Process Model for a Quality Management System. For customer : input process and output of process management, for measurement analysis and improvement : to achieve these, management responsibility is to be clearly defined and resource management streamlined, all of which need the cycle PLAN, DO, CHECK, and ACT at each stage.

NOTES

5. MANAGEMENT RESPONSIBILITY

5.1. General Guidance : Management Commitment the top management shall define, document and demonstrate its responsibilities, involvement and commitment for the fulfillments of customer needs and requirements by :

(*a*) establishing the quality policy and quality objectives,

(*b*) establishing a quality management system,

(*c*) ensuring the availability of necessary resources,

(*d*) ensuring that concerned personnel are fully aware of customer needs and requirements,

(*e*) performing management reviews.

5.1.1. Process efficiency

5.2. Custom Focus Customer Interest and Party Needs and Requirements : The organisation shall establish and follow procedures to identify and define customer needs and requirements with the aim of achieving customer confidence in the provided products and services.

To achieve such confidence, it is often necessary to translate the customer's implied needs into internal requirements of the organisation.

Note. Requirements include compliance with legal and regulatory requirements.

5.3. Statesmen! and Regulatory Requirement of Quality Policy : The top management shall define and document its policy for quality and ensure that it :

(*a*) is relevant to its goals and the needs and requirements of its customers,

(*b*) includes commitment to quality for all levels of the organisation,

(*c*) provides a framework for setting and reviewing quality objectives,

(*d*) is documented, communicated, understood and implemented throughout the organisation,

(*e*) is regularly reviewed for suitability and effectiveness. This will provide confidence to customers.

5.4. Quality Objectives and Planning :

5.4.2. Quality objectives and targets: The management shall establish and maintain documented quality objectives consistent with the quality policy.

The purpose of establishing quality objectives and targets is to facilitate implementation of the quality policy. This is the link between policy and operations.

5.4.3. Quality planning : Management shall define and document how the quality requirements for products and services, and related processes, will be met. This planning for quality shall be consistent with other requirements of the quality management system and shall be documented in a format to suit the operating practice.

The purpose of quality planning is to define and co-ordinate the activities needed to meet quality objectives.

The organisation shall establish quality plans to meet the specified quality requirements. Consideration shall be given to the following issues :

(*a*) quality objectives,

(*b*) allocation of resources, responsibilities and authority needed,

(*c*) processes the constitute the organisation's operating practice and for which specific procedures and instructions apply,

NOTES

(*d*) identification and acquisition of any equipment, resources and skills that are needed,

(*e*) clarification of standards of acceptability for all quality requirements, including those which contain subjective judgement,

(*f*) identification of suitable verification activities,

(*g*) need for and preparation of quality records.

5.5. Quality Management System Administration

5.5.1. General : Management shall establish, document and maintain a quality management system as a means of ensuring that products and services conform to specified requirements. The quality management system shall be structured and adapted to the organisation's particular type of activities.

5.5.2. Responsibility and Authority : The responsibility, authority and the interrelationships among personnel, shall be defined and documented, particularly for personnel who need the organisational freedom and authority to:

(*a*) initiate action to prevent the occurrence of non-conformities relating to the product and service, process and quality management system,

(*b*) identify and record problems relating to the product and service, process and quality management system.

(*c*) initiate, recommend or provide solutions through established line of reporting,

(*d*) verify the implementation of solutions,

(*e*) control further processing or delivery of non-conforming product and service until the deficiency or unsatisfactory condition has been corrected.

The purpose of this structure is to create a positive attitude in the organisation for continual improvement and giving the customer confidence.

5.5.3. Management Representative : Top management shall appoint a member of the organisation's own management who, irrespective of other responsibilities, shall have defined authority for

(*a*) ensuring that a quality management system is established, implemented and maintained in accordance with the requirements in this International Standards,

(*b*) reporting on the performance of the quality management system to the management for review.

(*c*) proposing new areas for improvement.

The management representative is appointed to maintain awareness of customer requirements, needs and expectations.

5.5.4. System Documentation-Internal Communication

5.5.5. Quality Manual: The organisation shall prepare a quality manual covering the requirements of this International Standard.

The quality manual shall:

(*a*) state the quality policy

(*b*) describe the quality policy

(*c*) include the presentation of the organisational structure

(*d*) shall include or make reference to the procedures to be used and the documentation required.

NOTES

5.5.6. Control of documents : The organisation shall establish and maintain procedures for controlling all documents and data required for the management of processes, to ensure that :

(*a*) they can be located,

(*b*) they are periodically reviewed, revised as necessary an approved for adequacy by authorised personnel,

(*c*) the current versions of relevant documents are available to all locations where operations essential to the effective functioning of the process are performed,

(*d*) obsolete documents are promptly removed from all points of issue and points of use, or otherwise preventing unintended use,

(*e*) any obsolete documents retained for legal and/or knowledge preservation purposes are suitably identified.

Documentation shall be legible, revision controlled and readily identifiable, maintained in an orderly manner and retained for a specified period. Procedures and responsibilities shall be established and maintained concerning the creation and modification of the various types of document.

5.5.7. Control of Quality Records : The organisation shall establish and maintain documented procedures for the *identification, collection, indexing access, filing*, maintenance and disposition of quality records to demonstrate conformance to specified requirements.

Quality records shall be maintained to demonstrate conformance to specified requirements and the effective operation of the quality management system. Pertinent quality records from the suppliers shall be an element of these data.

Quality records shall be legible, and shall be stored and retained in such a way that they are readily retrievable in facilities that provide a suitable environment to prevent damage or deterioration and to prevent loss. Retention times of quality records shall be established and recorded.

5.6. Management Review : The quality management system shall be reviewed by the top management and by persons from other appropriate management levels, at defined intervals. The defined intervals shall be sufficient to ensure continuing suitability, adequacy and effectiveness of the quality management system including the quality policy. Management review shall given consideration to:

(*a*) audit results,

(*b*) customer satisfaction,

(*c*) relevance of existing quality policy and quality objectives,

(*d*) whether product audit is necessary.

Management rewiew shall include review of the performance of the quality management system as *a* basis for improvement of the quality management system. Records of such management reviews shall be kept. The management review is done to ensure that customer confidence is being maintained.

5.6.1. General

5.6.2. Review Input

5.6.3. Review Output

NOTES

6. RESOURCE MANAGEMENT

6.1. Provision of Resources General: The organisation shall identify and provide resources needed to implement and maintain the quality management system.

6.2. Human Resources

6.2.1. Designation (Assignment) of Personnel: The responsibilities, authorities and functions of personnel performing activities affecting quality, as defined by management, shall be communicated within the organisation to enable clear understanding of roles.

6.2.2. Competency

6.2.2.1. Training. There is need for a system to evaluate training needs analysis, to design of training, and to develop of training plan to employees, customers, suppliers and other interested parties.

6.2.2.2. Qualification and Competence. Levels required for qualification and competence of personnel are to be specified, quiz/test to be utilised to measure competence in personnel selection, recruitment and training for development of skills and continuing education.

6.2.2.3. Training and Competence. Procedures for the management of education, training and qualification of personnel shall be defined, documented, implemented and maintained in order to provide for systematic development of individual competence.

6.2.3. Awareness and Involvement. This section emphasis on top managent's involvement to "continually promote policies and objectives to increase awareness, motivation and involvement of personnel, enhancing their skills by training, continuous improvement of human performance through individual efforts and team work so as to *Enhance The Results of the organisation,* emphasies the role of continuous education like introductory programme for new personnel, periodic refresher programmes for existing personnel, team spirit buildup campaigns for improvement of performance like Quality Circles, Kaizen, Jishu Kanri etc.

6.3. Infrastructure Facilities

The organisation shall define, document, implement, and maintain information such as knowledge, data and records necessary to ensure the quality of the product and service.

System for control, access (including communication), and the protection of such information shall be defined, documented, implemented and maintained to ensure integrity and availability of the information (See 7.2)

6.3.1.1. Content : Information Management processes include indentification acquisition, use, storage, updating, security and confidentiality, retrieval and disposal of information/data.

6.3.1.2. Characteristics : Legibility, accuracy, clarity, integrity relevance.

6.3.1.3. Media : For management of information, media types are contracting, designing, process control, verification and testing, compliance with regulatory requirements, protection of intellectual property, managing personnel, customer and supplier interface, interaction with interested party usage of audio-visual media/ documentation media/speech media.

6.3.2. Infrastructure : The organisation shall define, document, implement and maintain its infrastructure, such as plant, workspace, hardware, software, tools services, standards, communication, transport and facilities, necessary to realise its objectives relative to its products and services and ensure their quality.

6.4. Work Environment : The organisation shall define, document, implement and maintain any human or physical aspects of the work environment that are needed to ensure the quality of the product and service.

NOTES

6.5 Information

6.6 Suppliers and Partnership

6.7 Natural resources

6.8. Finance : Involves reporting Q.M.S. activities in financial terms which should be planned implemented and maintained. Internal reduction in error and waste and external enhancement of customer satisfaction as well as financial and other expectations of interested parties (employees, suppliers, owners, society). This section emphasies that management should plan, make available and control financial resources necessary to implement and maintain the Q.M.S. and achieve desired product and/or service quality. *It adds (printed in italics) that "Resource planning should plan, available* and control financial resources necessary to implement and maintain the Q.M.S. and achieve desired product and/or service quality. It adds (printed in italics) "Resource planning should include activities for determining needs for and sources of financial resources. The control of financial resources should include activities for comparing actual usage against the plants and taking necessary action." *Compare clause 6 entitled "Economics-quality related cost considerations" of Annexure* 2.

7. PROCESS MANAGEMENT

7.1. General : Production realisation the organisation shall identify and manage process that affect the quality of product or services. In identifying these quality related processes the organisation shall consider outputs from the quality planning process (see 5.4.2). This is to give assurance that the processes employed are controlled and relate to the organisations quality policy and objectives.

The *sequence and interaction* of quality releated processes shall be identified and managed to ensure that they operate together effectively.

Responsibilities for the development, operation and control of quality related processes shall be allocated to personnel with sufficient authority to ensure that process operation and output are consistent with the organisations quality policy and objectives.

To provide a basis for confidence in-consistent and effective operation the organisation shall:

(*a*) define the significant process parameters that impact on product or service characteristics

(*b*) define the methods used to control quality related processes

(*c*) where appropriate, define standards and codes of practice relevant to particular processes

(*d*) define that arrangements for measurement, monitoring, recording and controlling to ensure that processes operate effectively and the resultant product or service meets specified requirements (see 8.13 and 8.14)

(*e*) ensure the availability of process documentation that provides information and/or operating criteria to support the effective operation of the processes (see 5.5.3).

The organisation shall give consideration to:

(*a*) the capability of process to be operated and maintained

(*b*) personnel training and qualification requirements for process activities (see 6.2.2)

NOTES

(*c*) the facilities, equipment, materials and software necessary to support and process (see 6.3)

7.1.1. Process and Quality : Optimising organisational capability will required achievement of consistent and effective operation of the processes which produce outputs directly related to customer's needs, produce outputs affecting needs of Interested Parties and also produce outputs for use within the organisation like spare parts, tools etc.

7.1.2. Process Network : This section analyses how all inputs and outputs interrelate.

7.1.3. Managing Process Responsibility : This section outlines how process responsibilities and authorities for action are to be clearly assigned to personnel and reviewed by management periodically to ensure continuing improvement and results.

7.1.4. Planning for Process Control : This section emphasises listing quality characteristics and their interrelationship, process capability, methods of measuring, and type of corrective action required when out of control.

7.1.5. Process documentation : This section highlights various aspects of process documentation and emphasises that the documentation should be "user friendly" to support process efficiency and to establish basis for process improvement, identify training needs of concerned personnel/teams/groups who have the improve process efficiency.

7.2. Process Related to Interested Party

7.2.1. Identification of customer requirements, needs and expectations: The organisation shall establish a process for identifying customer requirements. This process shall address :

(*a*) the extent to which customer requirements are formally specified

(*b*) implied or unstated requirements which must be addressed to ensure fitness for purpose of the product or service

(*c*) obligations in relation to the product or service including warranties, liabilities,and legal compliance

(*d*) customer requirements for the availability and delivery of the product or service.

7.2.2. Review of customer requirements needs and expectations : The identified customer requirements shall be reviewed before a commitment to supply a product or deliver a service is made to the customer (*e.g.*, acceptance of a contract or order).

This review shall ensure that:

(*a*) the requirements are adequately defined and documented

(*b*) where no written statement of requirement is available for an order received verbally, a record of the agreed order requirements differing from those in the tender are resolved

(*c*) records of the outcome of the review are retained. The above review provisions shall also be applied to customer order amendments.

7.2.3. Review of organisational capability to meet defined requirements: Each commitment to supply a product or service shall be reviewed to ensure that the organisation has the capability to meet the defined requirements. Where applicable, relevant evidence of this activity shall be retained.

NOTES

The organisation shall identify how any amendment to an order to contract is reviewed against organisational capability and the changed requirements communicated to concerned functions within the organisation.

In establishing its arrangements for liasion the organisation shall consider to the communication requirements relating to :

(*a*) product or service information

(*b*) enquiry and order handling including amendments

(*c*) customer complaints and other reports relating to *non-conformities* (see 7.6 and 8.2.1.)

(*d*) product recall processes, where appropriate (see 8.2.1)

(*e*) *customer feedback on performance* (see 7.3.3 and 8.2).

7.2.4. Interested party communication : This section is a comprehensive guide to such communication 7.3. Design and development

7.3.1. Managing Process General Guidance

(*a*) relevant to the design and development of all product and service categories (*i.e*, hardware, software, processed materials and services)

(*b*) applicable to the design and development of any critical process operations where their effectiveness cannot be guaranteed by any other means (see 7.5.6).

7.3.1. Design and Development Planning: The organisation shall prepare plans for each design and development activity. The plans shall describe or refer:

(*a*) stages of the design and development process

(*b*) required review, verification and validation activities

(*c*) responsibilities for design and development activities

The design and development activities shall be assigned to *qualified personnel* equipped with adequate resources.

Interfaces between different groups involved in design and development processes shall be defined and the necessary information shall be documented, transmitted and regularly reviewed.

The plans and associated documentation shall be:

(*a*) made available to relevant personnel

(*b*) reviewed and updated as design and development evolves.

7.3.2. Design and development inputs : *The requirements to be met by the* product or service (or process where applicable) shall be identified and documented. These shall include identified customer or market requirements, applicable statutory and regulatory requirements, feedback from previous similar design and any other requirements considered essential for design and development. Incomplete, ambiguous or conflicting requirements shall be resolved.

7.3.3. Design and development outputs : The outputs of the design an development process shall be documented and expressed *in a manner that allows verification* against relevant input requirements.

Design and development outputs shall :

(*a*) *meet the design and development* input requirements

(*b*) contain or make reference to acceptance criteria

(*c*) identify those characteristics of the design that are crucial to the safe and proposes and application of the product or service (or process where applicable). Design and development output documents shall be reviewed and approved before lease for use.

NOTES

7.3.4. Design and development review : At defined stages of design and development, a formal, systematic and critical review of the results shall be conducted to monitor compliance with input requirements.

Participants in the design review process shall include representatives of all functions concerned with the design stage being reviewed.

Record of the design reviews and subsequent follow up actions shall be maintained.

7.3.5. Design and/or Development verification : At defined stages of design and development verification shall be performed to ensure that the design output meets the design input requirements. The results of verification shall be recorded.

Note: In addition to conducting design and development reviews, design verification may include activities such as:

(*a*) comparing the new design with a similar proven design, if available.

(*b*) undertaking tests and demonstrations

(*c*) undertaking alternative methods of analysis

(*d*) reviewing the design stage documents before releases.

7.3.6. Design and/or Developments Validation : Validation shall be performed to confirm that the resultant product or service is capable of meeting the defined needs of customers or users under intended conditions.

Note:

1. Wherever possible validation shall be defined, planned and completed prior to the delivery of the product or implementation of the service.

2. Partial validation of the design or development outputs may be necessary to provide confidence in their adequacy for use in production, construction or delivery. Such partial validation may use methods such as :

(*a*) reviews involving other stockholders

(*b*) modelling and simulation studies

(*c*) production, construction or delivery trials of key aspects of the product or service.

7.3.7. Control of Design &/or development change : All design and development changes and modifications shall be identified, documented, reviewed and approved authorised personnel before their implementation. This activity shall include consideration of the effect of changes on the compatibility of the product or service throughout its life cycle.

7.4. Purchasing

7.4.1. Purchasing Procedure : The organisation shall control its purchasing and procurement processes to ensure purchased products and services conform to the organisation's requirements. In order to determine the type and extent of the control required the organisation shall consider the impact of the purchased or procured products and services upon the final product or service.

The organisation shall evaluate and select suppliers based on their ability to supply products or services in accordance with the organisation's requirements.

The supplier shall maintain records of supplier quality performance, including records of quality audits where appropriate, and shall take these into account when selecting suppliers and determining the type and extent of control applicable to the acquired product or service.

7.4.2. Purchasing data: Purchasing documents shall contain data clearly describing the product ordered, including, as applicable :

(*a*) the type, class, grade or other precise identification ;

(*b*) the title or other positive identification, and applicable issue of specifications, drawings, process requirements, inspection instructions and other relevant technical data, including, requirements for approval or qualification of product, procedures, process equipment and personnel ;

(*c*) any applicable quality system requirements.

The organisation *shall review and approve purchasing documents for adequacy* of specified requirements prior to release.

7.4.3. Verification of purchased product and services: The organisation shall define the need for verification of purchased goods or services and implement the necessary controls.

Where the organisation, its customer or its customer's representative proposes to undertake verification activities at the supplier's premises, the organisation shall specify the required verification arrangements and the method of product release in the purchasing documents or associated documentation.

Note: Verification by the customer shall not absolve the supplier of the responsibility to provide acceptable product, nor shall it preclude subsequent rejection by the customer.

7.4.4. Purchasing Processes

7.5. Production and Service Operations

7.5.1. Services : Production and service provision operations shall be subject to planned arrangements and controls consistent with the requirements of section 7.1 and the following subclauses as appropriate.

Control of the product and service realisation processes : Control shall be achieved through :

(*a*) the use and maintenance of appropriate production, installation, servicing and service provision equipment, (see 5.3)

(*b*) the provision of suitable working environments (see 5.3.3)

(*c*) the availability of work standards, which shall be stipulated in the clearest practical manner (*e.g.*, written standards, representative samples or illustrations)

(*d*) the performance of appropriate monitoring, inspection or testing activities (see 8.1.3 and 8.1.4)

(*e*) the availability and use of appropriate inspection, measuring and test equipment that is capable of the necessary accuracy and precision (see 8.1.5)

(*f*) provision for identifying the status of products or services with respect to required measurement and verification activities

(*g*) appropriate methods for segregation and release of product or services.

7.5.2. Identification and Traceability. Where appropriate the organisation shall identify the product or service by suitable means through out all process operations.

7.5.3. Customer Property : The organisation shall exercise due care with respect to their customer's property while it is under the organisations control or being used by the organisation. Such control shall include the verification, storage and maintenance of customer supplied product provided for incorporation into the supplies

NOTES

or for related activities. Any customer product or property that is lost, damaged or is otherwise found to be unsuitable for use shall be recorded and reported to the customer (see 7.2.4).

7.5.5 Handling Packaging Storage and Preservation : Control shall be achieved through :

(*a*) methods that prevent damage or deterioration

(*b*) assessement of the condition of product in stock at appropriate intervals where product is liable to deterioration

(*c*) the use of packing, packaging and marking processes (including materials used) to the extent necessary to ensure conformance to sepcified requirements

(*d*) protection of the quality of product after final inspection and test until such times that it is no longer the responsibility of the organisation.

7.5.6. Process validation : The organisation shall identify any process:

(*a*) the results of which cannot be fully verified by subsequent inspection and testing of the product or service; or

(*b*) where processing deficiencies may become apparent only after the product is in use or the service has been delivered.

These processes shall be validated to demonstrate their effectiveness and acceptability. The arrangements of validation shall be identified and recorded and shall give consideration to any need for:

(*a*) such processes to be pre-qualified

(*b*) the pre-qualification of equipment or personnel

(*c*) the use of specific procedural documentation or records.

Records shall be maintained for qualified processes, equipment and personnel, as appropriate.

Note: Such processes requiring validation or pre-qualification of their process capability are frequently referred to as sepcial processes.

7.6. Control of non-conformity

7.6.1. General : Organisation shall ensure that any product or service which does not or will not conform to specified requirements is prevented from unintended use or installation.

Control shall provide for identification, documentation and review of the problem encountered and its extent.

The arrangements for ensuring the management of such situations until compliance with specified requirements can be re-established shall be defined (see also 8.2.1).

7.6.2. Non-conformity review and disposition : Instances of non-conformity shall be reviewed with regard to the action to be taken. They may be:

(*a*) corrected or adjusted to meet the specified requirements, or

(*b*) accepted with or without correction by concession, or

(*c*) reassigned for alternative applications, or

(*d*) rejected as unsuitable.

The responsibility and authority for review and resolving of non-conformities shall be defined.

When required by the contract, the proposed use or repair of non-conforming product or delivery of a non-conforming or modified service shall be reported for concession to the customer or customer's representative. The description of any accepted non-conformity, product repairs of service modifications, shall be recorded.

NOTES

Where it is necessary to repair or rework products or repeat services verification requirements shall be defined and implemented.

7.7. Delivery and post delivery services : Where there is a defined requirement of the organisation to provide services at delivery or subsequent to delivery these shall be subject to planned arragement and controls consistent with the requirements of section 7.1, together with other requirements of Section. 7.0, as appropriate.

In establishing the extent and scope of such service the organisation shall take account of contractual and legal obligations.

8. MEASUREMENT, ANALYSIS AND IMPROVEMENT

8.1. Measurement and Analysis

8.1.1. General : The organisation shall establish, document and maintain a measurement and analysis process of verifying the results of measurements of system, processes, product and customer satisfaction to provide for effective management and improvement of the quality management system.

Measurement results shall be recorded. The results of analysis of data and of improvement activities shall be an input to the management review process.

The type, location and frequency of measurements shall be defined base on the importance of the characteristics and measures, such as internal audit results and customer complaints.

8.1.2 Measurements of system performance

8.1.2.1 Internal Audit : The organisation shall carry out audits of its quality management system processes, and, as appropriate, products in order to determine if:

(*a*) the quality management system, processes and product conform to specified requirements and

(*b*) the quality management system and processes have been effectively implemented and maintained.

The organisation's internal audit programme, including a schedule, shall be based on the status and importance of the activities, areas or items to be audited and the results of previous audits.

The internal audit programme shall include :

(*a*) planning and scheduling the specific activities, areas or items to be audited and other inputs which include organisational changes, market feedback, previous audit results, non-conformity reports, customer complaints and surveys.

(*b*) assignments of personnel with the appropriate education, training and/or experience, independent of those performing the work being audited, as appropriate

(*c*) documentation, such as a checklist, used to provide a consistent base for the audit process.

The organisation shall record the result of the internal audits including:

(*a*) activities, areas, processes and as appropriate, products audited

(*b*) non-conformities or deficiencies found

(*c*) corrective actions taken as a result of previous internal audit non-conformities found

(*d*) recommendations for improvement.

Note: Guidance on quality management system audits is given in ISO 10011.

NOTES

8.1.2.2. Measurements of Customer Satisfaction : The organisation shall have a documented procedure for the determination, monitoring and feedback of customer satisfaction and satisfaction at appropriate stages of product/service realisation. The organisation shall specify the methodologies and the measures to be used to obtain customer knowledge and the frequency of reviews. The effectiveness of measures implemented shall be periodically re-evaluated. These measures, including their revisions, shall be approved by authorised personnel.

The organisation shall analyse the results of the customer satisfaction measures on a continual basis to take appropriate action. Trends in customer satisfaction and customer dissatisfaction shall be documented and compared to relevant market data.

The organisation shall establish and document customer satisfaction goals to meet customer expectations.

8.1.3.Measurements of Processes: The measurement of processes shall identify:

(*a*) characteristics which directly affect process performance

(*b*) the scope, type and frequency of measurement, and

(*c*) methods for ensuring consistency, validity, review, and timely access of quality measurement data.

8.1.4.Measurement of products : The organisation shall establish and maintain documented procedures to monitor and measure its products and/or services including incoming products and services, in order to verify that the specified requirements for the product and /or service are met, with attention to the crucial charcteristics. The required inspection and testing activities and acceptance criteria to be established, and the records to be maintained, shall be recorded in the quality management system documentation.

Records shall indicate if prodcuts and/or services have passed or failed inspections and/or tests according to defined acceptance criteria. Records shall also identify the inspection authority responsible for the release of products and/or services.

Product and/or services shall not proceed or be dispatched until all the activities specified in the quality plan and/or documented procedures have been satisfactorily completed and the related data and documentation are available and authorised. Except when product is released under positive recall procedures.

8.1.5.Control of measuring, inspection and test equipment : The organisation shall establish and maintain documented procedures to control, calibrate, maintain, handle and store inspection, measuring and test equipment, including test software, used by the organisation to demonstrate the conformance of product to the specified requirements. Inspection, measuring and test equipment shall be used in a manner which ensures that the measurement uncertainty, including accuracy and precision, is known and is consistent with the required measurement capability Calibration, inspection and testing shall be performed by competent personnel.

The organisation shall:

(*a*) calibrate and adjust inspection, measuring and test equipments, including test software, at prescribed intervals and/or prior to use, against certified equipments having a known valid relationship to international or national standards. Where no such standards exist, the basis used for calibration shall be documented.

(*b*) identify inspection, measuring and test equipment with a suitable indicator or approved identification record to show the calibration status

(c) maintain calibration records for inspection, measuring and test equipments:

(d) ensure that the environmental conditions are suitable for the calibrations, inspections, measurements and test being carried out;

(e) safeguard inspection, measuring and test equipment, including both hardware and software from adjustment which would invalidate the calibration setting;

(f) verify the validity of previous inspection and test results when equipment is found to be out of calibration;

(g) develop a reaction plan to be initiated when calibration verification results are unsatisfactory.

8.1.6. Control of quality records : The organisation shall establish and maintain documented procedures for the identification, collection, indexing, access, filing, storage, maintenance and disposition of quality records to demonstrate conformance to specified requirements.

Quality records shall be maintained to demonstrate conformance to specified requirements and the effective operation of the quality management system. Pertinent quality records from the suppliers shall be an element of these data.

Quality records shall be legible, and shall be stored and retained in such a way that they are readily retrievable in facilities that provide a suitable environment to prevent damage or deterioration and to prevent loss. Retention times of quality records shall be established and recorded.

8.1.7. Analysis of data : *The organisation shall analyse data to provide* information to relevant functions including management to ensure effectiveness of the quality management system and to demonstrate conformance to specified requirements.

The organisation shall plan the collection of, and gather data from relevant *sources such as records from internal audits, corrective action,* non-conforming product, customer complaints and customer satisfaction.

The organisation shall identify the need for statistical techniques required for analysing data including verifying process capability and product characteristics, and shall implement appropriate techniques. The organisation shall establish and maintain documented procedures to implement and control the application of the statistical techniques identified.

8.2. Measurement and Monitoring

8.2.1. Measurement and Monitoring of System Performance

Clause 8.2.2 of ISO 9001 requires: "The responsibilities and requirements for planning and controlling audits, and for reporting records and manufacturing records shall be defined in a documented procedure."

The above requirements indicate that essentially four stages are there in an audit cycle.

- Planning
- Execution
- Recording
- Close-out

Planning being the first stage in the audit cycle, is very crucial to the success of any audit, thus auditor must spend adequate time and effort in the preparation for an audit. Audit is very important activity and demands the time and attention of many people in many departments/organisations. Not everyone is too happy (to put it mildly)

NOTES

NOTES

at being audited, so it is necessary that an audit is carried out in a professional manner to make it a well accepted activity. This is possible when auditor has prepared himself/ herself properly.

Audits, especially internal audits, tend to lose their objective and thus become unacceptable in the organisation if the management has not done the homework. Thus management must take necessary actions to prepare the organisation before the audits are formally started in the organisation. Following steps are required to be taken to prepare the organisation for audit:

- Commitment from Top Management;
- Define audit objectives, and scope;
- Establish audit procedures;
- Nominate and train auditors:
- Explain the role and provide facilitation to auditees for audit;
- Review and monitor system effectiveness through audit findings.

(*i*) **Planning The Audit.** Reasons for carrying out audits may vary but the processes of preparation and performing the audits do not vary. What differs is the scale of effort required. Familiarity with processes and system is minimum in external audits, thus they need maximum effort for preparation.

Define audit objective. The objective can be any of the following:

To assess a company for its degree of compliance to the quality standard (Third party audit).

- To determine the company's ability top make a particular product and to deliver on time. (Second party audit)
- To determine where the greatest problem lies. (First party audit)

  Whatever may be the objective, it is essential to make it clear at the beginning.

(*ii*) **Define scope of the audit.** Scope indicates that areas/ activities to be audited to achieve the said objective. Scope can be :

- All activities of YOUNG ENGINEERS LTD. involved in the design, manufacture, installation and servicing of complete Chemical Plants.

  (Third Party Audit)
- Activities related to manufacture, inspection and delivery of refrigerators (for commercial use) only, carried out at Faridabad and Chennai units of M/ S COOLIN LTD. (Second Party Audit)
- To audit all activities of production line 1 or 2 (Internal Audit) ...etc.

In third party audit, scope is determined by the auditee organisation in agreement with the certification body. In second party audit, scope is decided by client and in internal (First Party) audit, it is decided by the auditee management only.

We must understand that this scope of audit is different from scope of defined Quality Management System. Scope of QMS is as defined in Clause 1.2 of ISO 9001 : 2000.

(*iii*) **Nomination of team Leader.** Having worked out above parameters, the person who is going to lead the audit team can be nominated. He or she is called Audit Team Leader or the Lead Auditor and has total responsibility for planning, performing and reporting the audit.

Team Leader needs briefing on the objectives and scope of the audit and is required then to specify the resources necessary, in terms of staff day to carry out the audit and other personnel required.

Team Leader may be chosen on the basis of particular experience – technical and/or audit experience.

NOTES

(*iv*) **Various factors may affect the decision of calculating audit duration:**

- Size of organisation;
- Geographical location (s);
- Range of products/services;
- Results of previous audits (if any);
- Level of automation;
- Complexity of written quality system;
- Type of Audit (Internal/External);
- Audit objective.

For the sake of example, if six monday are required to carry out on audit, Team Leader could decide to do the audit alone for six-days or there could be a team of two and spend three days or a team of three and spend two days or a team of six and spend one day. Which is preferable ? The differences in cost are not remarkable and so it is best to consider what configuration of time and manpower will most effectively achieve the audit's objectives. Too large a team can be disruptive for auditee and may also prove to be ineffective because of virtually no time available for interactions whereas too small a team for extended duration may create more pressure on auditees. Thus, two people for three days or three people for two days is likely to be optimum. It is not possible to be specific about this.

(*v*) **Select the Audit team.** Audit duration and geographical location would indicate the number of auditors required in the team.

Other factors affecting audit team selection are:

- Familiarity with industry sector to be audited – Technical Expertise;
- Inter personnel skills;
- Independence of the function being audited;
- Acceptability within the team;
- Acceptability to the auditee organisation;
- language skills.

(*vi*) **Contact with auditee.** *Having clarified objective, scope and resources* needed, the Team Leader needs to contact the auditee. A considerable amount of information is required from the company—its activities, organisational policies and procedures. Often initial contacts are established via the return of a questionnaire from the auditee. This can provide information relating to company size, product range, names, addresses, contacts etc.

(*vii*) Decide dates of audit with the auditee.

(*viii*) Preliminary Meeting.

It is often useful in second and third party audits and may be in internal audits for multilocational units or in a very large organisation to have preliminary meeting on-site with the auditee management. Purpose of such a meeting is to:

- collect quality manual/procedures;
- know about management priorities;

NOTES

- have a feel of quality problems;
- have trends of previous audits;
- gather product information;
- know the technicalities involved in the processes enabling him/herself to decide the need for any technical expert in the audit team.

A quick round of the plan/area of work would help Team Leader to judge any special requirements such as protective clothing, restrictive entries, transport facilities etc. required during audits. Any doubts in the minds of auditees regarding audit process can also be clarified.

It may be important to note at this point that an auditor may have to prepare to audit a supplier (in Second Party Audit), as a part of internal procedure, who has not yet documented its system, in which case irrespective of the fact that documented manuals and/or procedures are not available, other steps of preparation would remain the same. In such a case, going for an on-site preliminary meeting would be of a great value.

(*ix*) **Draw up a Programme:** Keeping in view all the information gathered, Team Leader draws up an audit programme. Format for audit programme may be different for First Party, Second Party and Third Party audits Examples of Third Party audit programme.

AUDIT PROGRAMME

YELL LTD.

Team Leader		
Team 1		
Team 2		
Audit Date		
DAY 1		
Time	**Team 1 & Team 2**	
0930 - 1000	Opening Meeting	
1000 - 1030	Audit Programme Review	
	Team 1	**Team 2**
	Management Process	**Product realisation process**
1030 - 1200	Policy deployment & Review	Design
1200 - 1330	Improvement process	Marketing and projects (Customer related process)
1430 - 1630	Customer satisfaction process	QA
1600 - 1700	Management Representative's	Servicing
DAY 2		
Time	**Team 1**	**Team 2**
0930 - 1200	HR Process	Production Planning and Production
1200 - 1330	Resource Management Process	Purchasing
	Team 1 and Team 2	
1400 - 1530	Preparation for Closing Meeting	
1500 - 1630	Closing Meeting	

Internal audit plans and programme may take different formats and are discussed in the next section of this chapter.

As per internal Audit requirement (8.2.2) of ISO 9001, audit plans must be prepared and audits to be scheduled on the basis of status and importance of the processes / areas to be audited.

NOTES

"Status" — Whether there have been problems in the past which reduce confidence in the area to be audited.

"Importance — How critical that area is to the quality of what is produced.

AUDIT PLAN

Process			*Department / Function*			*Month*						
	COE	*MR*	*Mktg*	*Pur.*	*Prod.*	*Jan.*	*Feb.*	*Mar.*	*April*	*May*	*June*	*July*
Management Responsibility	R	R	R		P				P			
Resource Management	R	–	–	R	–		P		P			
Purchasing	R			R	R			P	P			

R → Responsibility identified P → Planned Audit

Once the audit plan as drawn it does not mean that audit frequencies cannot be changed. Audit frequency may change due to:

- Results of previous Internal/External audits,
- Investigation of problems,
- Changes to the Quality System,
- Any specific customer requirements. Audit programme can be drawn as :

(*x*) **Brief Audit Team.** It is responsibility of Team Leader to give briefing to the members of the audit team regarding objective and scope of audit, applicable standard and related company's documentation, audit programme and assignment of members responsibilities ensuring members prepare checklists for audit.

(*xi*) **Draw up checklist.** No preparation activity can be considered as complete if audition not prepare checklist.

Checklists are discussed in detail in Section 8.

AUDIT PROGRAMME

Month ***January***

Process	*Deptt.*	*Auditee*	*Auditor*	*Date & Time*	*Report No.*	*Remarks*
Management Responsibility	CEO	D. Aggarwal	A. Syam	Jan 5 10-11 AM	AR/01/01	
	Mr	Sriram	R. Bhardwaj	Jan 5 11-12 Noon	AR/01/02	
	Mktg.	D. Sunder	Vikas	Jan 5 12-1 PM	AR/01/03	
Resource	CEO	D. Aggarwal	A. Sayam	Jan 5 10-11 AM	AR/01/04	
Management	Pur.	VikasSriram		Jan 5 3 -4PM	AR/01/05	

This is one of the examples of the programme. *Format may* be of different shapes to out the organisation's needs.

Once the auditees are informed of the audit details, it is expected that all auditees would prepare to participate actively in the audits. This means that they must go through procedures if received, keep their records readily retrievable and ask the department's personal to be available for audit.

8.2.3. Monitoring and Measurement of Process

8.2.4. Monitoring and Measurement of product

8.3. Control of Non-conforming product

NOTES

8.4. Analysis of data for improvement: This section asks you to refer to the standard ISO/TR 1425, entitled ISO H.B on Statistical Methods for Quality Control and also to the IEC/TR standard No. 56.

8.5 Improvement of the organisation

8.5.1. Continual Improvement : Compare clause 15 of annex 2. This is almost a reproduction of 1994 standard but in different section title and hence not analysed in detail.

8.5.2. Corrective action : The organisation shall establish and maintain documented procedures for eliminating the causes of non-conformity, defects or other undesirable situations in quality characteristics and the quality management system to prevent reoccurrence.

The organisation shall use non-conformity report, customer complaints and other relevant quality management system records as inputs to the corrective action process, as appropriate.

Responsibilities for corrective action shall be defined. The procedures for the corrective action process shall include : "identification of non-conformities of product, process or quality management system and customer complaints.

8.5.3. Preventive Action : This section emphasies that one should not rely merely on verification activities (as in the past for 1994 series of standards) and focuses of *Defect Prevention Methods* such as statistical techniques, "Mistake Proofing and visual controls".

8.5.4. Measurement of products and/or services : Quality plan documents should indicate relevant inspection and test plan, methods to verify supplier products and services conformance requirements of inspection/tests, and of location/method/evaluation/procedure/acceptance criteria/proof testing before it reaches customer, pilot samples, prior to bulk orders, code of practice, standards, drawings, specifications, usage instructions, and demonstrations to customer.

Control of measuring, inspection and test equipments. Compare clauses 12.2. alongwith clauses 13 of annex 2. This section defines processes for calibration of measuring/inspection and test equipments, for carrying out statistical study on the consistency and accuracy of these equipments, and to do all that is needed for generation of reliable data and include training of personnel, provision of spare parts, giving necessary external help from laboratories, allocate financial resources etc. Full details are given in the standard ISO/IEC GUIDE 25 (especially if the work is out sourced).

8.3.3. Prevention Action

"Design and Development". Where the organisation has no responsibility for design and development of the product it provides.

"Identification and Traceability". This clause would only be partially applicable where there is no specific traceability requirement for the organisation's product.

"Customer Property". Where the organisation uses no customer property in its product realisation processes.

"Control of Monitoring and Measuring Devices". Where the organisation needs no monitoring or measuring devices to provide evidence of conformity of its product.

Requirements that may not be excluded

- Where an organisation fails to comply with the requirement in clause 4.2.2 (a), "Quality Manual" to provide justification for the exclusion of specific clause 7 (Product Realisation) Requirements.

- Where an organisation decides not to apply a requirement in clause 7 based only on the justification that this was not a requirement of either ISO 9001 : 1994 ; ISO 9002 :1994 or ISO 9003 : 1994, and had not been included in the organisation's QMS.

NOTES

• Where requirements is clauses 7 have been excluded because they are not required by regulatory bodies, but this affect the organisation's ability to meet customer requirements.

THE REVISED ISO 9001:2000 STANDARD CHARACTERISTIC

- Is a flexible management system;
- Is process, not procedures based;
- Encourages continual improvement;
- Views customer satisfaction as a measure of system performance;
- Motivates everyone through a common goal, ensuring participation;
- Involves Top Management Extensively-Business Excellence cannot be Delegated;
- Relates to statutory and regulatory requirements;
- Requires measurable objectives at different levels of system, function and product;
- Focuses on effective internal communications;
- Directs attention to the availability of resources;
- Asks for the effectiveness of training, and quality management to be evaluated.

TEN TIPS FOR MOVING TO ISO 9001: 2000

When you're planning a trip, you must know your starting point and ultimate destination to determine the best route. Similarly, before plotting your transition path to ISO 9001:2000, you need to understand the new and changed requirements. You can begin this process by ordering the ISO 9000:2000 family of standards (ISO 9001:2000, ISO 9000:2000 and ISO 9004:2000). Then take a look at the following 10 tips, which will help you navigate from the old standard to the new without getting lost along the way.

1. Understand the new and changed requirements: Before opening the ISO 9001:2000 standard, review the quality concepts found in ISO 9000:2000 *Quality management system—Fundamentals and vocabulary*. If you're unsure of any of the terms, look up their definitions in section 3 of ISO 9000:2000. When you examine ISO 9001:2000, pay particular attention to the process approach described in its introduction. This model illustrates the clause links based on the plan-do-check-act approach.

Refer to Annex B in ISO 9001:2000 to see the clause correspondence between ISO 9001:2000 and ISO 9001:1994. Now you're ready to begin reading through the requirements to understand the differences.

ISO 9004:2000 provides guidance on performance improvements beyond the basic requirements of ISO 9001:2000. For ease of reference, these requirements are shown in ISO 9004:2000 as boxed text. Because ISO 9004:2000 uses the same clause structure as ISO 9001:2000, it can be used to gain a better understanding of the requirements by seeing possible practices. Remember, however, that your system will be evaluated against ISO 9001:2000, not ISO 9004:2000.

NOTES

CORRESPONDENCE between ISO 9001:2000 and ISO 9002:1994

	ISO 9001 : 2000	ISO 9002 : 1994
1	Scope	1
1.1	General	
1.2	Application	
2	Normative reference	2
3	Terms and definitions	3
4	Quality Management System (title only)	
4.1	General requirements	4.2.1
4.2	Documentation requirements (title only)	
4.2.1	General	4.2.2
4.2.2	Quality manual	4.2.1
4.2.3	Control of documents	4.5.1 + 4.5.2 + 4.5.3
4.2.4	Control of records	4.16
5	Management responsibility (title only)	
5.1	Management commitment	4.1.1
5.2	Customer focus	4.3.2
5.3	Quality policy	4.1.1
5.4	Planning (title only)	
5.4.1	Quality objectives	4.1.1
5.4.2	Quality management system planning	4.2.3
5.5	Responsibility, authority and communication (title only)	
5.5.1	Responsibility and authority	4.1.2.1
5.5.2	Management representative	4.1.2.3
5.5.3	Internal communication	
5.6	Management review (title only)	
5.6.1	General	4.1.3
5.6.2	Review input	
5.6.3	Review output	
6.	Resource management (title only)	
6.1	Provision of resources	4.1.2.2
6.2	Human resources (title only)	
6.2.1	General	4.1.2.2
6.2.2	Competence, awareness and training	4.18
6.3	Infrastructure	4.9
6.4	Work environment	4.9
7.0	Product realisation (title only)	

CORRESPONDENCE between ISO 9001:2000 and ISO 9002: 1994

	ISO 9001 : 2000	ISO 9002 : 1994
7.1	Planning of product realisation	4.2.3 + 4.10.1
7.2	Customer-related processes (title only)	
7.2.1	Determination of requirements related to product	4.3.2 + 4.4.4

NOTES

7.2.2	Review of requirements related to product	4.3.2 + 4.3.3 + 4.3.4
7.2.3	Customer communication	4.3.2
7.3	Design and development (title only)	4.4(title only)
7.4	Purchasing (title only)	
7.4.1	Purchasing process	4.6.2
7.4.2	Purchasing information	4.6.3
7.4.3	Verification of purchased product	4.6.4 + 4.10.2
7.5	Production and service provision (title only)	
7.5.1	Control of production and service provision	4.9 + 4.15.6 + 4.19
7.5.2	Validation of processes for production and service provision	4.9
7.5.3	Identification and traceability	4.8 + 4.10.5 + 4.12
7.5.4	Customer property	4.7
7.5.5	Preservation of product	4.15.2 + 4.15.3 + 4.15.4 + 4.15.5
7.6	*Control of monitoring and measuring devices*	4.11.1 + 4.11.2
8.	Measurement, analysis and improvement (title only)	
8.1	General	4.10.1 + 4.20.1 + 4.20.2
8.2	Monitoring and measurement (title only)	
8.2.1	Customer satisfaction	
8.2.2	Internal audit	4.17
8.2.3	Monitoring and measurement of processes	4.17 + 4.20.1 + 4.20.2
8.2.4	Monitoring and measurement of product	4.10.2 + 4.10.3 + 4.10.4 + 4.10.5 + 4.20.1 + 4.20.2
8.3	Control of non-conforming product	4.13.1 + 4.13.2
8.4	Analysis of data	4.20.1 + 4.20.2
8.5	Improvement (title only)	
8.5.1	Continual improvement	4.1.3
8.5.2	Corrective action	4.14.1 + 4.14.2
8.5.3	Preventive action	4.14.1 + 4.14.3

Steps for ISO 9000 Certification

1. Appointment of Management Representative
2. Identification of area for ISO 9000 certification
3. Formation of core group of Resource persons and Trainers
4. Identification and training of Internal Auditors
5. Awareness training
6. Writing of SOPs and WIs
7. Training on SOPs and WIs
8. Issue of common procedure for
   - *Document Control* — Record Control
   - Quality Audit — Training, etc.

NOTES

9. Implementation of SOPs and WIs
10. Preparation of Apex Quality Manual linkage with SOPs and WIs
11. Adequacy audit
12. Compliance audit through internal audit
13. Pre-certification assessment through external consultants
14. Corrective actions after every audit
15. Management review after every audit
16. Apply for certification

STEPS IN LAUNCHING A QUALITY MANAGEMENT SYSTEM

MANAGEMENT RESPONSIBILITY	Have a quality policy, fix objectives, plan for quality, defined responsibility and authority, Appoint a Management Representative, document the systems and procedures, define the mechanism for control of documents, data and records, Plan a system of review by Top Management and a system of internal audits
RESOURCE MANAGEMENT	Plan, acquire, provide resources and train the people
PRODUCT REALIASATION	Understand customer needs, Design the product, Purchase necessary inputs, go through the process of converting the inputs into desired outputs, control the process, control the product, pack deliver and provide post delivery services
MEASUREMENT	Measurement of system, process, products, customer satisfaction dissatisfaction
ANALYSIS	Corrective and Preventive action and Management Reviews
IMPROVE	Improvement

QUALITY SYSTEM AUDITS

Purpose of the Audit

— indicating deficiencies

— introducting corrective action

Tasks of the Audit

— To check quality assurance measures are established

— To check established measures being implemented

— To check quality assurance measures are effective

Basic type of Audit

Adequacy Audit. To find how far documented Quality System adequately meets the requirements of the standard.

Compliance Audit. To find out to what extent document system is implemented.

Internal Audit. A company looking in on its own system, procedures for adequacy as well as compliance.

What to do during an audit :

Answer the auditor's question briefly and courteously. If the question does not concern your area you should not answer it. However you may direct the auditor and guide to the right person.

Do not offer opinions, and don't argue with the auditors.

STUDENT ACTIVITY

1. Prepare Quality management for your organisation as per ISO 9001 : 2000.

2. What are steps for ISO 9000 certification ?

NOTES

SUMMARY

1. This chapter deals with standards and codes. Standards and codes an necessary for better working of organization. What is standard, what is code ? What is standardization ? Standardization is applied in organization, we have got national and International standards. ISO 9000 is Quality Management System. Organization has to prepare Quality Manual and Organization has to apply for certification. Certifying agency is third party approved by ISO Geneva.

TEST YOURSELF

1. What is Standard ?
2. What is standardisation ?
3. What is Code ?
4. In which areas Standardisation is applied ?
5. What are National and International level Standards ?
6. What is ISO 9000 ?
7. What is Quality Management system ?
8. Write about ISO 9001 : 2000.
9. Write about Quality management system documents.
10. Write about QMS records.
11. What is Management responsibility ?
12. What is Resource Management ?
13. What is Process Management ?
14. What is Measurement of system performance ?
15. What are characteristics of ISO 9001 : 2000 ?

NOTES

C H A P T E R

10

REPAIR AND MAINTENANCE

LEARNING OBJECTIVES

- Introduction
- Maintenance Objectives
- Range of Maintenance Activities
- Different Types of Maintenance

10.1. INTRODUCTION

To keep assets in its original state assets are to be maintained regularly from time to time.

Now question arises what is maintenance ?

Maintenance is a combination of any action carried out to retain an item in or restore it to an acceptable condition.

Efforts directed towards the upkeep and the repair of machines and facilities is maintenance.

Activities required to keep the facilities in a built condition and prolong its utility with minimum costs is maintenance.

Neglecting maintenance will lead to

(*i*) Frequent breakdown

(*ii*) Increased downtime. Downtime is the period of time during which an item is not in a condition to permits intended function.

(*iii*) Fast deterioration of equipments

(*iv*) Loss of production

(*v*) Low motivation of employee

(*vi*) Cost of production will rise.

NOTES

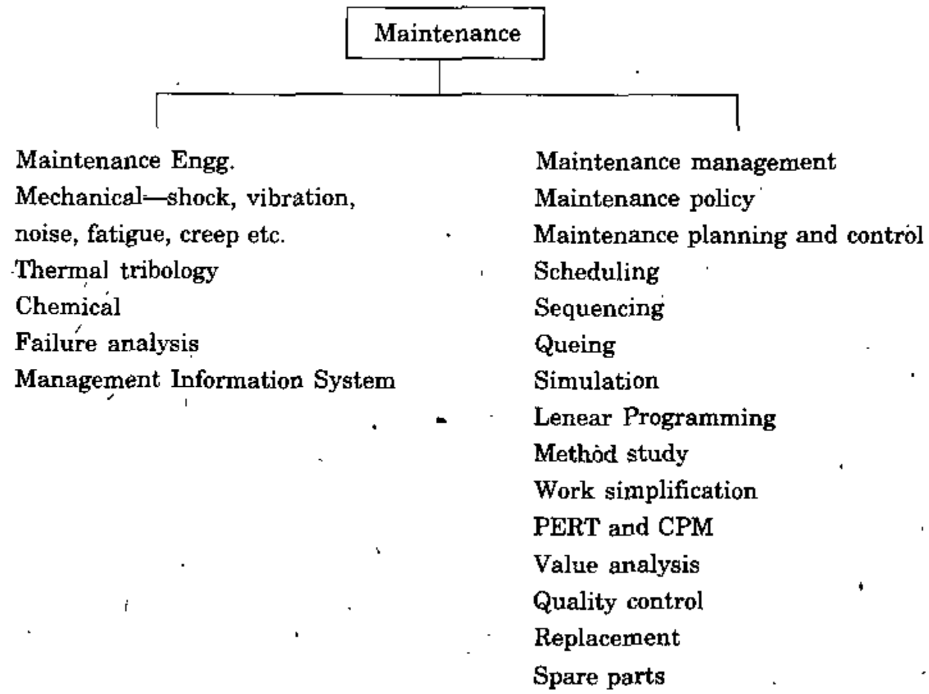


Fig. 10.1

Issues of Maintenance

(*i*) Scheduling of maintenance work.

(*ii*) Maintenance crew-size, remuneration, supervision, inspectors. Mechanic, electrician, cleaner, plumbers, carpenters, painters, welders, masons etc.

(*iii*) Controlling cost.

(*iv*) Record of maintenance.

Importance of maintenance

(*i*) Continuous operation

(*ii*) Less breakdown time

(*iii*) Less accidents

(*iv*) Less adverse effects on employee

(*v*) Less overtime

(*vi*) Reduce large scale repairs

(*vii*) Less stand by equipments an needed.

10.2. MAINTENANCE OBJECTIVES

(*i*) To maintain plant and equipment at its maximum operating efficiency ensuring safety and reducing downtime.

(*ii*) Minimising rate of deterioration.

(*iii*) To maximise the availability and reliability of all the assets.

(*iv*) To obtain the maximum possible return on investment.

(*v*) To extend the useful life of the assets.

(*vi*) To minimise the cost of maintenance.

(*vii*) To increase the operations stability.

(*viii*) Protecting asset.

10.3. RANGE OF MAINTENANCE ACTIVITIES

NOTES

The important function of the maintenance programme are (*i*) inspection or check ups (*ii*) lubrication (*iii*) planning and scheduling (*iv*) records and analysis (*v*) training to maintenance staff ; and (*vi*) storage of spare parts. Each of the functions are described separately as below :

1. **Inspection or Check-ups.** Inspection is an essenstial function of the maintenance programme. Crews kept for this purpose should be well-trained. These crews carry out both the external and internal inspection. External inspection means to watch for, and detect defects from abnormal sound, vibration, heat, smoke etc. When machine is in operation ; internal inspection means inspection of internal parts, such as gears, bushes, bearings, tolerances in the parts etc., during the period. Frequency of inspection should be decided very carefully, as too less inspection may cause break down, as defects could not be traced out and rectified immediately ; while too much inspection means wastage of machine time and labour productivity. Hence frequency should be decided on the basis of past experiences and scheduled programme for inspection. The machines, which can disrupt whole of the production, are delicate and require much time for the repair. More attention should be given for inspection of these machines in respect of schedule for inspection, cleaning and lubrication. But in case of ordinary machines, frequency of inspection can be kept low, as they do not affect the production considerably.

2. **Lubrications.** Mechanical components like gears, bearings, bushes and other friction surfaces etc., give good performance for long periods, when they are systematically lubricated. Systematic lubrication means the application of right type of lubricant at the right time, at right place and in right quantity. For lubrication, a lubrication schedule should be prepared and that should be followed strictly.

3. **Planning and Scheduling.** Every preventive maintenance work should be pre-planned in detail on the basis of the analysis done on the past records. A scheduled programme thus prepared should followed strictly. Thus programme should be in detail specifying the point requiring daily, weekly, monthly, half yearly or yearly attention.

4. **Records and Analysis.** Good record keeping is essential for good maintenance, as it helps in maintenance. The records maintained generally for this purpose are operation manual, maintenance instruction manual, history cards and history registers, spares procurement register, inspection register, log books and defects register etc. With the help of these records, possible cause for major repetitive failures can be examined and rectified so as not to repeat so early. These records helps to take decisions and such analysis further help in preventing defect rather than rectifying after breakdowns ; knowing the machines reliability and thus helps in production planning ; deciding life of the machine ; forcasting defects and planning to rectify them before the failure occurs ; frequency of inspection and check ups ; deciding for the purchase of a machine, which may suit best on the basis of past experience. Inspite of best inspection and other measures failures are bound to occur but they can be reduced to large extent.

5. **Training of Maintenance Personnel.** For the success of maintenance a sound training is essential for the maintenance personnel. Hence the technicians and

supervisors are trained to carry out maintenance, inspection and repairs in a systematic way.

NOTES

6. **Storage of Spare Parts.** Sometimes machine remains idle for the want of spare parts for considerable time and thus it, affects considerable loss of production. Hence it is essential to keep the spare parts so as to avoid loss of production. But the judgement and experience of high order is required for deciding the number of such parts, as storage of a large number of parts will mean blocking of capital. The level of spare parts must be determined by considering different factors such as source of supply, delivery period and availability of that spare part in the market. Standardisation will help to reduce the spare parts inventory and will also help in specialisation of maintenance of particular type of machine.

However for achieving maintenance of high order, these are certain requirements as under :

Good supervision and administration of maintenance department ; Proper control of work *i.e.*, priority be fixed with care and after consultation with production, and engineering departments ; Correct clear and detailed instructions be given to the maintenance crew and to the operators ; Operators should be well trained ; A good lubrication programme should be chalked out ; Proper maintenance record should be maintained ; Adequate stock of spares should always be kept ; Surroundings should be dust free and clean with proper ventilation and illumination ; Manufacturers of the machine tools should be consulted as and when required ; Maintenance department should remain in contact with planning and purchasing department in deciding the type of machine tools to be purchased ; and A machine tool to be purchased should be of best design, adequately, safe good lubrication arrangements, minimum of moving parts easy availability of spares.

10.4. DIFFERENT TYPES OF MAINTENANCE

(*a*) Breakdown or Unscheduled Maintenance
(*b*) Corrective Maintenance
(*c*) Routine Maintenance tasks or Servicing
(*d*) Preventive Maintenance
(*e*) Production Maintenance
(*f*) Predictive Maintenance System
(*g*) Condition based Maintenance System
(*h*) Time based (Periodic) Maintenance
(*i*) Total Productive Maintenance
(*j*) Autonomous Maintenance
(*k*) Planned Maintenance
(*l*) Emergency Maintenance
(*m*) Running Maintenance
(*n*) Designs out Maintenance
(*o*) Shut down Maintenance
(*p*) Value added Maintenance

An efficient planned Maintenance, programme combines Time based Maintenance, Condition based Maintenance and Breakdown Maintenance as rationally as possible.

NOTES

Types of Maintenance Systems

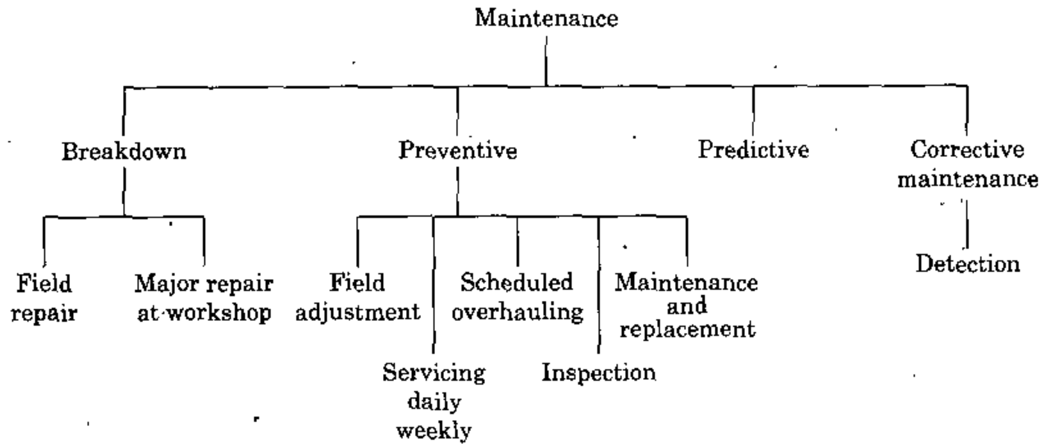


Fig. 10.2

(*a*) **Breakdown/Unscheduled Maintenance**

It is carried out whenever there is some unforeseen failure of the equipment.

(*i*) Non-critical equipment whose downtime and repair costs are less.

(*ii*) Low cost components of auxilliary equipment.

(*iii*) Standby plant is available.

The causes of the breakdown should be noted and steps are to be taken to see that similar breakdowns do not occur in future.

The activity of repair

(*i*) Locating the trouble in parts

(*ii*) Opening it

(*iii*) Replacing parts if necessary

(*iv*) Clean the component—kerosene, gasoline, alkali solution

(*v*) Inspect wear, crack, dirts

(*vi*) Repair

(*vii*) Put back in use, lubricate

Breakdowns may be

(*i*) Minor

(*ii*) Major

(*iii*) Complete stoppage of equipment.

Repairable/Irrepairable

Reasons for breakdown

(*i*) Less lubrication

(*ii*) Running the equipment with worn out parts

(*iii*) Improper cooling system

NOTES

(iv) Neglecting the attending minor faults
(v) Too high voltage
(vi) Wrong fuel is used

Effects of no maintenance

(i) Less production
(ii) Increased chance of accidents
(iii) Loss of profit
(iv) Wastage of material of nation

Cannot be used for cranes, lifts, boilers
Statutory provision

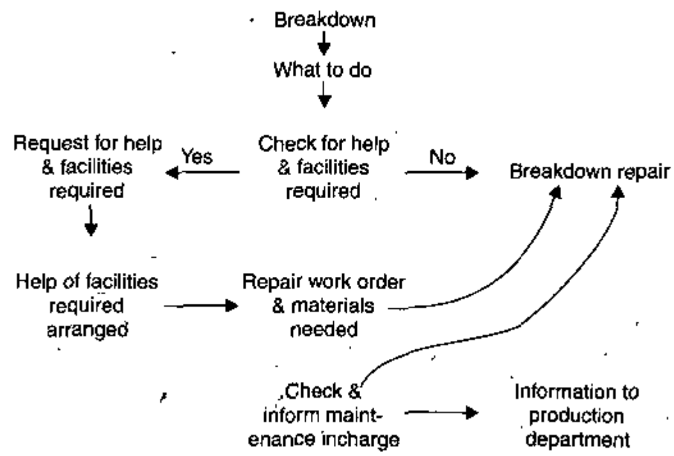


Fig. 10.3. Breakdown flow diagram.

(b) **Corrective Maintenance.** Corrective Maintenance improve equipment and its components so that preventive maintenance can be carried out reliably. Equipments with design weakness must be redesigned.

(c) **Routine Maintenance tasks or Servicing.** Routine Maintenance tasks or servicing include cleaning, greasing, oiling and adjustments and other similar tasks.

The time interval should be established on the basis of the manufacturers recommendation as well as the site operating conditions.

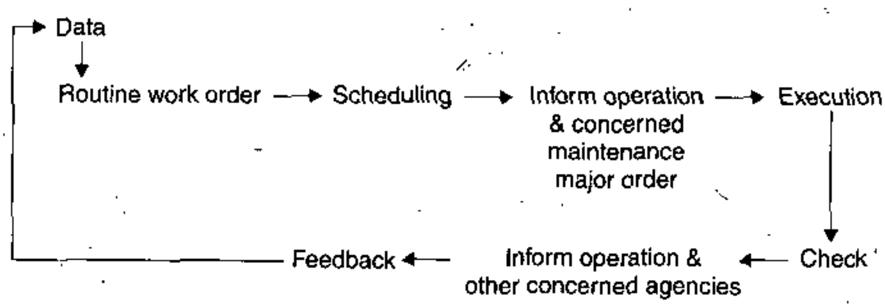


Fig. 10.4. Routine maintenance flow diagram.

(d) **Preventive Maintenance.** Regular inspection of plant/equipment at stipulated intervals to detect the adverse operating conditions, maintain deteriorated components which might lead to breakdown.

Inspection and check up.

Lubrication, adjustment, alignment, repair overhaul, outright replacement of parts which have a known (short) life. Replacement of defective parts.

Routine regular maintenance—oiling, cleaning, greasing.

NOTES

Inspection should be scheduled according to the needs of given situation.

PM operations require shutdown of plant. Scheduling the maintenance operation has to be planned in such a way, that the production programme is not upset.

Used for

(*i*) Essential item, Material Handling, safety, process equipment

(*ii*) Average cost of PM < Average cost of breakdown

(*iii*) M/c breakdown result in high idle labour cost, idle time—PM

(*iv*) Single m/c, Bottleneck m/c, critical m/c, product line.

In case of heavy industries where *equipments are placed in stream PM is must.*

Requirements of Preventive Maintenance

(*i*) Good supervision of maintenance department.

(*ii*) Priority to be fixed with care and after consultation with production department.

(*iii*) Detailed instructions be given to maintenance crew.

(*iv*) Operators should be well trained.

(*v*) Good lubrication record should be chalked out.

(*vi*) Proper maintenance record should be there.

(*vii*) Adequate spare-parts should be there.

(*viii*) Surroundings should be dust free, clean, proper ventilation and illumination.

(*ix*) Maintenance department should remain in contact with planning and purchasing department.

Advantages of PM

(*i*) Reduction in downtime.

(*ii*) Less standby equipments are needed.

(*iii*) Less overtime pay for maintenance staff.

(*iv*) Less expenditure on repairs.

(*v*) Less storage of spare parts.

(*vi*) Greater safety of employees.

(*vii*) Increased equipment life.

(*viii*) Better product quality.

The different steps in an organising and implementing PM are

(*i*) Education and training of personnel.

(*ii*) PM during construction stage of the project.

(*iii*) PM in production stage—General Organisation.

Scheduling, Planning and Inspection, Records and Reports formulation.

Analysis and action.

Detailed organisation and definition of duties of inspectors.

NOTES

Preventive Maintenance Schedule Chart

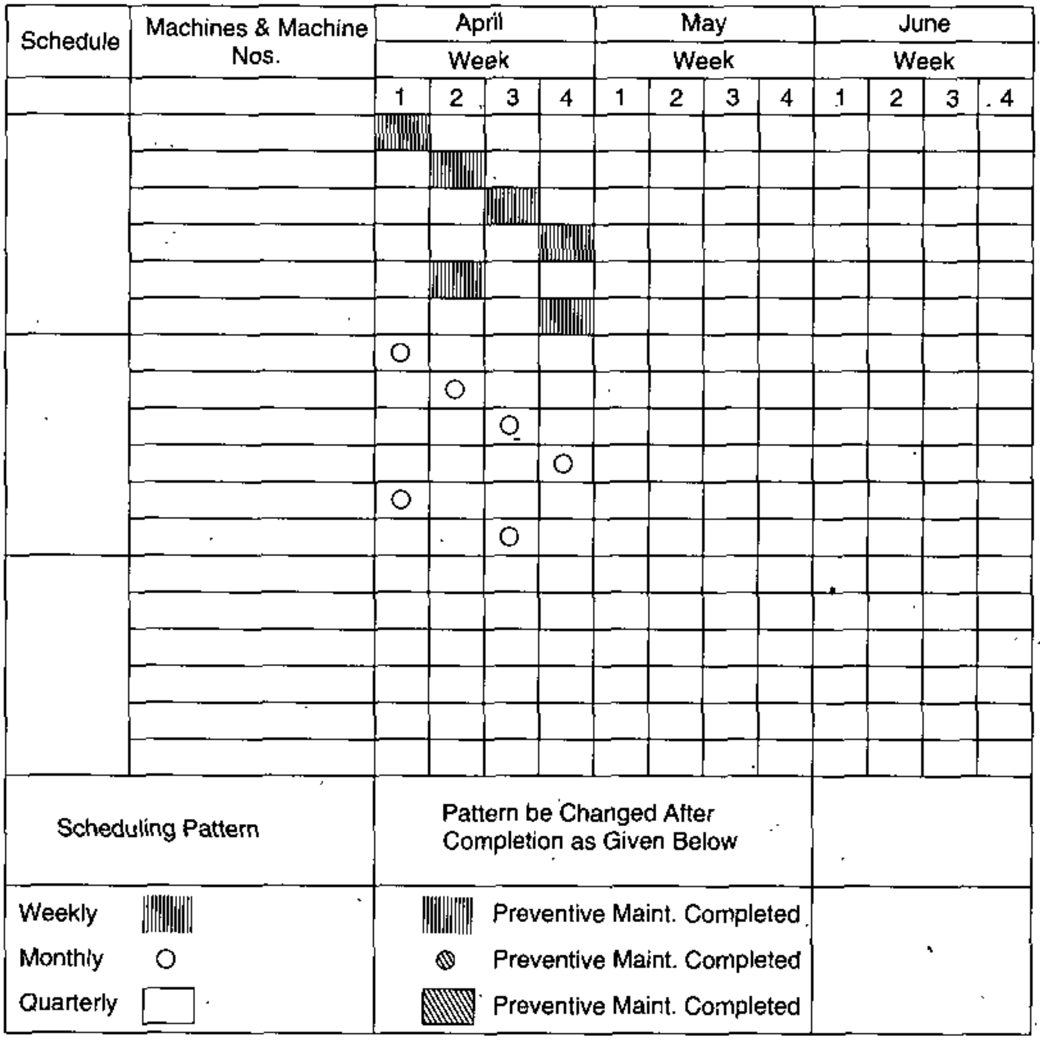


Fig. 10.5

(*e*) **Production Maintenance (1960).** When breakdown and defects in machine are eliminated, equipment operation rates would improve, cost reduces and production raised automatically and as a consequence labour and material productivity improves.

This is characterised by

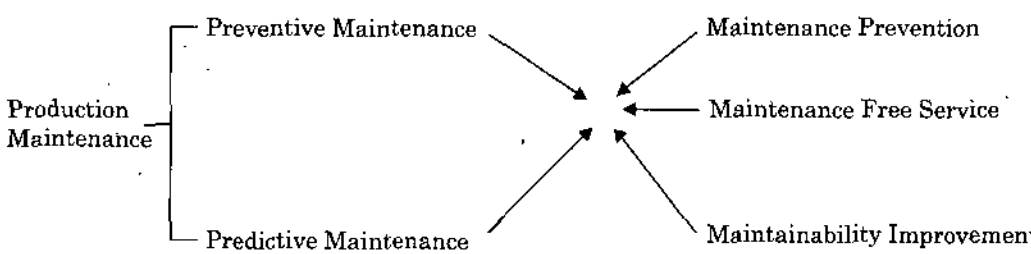


Fig. 10.6

NOTES

(*f*) **Predictive Maintenance.** With the help of proper test equipments the condition of the vital parts of m/c and plants are assessed.

Condition of equipments are measured on a continuous basis at random or at periodic intervals. Parts/components found unhealthy are replaced before they actually fail.

Sensors on autoguages, vibration analyser, Amplitude meter etc.

(*g*) **Condition Based Maintenance System.** Detect the fault generated.

It uses equipment diagnostics to monitor and diagnose machines conditions continuously or intermittently during operation and on stream inspection—checking the condition of equipment and monitor signs of change.

(*h*) **Time Based (Periodic) Maintenance**

Time-based maintenance consists of periodically inspecting, servicing, and cleaning equipment and replacing parts to prevent sudden failure and specialised maintenance activities.

(*i*) **Total Productive Maintenance (1971).** Productive maintenance was first introduced by M/s General Electric USA (1960).

TPM emphasises preventive maintenance and transfers routine maintenance activities from specialised maintenance personnel to m/c operators.

TPM involves everyone from the top executives to the shop floor workers to promote productive maintenance through morale building management and voluntary small group activities in an effort to maximise equipment efficiency.

It adopts preventive maintenance coupled with predictive maintenance and condition monitoring.

TPM combines production quality and maintenance all together with the belief that it is the job of every department to take care of machines effectiveness in order to achieve excellence corporate culture by increasing productivity and quality.

(*j*) **Autonomous Maintenance**

The system in which operators carry out routine operation as well as maintenance and inspection to prevent a accelerated deterioration of the equipment.

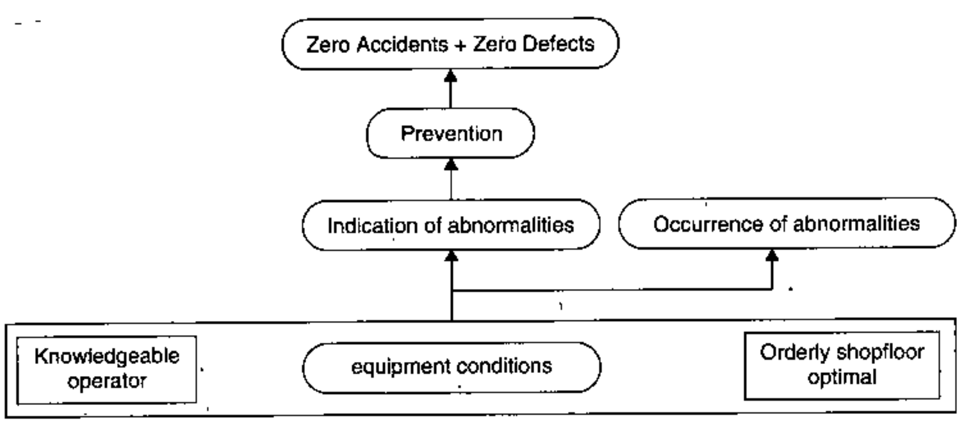


Fig. 10.7. Autonomous maintenance.

The role of maintenance personal will be to carry out shut down maintenance.

(*k*) **Planned Maintenance**

Planning of maintenance before the installation of equipment

Planning of maintenance during running of equipment

NOTES

Maintenance planning after breakdown

The goal by planned maintenance is not merely to plan the timing and technique of maintenance, but also to plan methods for effectively maintaining equipments expected functionality and reliability. Basically, planned maintenance system is the effective maintenance; techniques for eliminating failure that lead to degradation or total loss of the equipments production functions.

The work of maintenance system evaluation is assessing how well the maintenance and production department work together. It should be a two pronged system ; the maintenance department is responsible for periodic maintenance in accordance with the maintenance calendar and productive maintenance using equipment diagnostics and condition monitoring : the production department is responsible for keeping the equipment in peak condition through regular daily checks.

To assess the efficiency, timeliness and economic possibilities of maintenance, look at what actually happens to the equipment in the work place. To gauge whether the planned maintenance system is permanently in place, check whether the various supporting sub-systems control standards, technical standards, and so on are properly established.

(*l*) **Emergency Maintenance.** An unplanned maintenance which is necessary to put in hand immediately to avoid serious consequences for instance loss of production, extensive damage to assets or for safety reasons. Emergencies should remain exception rather than rule. To ensure such a possibility it is better to have planned maintenance system.

(*m*) **Running Maintenance.** Maintenance which can be carried out when the item is in service.

(*n*) **Shutdown Maintenance.** Maintenance which can only be carried out when the item is out of service.

(*o*) **Design out Maintenance**

Aims to eliminate the cause of maintenance

Suitable for items/equipments of high maintenance costs

The maintenance organiser involves design engineer

Small and simple redesign.

Needed because

(*i*) Inadequacy in original design

(*ii*) Equipments/components not made as per design, not erected or commissioned as per specification

(*iii*) Change in performance parameters and needs from original specifications

(*iv*) Non-availability of spares and components because of obselence

(*v*) Availability of much cheaper and better spares, components

(*vi*) Changes in statutory obligation. Pollution, Environment, Safety.

(*vii*) Better maintainability.

After carrying out the design out maintenance jobs, plants' permanent records must be updated.

Such design out maintenance jobs may be done in one installment or in form of small continuous improvements. However, the extent and type of design out maintenance would depend on actual need from case to case basis.

NOTES

(*p*) **Value Added Maintenance**

A Mixture of Predictive Preventive and Reactive Maintenance

Reactive maintanance approach. The reactive maintenance appraoch is one is which industry runs the equipment until it breaks. These are no routine maintenance tasks to perform and equipment is repaired or replaced only when obvious problems occur. Since industries do not incur any maintenance expenses until something breaks or fails to perform may look cheapest approach. The reality is that industries relying solely on reactive appraoch ultimately spend more time and money maintenance due to lack of basic preventive measures. People actually shorten M.T.B.F (mean time between failures). The result is more frequent placement and higher capital costs more over repair cost are always higher because down time events are often unplanned, more frequent and of long duration. In other words reactive maintenance approach works excellent if the equipment is not critical and breakdowns do not affect product quality or revenue generation.

In general maintenance strategy must be a mix of predictive preventive and reactive methods depending on the desired goals and part of the process being maintained. The right mix is developed with predetermined expectations of performance and up time requirements as the end goals, keeping in mind direct and indirect life cycle cost of the equipments. Utilising this approach will always produce an optimal production environment that maximises machine uptime reduces costs and increase profit compelling industries to rethink on maintaining strategies to consider mainteneance as separate profit centre.

STUDENT ACTIVITY

1. What is maintenance practice in your organisation for building, plant.

2. Why your organisation is following this practice ?

SUMMARY

1. This chapter deals with maintenance of plant. Maintenance is necessary because there will be always failure probability. Different types of maintenance are discussed. Maintenance activities are also discussed.

NOTES

TEST YOURSELF

1. What is maintenance ? If maintenance is not done what will happen ?
2. What are the objectives of maintenance management ? What are requirements of maintenance ?
3. What is maintenance engineering ?
4. Why *maintenance is important* ?
5. What are the maintenance objectives ?
6. What are the range of maintenance activities ?
7. What are the types of maintenance ?
8. What is breakdown or unscheduled maintenance ?
9. What is corrective maintenance ?
10. What is routine maintenance ?
11. What *is preventive maintenance* ? What are requirements of P.M. ? What are advantages of P.M. ? What are the steps in organising and implementing P.M. ?
12. What is production maintenance ?
13. What is predictive maintenance ?
14. What is condition based maintenance ?
15. What is time based maintenance ?
16. What is total productive maintenance ?
17. What is autonomous maintenance ?
18. What is planned maintenance ?
19. What is emergency maintenance ?
20. What is running maintenance ?
21. What is design out maintenance ?
22. What is value added maintenance ?

OBJECTIVE TYPE QUESTIONS

1. Which of the following is not planned maintenance ?
   (*a*) Preventive maintenance (*b*) Emergency maintenance
   (*c*) Design out maintenance (*d*) All of the above.
2. Availability in the context of maintenance means :
   (*a*) Availability of spares
   (*b*) Availability of the system in up status
   (*c*) Availablility of manpower (*d*) All of these.
3. "Signature Analysis" is associated with
   (*a*) Emergency Maintenance (*b*) Prevention maintenance
   (*c*) Condition based maintenance (*d*) Shutdown maintenance.

NOTES

C H A P T E R

11

COST ESTIMATION

LEARNING OBJECTIVES

- Introduction of Cost Estimation and Functions of Cost Estimation
- Cost Estimation Procedure
- Components of costs
- Costing
- Depreciation of Fixed Assets Methods of Calculating Depreciation
- Calculating cost of machine and metal

11.1. INTRODUCTION OF COST ESTIMATION AND FUNCTIONS OF COST ESTIMATION

It is an art of finding the cost which is likely to be incurred for the manufacture of an article before it is actually manufactured.

It also includes predetermination of the quantity and quality of materials and its cost, manufacturing method and its cost of manufacturing, labour cost, time required to manufacture etc.

Tenders are advertised in Newspapers. Manufacturers who are interested to fill tender want to which price they should quote based on drawings supplied by tender. Tender sumitter can know name of material, quantity required, manufacturing process, standard parts needed, semifinished products; cost of material, standard parts costs, semifinished product cost, manufacturing cost including labour. Adding taxes and profit he can quote price of supply.

Aims of cost estimating

Factory owner can decide the manufacturing and selling policies :

— To decide about the overheads.

— To decide about wage rate of the workers.

— To decide make or buy policy.

Functions of cost estimating Department :

(*i*) To determine the material cost – Actual material used + wastage.

(*ii*) To determine labour cost, lobour time, wage rates.

(*iii*) To determine the cost of tools, equipments needed.

(*iv*) To determine overhead charges, selling, packing, transportation.

(*v*) *To determine selling price = total cost + profit.*

(*vi*) To determine manufacturing time.

Qualities of Cost estimator

(*i*) Able to read and understand drawing.

(*ii*) Having knowledge about machines, process planning.

(*iii*) Having knowledge of the use of tools, Jigs and fixtures.

(*iv*) Knows calculating manufacturing time.

Cost-may be defined as resource sacrified to achives a specific objective.

NOTES

Functions of Cost Estimator

(*i*) To prepare estimate.

(*ii*) To consult production department, purchase department and other connected departments for collecting latest information related to various aspects.

(*iii*) To consult the reference files.

(*iv*) To collect information related to design specification of the product, manufacturing methods, tools, equipments and material handling.

(*v*) To collect information about tool, equipment, pattern, transportation costs and profits.

11.2. COST ESTIMATION PROCEDURE

(*i*) Production planning department :

(*a*) Decides the specification of the product to be manufactured.

(*b*) Make out the drawings :

Lays down the method of manufacturing and required operations

Machines to be used

Labour rates

Accuracy and finish required

Prepare a list of components of the product.

Make or buy decision.

(*ii*) *Determine the material cost.*

(*iii*) Determine the time required for various operations. Standard time.

(*iv*) Determine labour cost.

(*v*) Determine the prime cost = Direct expense + Direct material cost + Direct labour cost.

(*vi*) Determine the factory *overheads, depreciation, maintenance cost*, insurance cost, power cost etc.

(*vii*) Determine the administrative overheads.

(*viii*) Determine the packing and delivery charge.

(*ix*) Determine the total cost.

(*x*) Determine the sale price = Total cost + Profit.

(*xi*) To decide discount allowed to distributors.

(*xii*) To decide delivery time.

NOTES

Example 11.1. *A factory produces 1000 bolts and nuts per hour on a m/c. Its material cost is Rs. 375, labour cost Rs. 245 and the direct expense is Rs. 80. The factory on cost is 50% of the total labour cost and the office on cost is 30% of the total factory cost. If the selling price of each bolt and nut is Rs. 130. Calculate the profit or loss per unit.*

Solution. Prime cost = Direct material cost + Direct labour cost + Direct expenses

= Rs. 375 + 245 + 80 = 700/-

Factory Cost = Prime cost + Factory on cost

= 700 + 1.5 × 245 = 1067.50

Total cost = Factory cost + Office on cost

= 1067.50 + 0.3 × 1067.50 = 1387.75

$$\text{Cost/unit} = \frac{1387.75}{1000} = 1.38775$$

Loss = Cost – S.P. = 139 – 130 = 9 paise/unit.

11.3. COMPONENT OF COSTS

In order to compute profit and loss of a firm it has to analyse the components of total cost.

Prime cost = Direct materials + Direct wages + Direct expenses

Production overhead = Indirect materials + Indirect wages + Indirect expenses

Production cost = Prime cost + Production overhead

Total cost = Production cost + General administration + Marketing/Sale + Research + Development

Direct materials

Raw materials.

Materials purchased for specific use, process job.

Components and spares purchased or produced.

Packing materials.

Direct labour

Labour directly associated with the production process or commodity.

Labour engaged in the maintenance, supervision.

Labour engaged in inspection, quality control analysis.

Direct expenses

Fee for preparing project report

Architect and surveyor's fee

Travelling expenses to the site

Royalty

Expenses of designing or drawing of models and patterns

Experiment expenses of pilot projects

Repair charges paid to hire mechanics

Hire of any machinery or equipment on a contractual basis.

Excise duty etc.

NOTES

Indirect materials. Stocks used for the maintenance of machinary, plant, factory, building etc. like lubricants, bricks, cement.

Stores used by the service departments like boiler house, power house, canteen.

Indirect labour. Maintenance workers, supervisors, apprentices, men employed in service departments, trainees, instructors, security, time office staff.

Indirect expenses. Rent, Insurance, local taxes, power, fuel, lighting, heating, training new employees, general manager, telephone expenses.

Overhead/Burden. Indirect expenses which cannot be conveniently charged direct to specific cost units are called overhead.

Production/works overhead. Getting an order, dispatch of the finished good, insurance charges of fixed capital assets, repairs and maintenance of fixed assets, fuel charges, rent, taxes on works, land and properties, stationery, telephone, telegram, fax, E-mail, medical expenses, recreation and other welfare facilities.

Administrative overheads. Rent, light, salaries and wages of secretaries and accountants, clerks, credit approval, general managers, directors, executives, legal and accounting machine services, experiments and investigations.

Selling overheads. Advertising, publicity charges, salesmen's salaries and commissions, show room rents, travelling expenses of salesmen, samples and free gifts, after sales service, exhibition, demonstration expenses.

Distribution overheads. Warehouse rent, salaries of warehouse staff, insurance of warehouses, transportation, packing, damages in transit, losses in warehouses.

Labour cost. Production programmes, schedules and layouts should be prepared in advance so that workers are not kept waiting for instruction or material.

Inventive and suggestion schemes should be introduced.

Appropriate labour deployment

Absenteeism should be checked

Material cost

Product design study

Value analysis

Simplification, standardization, specialization

Inventory control

Method study for internal transport

Waste control.

General expenses

Fixed costs. Logical organization chart and well defined responsibility areas.

Matching of authority with responsibility

Forecast of the future volume and pattern of activities

Efficient procedures for cost compilation and analysis.

Reporting of relevant information at periodical intervals to management for corrective action.

11.4. COSTING

NOTES

Costing is a techniques and a process of determinating the cost of doing something.

Costing is determination of actual cost of an article after adding different expenses incurred by different departments.

Costing is the operating of, calculating the cost of an articles as to fix its selling price.

Importance of costing will be appreciated at times of trade depression.

Methods of Costing

Type of costing	Application
Job Costing	Painter
Contract cost	Construction
Output costing	Cement/coal manufacturing
Batch costing	Readymade
Process costing	Soap/Chemical/steel manufacturing
Operation costing	Toy manufacturing
	Railway, Road transport, Nursing home.

The objects of costing are always activities. The article manufacturing service renderd or fuction performed is known as objects of costing.

11.5. DEPRECIATION OF FIXED ASSETS. METHODS OF CALCULATING DEPRECIATION

It may be arising through determination, obsolescence.

I. The technical obsolence are directly due to the asset getting outdated that is a new model of the m/c has been invented. Which reduces the production time unit or the dependance of manual labour.

II. The economic reason of obsolescence relate to products or services which a particular assets produce or render such product or service may have lost its market demand or it may not be worthwhile to use an asset at all.

Depreciation is a process of allocating the cost of an asset less residual value within the asset life.

Depreciation is measured in different purposes.

(*a*) The rate of depreciation is influenced by the tax laws.

(*b*) To allocate the cost of the fixed asset to the product it produces.

(*c*) As per income tax law provisions.

Methods of Calculating Depreciations

(*a*) Straight line method

The value of an asset decreases at a constant rate. The loss in the value is directly proportional to the age of the structure.

Let P = First cost of the asset

L = Estimated salvage value

n = Estimated life of the asset

NOTES

Then the annual cost of depreciation = $\frac{P-L}{n}$.

The method is simple and gives uniform annual charge.

This method does not take into account interest, operation and maintenance costs or profits.

Problem. *Determine the yearly cost of depreciation, salvage values at the end of the sixth year and total depreciation up to the end of the sixth year on a structure which cost Rs. 12000 new and has an estimated scarp value of Rs. 2000 at the end of ten years. Use straight line formulae.*

Solution. The annual cost of depreciation = $\frac{12000-2000}{10}$ = Rs. 1000 per year

Depreciation upto ages of 6 years

$$\frac{6\,(12000-2000)}{10} = \text{Rs. } 6000/-$$

The value at the end of six years

$$= 12000 - \frac{6\,(12000-2000)}{10} = \text{Rs. } 6000/-$$

(b) Multiple straight line method

In this method 3/4 of the original cost of the asset is amortized uniformly over the first half of the life and remaining 1/4 of the original cost of the asset is uniformly distributed to another half span of the life.

(c) Diminishing Balance Method/Declining Balance/Constant Percentage Written Down Method/Matheson Formulae

The value of an asset decreases at a decreasing rate. The capital recovered during any year is equal to the unrecovered capital at the beginning of year times D where $D \times 100$ is the fixed percentage rate used. Undepreciated balance remaining at the end of any year equal the unrecovered capital at the beginning of the year time $(1-D)$. The unrecovered capital at the end of first year $P(1-D)$

Second year $P(1-D)^2$

and so on nth year $P(1-D)^n = L$ = Salvage Value

Where P = First cost of the asset.

Therefore $D = 1 - \sqrt[n]{\frac{L}{P}}$

Defects of diminishing balance method :

(a) Rate of depreciation tends to be substantially higher than straight line method. Usually the rate is double than that under the S.L.M – double declining method.

(b) The annual cost of depreciation is different in each year, heavier in the early life.

(c) A structure can never be depreciated to zero level.

Problem. *A machine was purchased on 1st Jan. 2005 at a price of Rs. 160000/. The estimated life of the machine is 5 years and the salvage value at the end of the useful life is estimated to be Rs. 10000/-. Calculate the amount of depreciation for each year till the useful life of the machine, under the diminishing balance method.*

Solution. Rate of depreciation $= 1 - \sqrt[5]{\frac{10000}{160000}}$

2(a) The sum of year's digit method/Accelerated method of depreciation

NOTES

Sum of year's digit $= \frac{n(n+1)}{2}$

where n = life of an asset in years.

$$\text{Specific rate} = \frac{\text{Inverse digit of the year}}{\text{Sum of years digit}}$$

Depreciation of the specific year = (Specific rate of that year) $(AC - SV)$

Where AC = Acquision cost of an asset

SV = Salvage value at the end of the useful life.

This method is similar to written down method.

e.g., years 1 2 3 4 5

Sum of years = 1 + 2 + 3 + 4 + 5 = 15

Specific rate of year 5/15, 4/15, 3/15, 2/15, 1/15.

Problem. *On 1st Jan. 2006 a machine was purchased at a cost of Rs. 3,20000/-. The estimated life of the machine is 5 years and the salvage value at the end of the estimated useful life is Rs. 20000/-. Calculate the amount of depreciation for each year under the SYD method.*

Solution. Depreciation = Specific rate $(AC - SV)$

= (320000 – 20000) specific rate

= 300000

First year's depreciation = 1/3 × 300000 = 100000

Second year's depreciation = 4/15 × 300000 = 80000

Third year's depreciation = 3/15 × 300000 = 60000

Fourth year's depreciation = 2/15 × 300000 = 40000

Fifth year's depreciation = 1/15 × 300000 = 20000

(b) Compound Interest Method

Value of an asset decreases at an increasing rate. A series of equal amounts is assumed to be deposited into a sinking fund at the end of each year of the assets life. The sinking fund is usually invested in some outside securities. Sinking fund is established in which funds will accumulate for replacement purposes. The capital recovered during any year is the sum of the amount deposited into the sinking fund at the end of the year and the amount of interest earned on the sinking fund amount during the year.

$$\text{Annual cost of depreciation} = \frac{1}{Sn}(AC - SV)$$

$$Sn = \frac{(1+i)^n - 1}{i}$$

where i = interest rate

2. Annuity method

The depreciation cost of each year must include a portion of the cost of asset plus a specified return in the investment in that asset.

The amount of the annual depreciation and the expected interest income will be credited to a separate account *i.e.,* accumulated depreciation account.

The amount of depreciation is retained to the business and is used for business operations.

$$\text{Rate of depreciation} = \frac{[AC(1+i)^n - SV][1-(1+i)]}{[1-(1+i)^n]}$$

Problem. *Find the depreciation by annuity method AC = 100000, SV = 50000 i = 12% n = 2*

$$\textbf{Solution. } d = \frac{[100000-(1+0.12)^2-50000][1-(1+0.12)]}{[1-(1+0.12)^2]}$$

3(*a*) Unit of out put method

It consider the life in terms of units of service e.g. Kilometers, machine hours, units produced etc.

$$\text{R, Rate of depreciation} = \frac{AC - SV}{TP}$$

TP = Total estimated production is units during the services life.

Problem. *A truck acquired at a cost of Rs. 3,90,000/- has a scrap value of Rs. 30000/- at the end of its service life. It is estimated that during its service life it will run for 3,00,000 kms. During the year 2005 the truck rolled 20000 kms. Find the depreciation in 2005 by unit of out put method.*

$$\textbf{Solution. } R = \frac{3{,}90{,}000 - 30000}{300000} = \frac{3{,}60{,}000}{300000} = 1.2 / \text{km.}$$

The depreciation will be = 1.2 × 20000

= Rs. 24000

3(*b*) Retirement method

The cost of the asset less salvage value is charged as expenses and debited to profit and loss account in the year in which the asset is retired from the service.

This method is applicable to only such assets whose service life is very short.

3(*c*) Replacement method

The acquisition cost of an asset is treated as capital expenditure and the amount is shown as an asset amount in the balance sheet. The costs of the replacement is charged as revenue expenditure in the year of replacement.

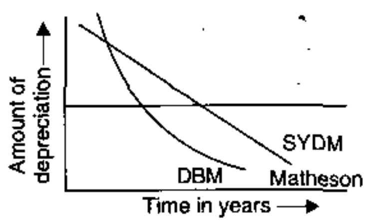


Fig. 11.1

NOTES

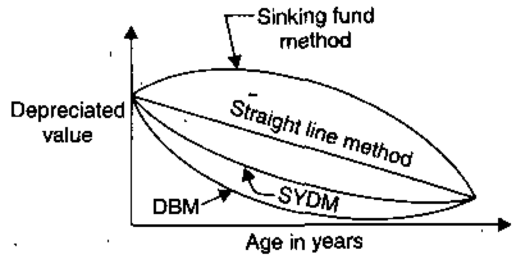


Fig. 11.2

3(*d*) Present worth method

Value of asset is the present worth of all the future profits to be expected from the asset.

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

Where S = sum of money in the future

i = interest rate

$$P = S\left[\frac{1}{(1+i)^n}\right]$$

11.6. CALCULATING COST OF MACHINING AND METAL

Metal cost can be known from volume of metal and density of metal.

Cost of machining can be known from machining time.

1. Lathe Time of machining

$$\text{Time} = \frac{L}{fN} \text{ min per pass (cut)}$$

where, L – Total length of travel of the tool or of the work piece.

f – feed

N – rpm.

2. Shaper, Planer, Slotter

$$\text{Machining time} = \frac{B+x+y}{fN} \text{ min}$$

where B = width of the machined surface

n = Side approach of the tool

y = Side over travel of the tool = 2 to 3 min

3. Drilling.

$$\text{Machining time} = \frac{L+x+y}{fN} \text{ min.}$$

where L = hole length /depth

n = Tool approach

y = travel.

4. Broaching

$$\text{Maching line} = \frac{Lw + Lb}{V}$$

where Lw = Length of workpiece

Lb = Length of broach.

NOTES

STUDENT ACTIVITY

1. What are aims of cost estimation ?

2. What is depreciation ?

SUMMARY

NOTES

1. This chapter deals with cost estimation what are aims of cost estimation ? Cost estimation procedure is given. Components of cost are given Depreciation of assets is money as per Income tax provision number of methods are given for calculating Depreciation. Correct method is a per year 2007-2008 Income tax act. Tender cost can be decided after giving this chapter.

TEST YOURSELF

1. What is cost estimation ? What is cost ?
2. What is importance of cost estimation ?
3. What are functions of cost estimation ?
4. What is procedure of cost estimating ?
5. What are functions of cost estimating department ?
6. What are qualities of cost estimators ?
7. What are components of cost ?
8. What is costing ?
9. What are methods of calculating depreciation ?
10. What are indirect expenses ?
11. What do you mean by over head ? State any two examples ?

OBJECTIVE TYPE QUESTIONS

1. Costing refers to
   (*a*) Ascertainment of cost (*b*) Control of cost
   (*c*) Budgeting cost (*d*) None of the above.
2. Which of the following is true
   (*a*) Price = Cost (*b*) Price = Profit
   (*c*) Price = Cost + Profit (*d*) Price = sunk cost.

NOTES

CHAPTER

12

VALUE ENGINEERING

LEARNING OBJECTIVES

- Basic Concepts in Value Engineering
- Historical Perspectives
- Functions and Value
- Value Engineering Job Plan
- Fast Diagram as Value Engineering Tool
- Some Case Studies in Value Engineering
- Behavioural and Organisational Aspects of Value Engineering
- Benefits of Value Engineering and Concluding Remarks

12.1. BASIC CONCEPTS IN VALUE ENGINEERING

Value Engineering and Value Analysis

Value Engineering (VE) or Value Analysis (VA) is an important and powerful approach for improvement in the performance of the products, systems or procedures and reduction in costs without jeopardising their function. The terms VE and VA are used almost interchangeably. Other terms used to convey the same concepts are Value Assurance and Value Management (VM).

L.D. Miles defined Value Analysis in his book **Techniques of Value Analysis and Engineering** (1961) as "an organised creative approach which has for its purpose the efficient identification of unnecessary cost *i.e.*, cost which provides neither quality, nor use, nor life, nor appearance, nor customer features". Various other definitions are proposed such as "an organised systematic study of the function of a material, component, product or service, with the objective of yielding value improvement through the ability to accomplish the desired function at the lowest cost without degradation in quality". Thus the basic objective of VE/VA is to achieve equivalent or better performance at a lower cost while maintaining all functional and quality requirements. It does this largely by identifying and eliminating hidden, invisible and unnecessary costs. We may simply perceive VE as the systematic application of recognised techniques to identify the functions of a product or service and provide those functions at the lowest total cost.

Value Engineering should not be treated as a mere cost reduction technique or cheapening of the product. It is more comprehensive and the improvement in value is atained without any sacrifice in quality, reliability, maintainability, availability, aesthetics, etc. It was traditionally applied in the area of hardware projects, such as product design, though these concepts are equally applicable in software projects, in the systems and procedures. Recently these concepts have been applied to non-traditional areas such as urban slum development programmes, staff welfare motivation enhancement and courtesy improvement plans.

Reasons for Poor Value

One of the important reasons behind poor value in products, systems and procedures that we come across is the lack of organised effort in devising such systems. Many times the designs are created under highly compressed time frame and the designer may play safe by giving product designs with sole emphasis on technical feasibility and may prescribe thicker, costlier materials and other unnecessary features which are not needed by the customer. Sometimes, ad hoc decisions get permanency due to lack of review of product designs. Often lack of consultation with others contributes to poor value. Lack of information, wrong beliefs, habits and attitudes are some of the other reasons.

12.2. HISTORICAL PERSPECTIVE

Value Engineering had its origin at the General Electric Company (GEC). As a result of World War II, many materials were in short supply and L.D. Miles was associated with a committee to identify substitute materials without sacrifice in quality and performance. He organised a formal methodology in which a team of people examined the functions of products manufactured by GEC. Through team-oriented creative techniques they made changes in products to lower their cost without affecting their utility and quality. This methodology was given the name Value Analysis (VA). L.D. Miles who wrote his book in 1961 is generally recognised as the father of Value Engineering. Miles found that many of the substitutes used were providing equal or better performance at lower costs.

The first organisation to initiate a formal VE programme was Navy Bureau of Ships in 1954. In 1959, Society of American Value Engineers (SAVE) was set-up to propagate the philosophy of Value Engineering. Many companies in USA, UK, Japan, etc. subsequently set-up formal VE programmes. The Department of Defence in US encouraged application of VE in defence projects. A number of success stories of VE/VA are reported.

In India, VE/VA is now a well recognised programme and many organisations in military and navy as well as in other public and private sectors have set-up directorates or cells of Value Engineering. A professional society Indian Value Engineering Society (INVEST) came up to create awareness in VE/VA and they publish a journal, organise conferences and provide other services. It is now considered as an effective management tool.

12.3. FUNCTIONS AND VALUE

NOTES

Types of Values

The term 'Value' is used in many different ways and is frequently confused with the monetary price or cost of an item. However value is not synonymous with cost. Value may be perceived as the ratio of the sum of positive and negative aspects of an object. Thus value can be considered as a composite of quality and cost. It is more in terms of worth or utility. Thus a ratio of quality to cost can be treated as the value of a product. If its costs can be reduced for same quality or quality can be improved with same cost, then the value improvement can be said to occur. The term value can be divided into following types:

(*a*) **Use Value.** The properties and qualities which accomplish a useful purpose or service.

(*b*) **Esteem Value.** The properties, features or attractiveness which cause us to want or own it.

(*c*) **Cost Value.** The sum of labour, material and various other costs required to produce it.

(*d*) **Exchange Value.** The properties or qualities which enable us to exchange it for something else we want.

Types of Functions

VE discipline deals with the functions of items, products, systems and procedures. It is a functional approach, a customer-oriented approach. Identification of the functions, therefore, constitutes an important aspect of VE. The term 'function' is used to mean the purpose or use of a product.

Functions can be of two types:

(*a*) Basic functions—the primary purpose of a product

(*b*) Secondary functions—other purposes not directly accomplishing the primary purpose but supporting it or resulting from a specific design approach.

Many a time poor value may result in because the functions have not been precisely understood and redundant or unnecessary functions have been imposed.

Value Tests

VE is essentially a questioning attitude looking at the function and costs. L.D. Miles designed a set of value tests to ascertain whether there is a scope for value improvement. If these value tests are honestly applied, there is bound to be room for improvement in most of the products, systems and procedures that we come across.

Some of these questions which can work as thought-starters for developing better value alternatives could be as follows:

(*i*) Can the design be changed to eliminate the part ?

(*ii*) Can you purchase it at lower cost ?

(*iii*) Does it need all its features ?

(*iv*) Is there anything better for the intended use ?

(*v*) Can a usable part be made by a lower-cost method ?

(*vi*) Can a standard part be used ?

(*vii*) Is it made on proper toolings considering the quantities involved ?

STUDENT ACTIVITY

1. Choose any product, system or procedure that you are very well conversant with in your day-to-day life and apply the above tests to find out if there is a scope for value improvement in it.

2. Is value engg. is used in your organisation ? If yes, where it is applied ?
   Materials
   Design
   Manufacturing process.

(*viii*) Are there any newly developed materials that can be used ?

(*ix*) Can two or more parts be combined into one ?

(*x*) Can any specifications be changed to effect cost reduction ?

NOTES

Identification of Poor Value Areas

By applying the value tests we amy come across poor value areas which are responsible for unnecessary costs. These could be in the design of the product, procurement, handling and storage of materials, production processes, packaging and distribution of the final product. Once we are able to identify poor value areas, we can focus our attention on these so that these unnecessary features can be eleminated.

Another way to identify the poor value areas is through function cost matrix approach. If a function is relatively less important but accounts for a larger percentage of product cost then it is a potential area for value improvement. By determining alternative cheaper ways to achieve that function we can reduce the cost and improve value.

In simple terms a soundly conducted Value Analysis programme should essentially provide answers to the following questions:

(*i*) What is the item ?

(*ii*) What does it do ?

(*iii*) How much does it cost ?

(*iv*) Can anything else do the same thing ?

(*v*) How much does that cost ?

12.4. VALUE ENGINEERING JOB PLAN

Value Engineering Process

As mentioned earlier, the major advantage of the approach is that it is a systematic and organised approach that examines all aspects of a problem employing a questioning attitude. Thus a formal approach has to be adopted to go through the VE programme. This formal procedural model of VE process is called VE Job Plan. In the beginning, when Miles proposed VE Job Plan, it was just a modified form of the steps involved in work study. Subsequently, it has been modified and a number of approaches have emerged which are essentially similar. These job plans have various steps and phases with their associated VE techniques at each phase.

In this unit we shall briefly outline the salient features of three different approaches to conduct a VE programme. These are :

(A) Job Plan due to Mudge

(B) DARSIRI method

(A) **FAST (Function Analysis System Technique)**

Since the Job Plan due to Mudge is a very well recognised approach, we will deal with it in this section. The seven phases of Job Plan are :

(*i*) General phase

(*ii*) Information phase

(iii) Function phase
(iv) Creation phase
(v) Evaluation phase
(vi) Investigation phase
(vii) Recommendation phase.

NOTES

Each of these phases comprises or is supported by one or more techniques. There are work-sheets for each phase. The practice of Job Plan and the application of VE techniques should be made on properly selected project. Thus selection of VE project is important. Those products should be chosen for the study which are significant in terms of cost reduction potential. In step-by-step application of the Job Plan the project unfolds from the information phase right up to recommendation phase.

The general phase plays vital role thoughout and provides a good base for other phases to succeed.

Brief description of each phase together with associated VE techniques are given in the following sub-sections.

(i) **General Phase**

Throughout the application of the entire Job Plan the techniques of this phase must be diligently applied to create the right environment for Value Engineering job plan to be effective. There are five techniques associated with this phase:

(a) **Use good human relations:** It will be seen that considerable personal contact is necessary throughout the Project. The use of good human relations means assistance in place of resistance.

(b) **Inspire team work:** This is one of the easiest to talk about, yet one of the hardest to accomplish. It calls for subordinating personal prominence or ego in the interest of the group as a whole.

(c) **Work on specifics:** We should avoid generalities and work on specifics. Concrete data and information on specific problems must be secured. Only opinions and hearsay cna be expected when talking in generalities.

(d) **Overcome roadblocks:** In any organisation a group of dissenters can be found. These individuals knowingly or unknowingly, will use every means at their command to resist change. It is important to be able to recognise roadblocks and then take steps to overcome them. Mudge has in fact compiled an impressive list of 'killer phrases' which people use to kill an idea. It is very crucial to avoid such mental roadblocks.

(e) **Apply Good Business Judgement:** Business decisions and judgements must be based on facts. Poor business decisions and poor judgement become prevalent when personal opinions and feelings take control. To apply good business judgement one must be resourceful, able to think and should be able to pursue new knowledge.

With the general phase as the base of foundation of the job plan, we can enter the second phase—information phase. The techniques included in the second phase, though seemingly simple, incorporate some of the most difficult portions of the approach.

(ii) **Information Phase**

The objective of this phase is to gain an understanding of the project being studied and to obtain essential facts relating to the project as also to estimate the potential value improvement. This phase comprises of three techniques:

NOTES

(*a*) **Secure facts.** Information gathered must be authentic; it is one of the most arduous tasks. The type of information required will be:

(*i*) Technical specifications—dimensions, grades, tolerances, quality, appearance.

(*ii*) Environmental specifications—Seventy, test conditions.

(*iii*) Engineering drawings.

(*iv*) Production sample—actual or model of it.

(*v*) Production data—operations, speeds, rates, output and stock levels.

(*vi*) Cost data—material, labour, overhead-costs.

(*vii*) Work specifications—work place layout, standard times.

(*viii*) Features preferred by Customers.

(*ix*) Development, testing and service records.

(*x*) Quantities involved.

(*xi*) Scrap rates.

(*b*) **Determine costs.** In order to direct towards those areas promising the greatest return on time and efforts in VE, the complete and accurate costs must be secured.

(*c*) **Fix Costs on Specifications and Requirements.** By establishing a relationship between the costs and the specifications and requirements, a means is presented by which the latter two can be quntitatively evaluated. Extreme care should be taken during this phase to be sure that true facts are gathered, accurate costs are secured, and these costs are truly related to the specifications and requirements.

Once the techniques of the information phase have been used to secure pertinent data, the function phase of the Job Plan can be used.

(*iii*) **Function Phase**

The objectives of this phase are to define the functions that a product actually performs and is required to perform as well as to relate these functions to the cost and worth of providing them.

The two techniques of this phase are a major part of the functional approach. When combined with the other techniques of the Job Plan it produces a systematic approach which is different and more productive than any other product improvement or cost reduction approach.

The two techniques of this phase are:

(*a*) **Define function.** This is one of the most crucial stages in Value Engineering. The method of functional analysis requires functions to be described with only two words, a verb and a noun. By so restricting the functional specifications, clear descriptions of the functions are possible. Concise function descriptions reduce the possibility of a detailed semantic elaboration. They force a rational approach by eliminating superfluous frills. The rules of function description are:

(*i*) Determine user's need for a product or service

(*ii*) Use only one verb and one noun. The verb should answer the question "What does it do?" The noun should answer "What does it do"? Where possible, noun should be measurable and verb should be action oriented.

(*iii*) Avoid passive or indirect verbs.

(*iv*) Avoid goal-like words or phrases, such as improve, maximise, minimise, optimise, etc.

(*v*) List a large number of two-word pairs and then select the best pair.

NOTES

Example 1: Some functional definitions are:

Product	Function
(*a*) Mirror	Reflect light
(*b*) Brake	Arrest motion
(*c*) Clutch	Transfer power
(*d*) Election tube cover	Shield Tube
(*e*) Cigarette lighter	Provide ignition
(*f*) Ligh bulb	Emit light
(*g*) Screwdriver	Transfer torque
(*h*) Coffee cup	Hold Liquid.

(*b*) **Evaluate Function Relationship.** This technique attempts to determine relative importance of various functions. Through this technique a descending order of importance of the functions is established alongwith the relative value of their importance.

A paired comparison technique to determine the numerical value of various functions is very simple and effective to use. In this, paris of functions are compared and it is sought to determine which is more important and whether the degree of variation is major, medium or minor. Suppose we are comparing A with B. Then A-3 will mean that A is more important than B and there is a major difference in their importance. B-1 would have meant that B is more important than A but there is a minor difference only. This way a total number of n $(n - 1)/2$ pairs are compared and values entered in a cell if n-functions are to be compared. Then the score is obtained by adding all the numerals following a particular function. The function score divided by the total score *gives relative importance of that function.*

Function description should be derived for the product and all its components. The evaluation process also helps to find out whether it is a primary (basic) function or a secondary function. The basic function will have the highest score in the above-mentioned process of evaluation. The technique not only establishes the basic and secondary functions but also identifies those functions which are present because of specifications and requirements or present design approach. Generally, a product or component will have only one basic function and a number of secondary functions. If you have more than one basic function, it must be a mere restatement of the other.

Example 2: *Here we illustrate the application of function* phase on the item. 'Door Assembly' of a refrigerator. The two-word definition of each part or component of the door assembly is shown in Table 12.1 in the form of Functional Analysis Worksheet. The paired comparison of various functions is shown in Table 12.2. Figure 12.1 shows the graphical display of the relative importance of various functions which identify them as basic and secondary. You can also distinguish functions which are there due to present design approach as well as due to specifications and requirements. The basic function of the door assembly emerges as 'Provide Security' with the highest score.

Having defined the functions, the next step is to establish the worth of each *function. The objective is to* detemine the poor value functions and to obtain a reference point from which the cost of alternatives can be compared.

Function cost matrix is an effective technique of finding out the relative importance of a function and the percentage cost incurred in attaining that function. If the importance is low and cost is high then it reflects a poor value area.

NOTES

Example 3: Table 12.3 shows a Function Cost matrix for a typical product (compass). It describes in two-words the function of a component. Its percentage imporance (I) as obtained by paired comparison and percentage cost (C) obtained by allocating cost to attaining that function by that component. The Value index is given by I/C. A low value of I/C ratio shows a poor value area.

Table 12.1. Functional analysis work sheet

Item: Door Assembly

Qty	*Description*	*Function*		*Part*		*Assembly*	
		Verb	*Noun*	*Basic*	*Sec*	*Basic*	*Sec.*
1	Outer Pan	Provide	Support		X		
		Provide	Security	X		X	
		Permit	Rotation		X		
		Provide	Appearance		X		
4	Gusset Plates	Provide	Strength	X			
1	Handle	Provide	Location	X			
	Reinforcement	Provide	Stiffness		X		
1	Center Stiffner	Provide	Stiffness	X			
1	Lock Assembly	Provide	Fastening	X			
2	Sleeve door	Provide	Location		X		
	Hinge	Provide	Rotation	X			
		Support	Weight		X		
1	Handle	Facilitate	Grip		X		
		Facilitate	Opening	X			
1	Liner	Accommo-date	Articles	X			
		Prevent	Leak		X		
		Provide	Insulation		X		
		Support	Insulation		X		
4	Retainer	Apply	Force	X			
	Strip (Gasket)	Provide	Location		X		
1	Gasket	Provide	Seal	X			
4	Magnetic Strip	Provide	Force	X			
1	Decorative Strip	Provide	Aesthetics	X			
—	Insulating Glass	Prevent	Conduction		X		
	Wool	Provide	Insulation	X			

NOTES

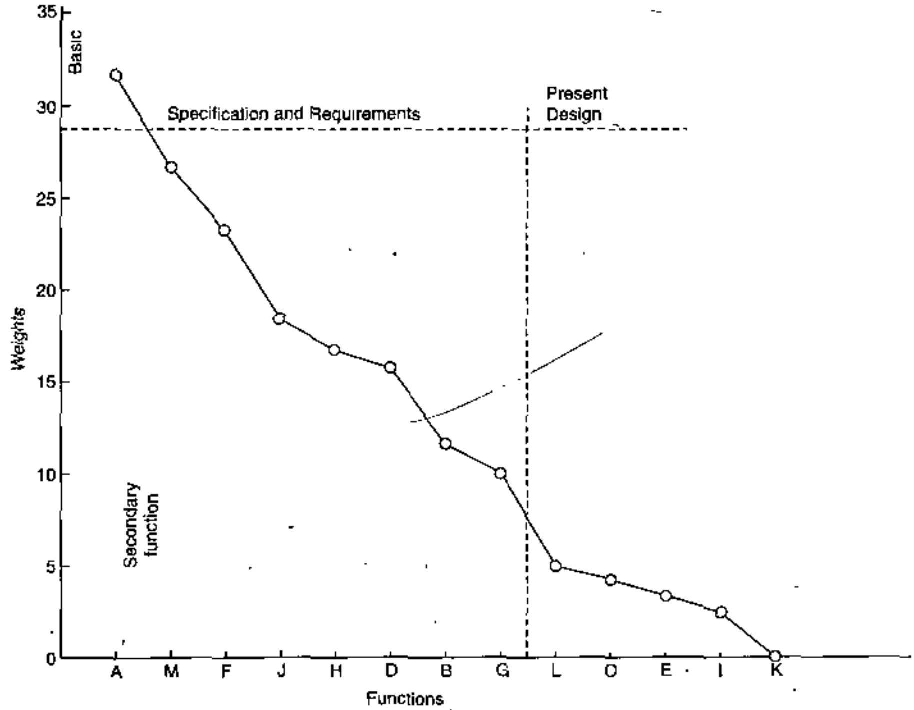


Fig. 12.1. Weight Factor vs. Function.

Table 12.2. Numerical evaluation chart for functions

Part No / Part Name: 1 outer Pan; 2 Gusset Plates; 3 Handle reinforcement; 4 Centre Stiffner; 5 Lock assy; 6 Sleeve Door Hinge; 7 Handle; 8 Liner; 9 Gasket retains Strip; 10 Gasket; 11 Magnetic STR; 12 Decorative Strip; 13 Insulation Glass Wool

Basic Function: A Provide security; B Provide strength; C Provide location; D Provide stiffness; E Provide fastening; F Provide rotation; G Facilitate opening; H Accommodate articles; I Provide retention; J Provide seal; K Provide force; L Provide aesthetics; M Provide insulation

	B	C	D	E	F	G	H	I	J	K	L	M	Weights	Adjusted weights	Percentage weights	Percentage cost	Value index = cost/worth	
A	A2	A3	A3	A3	A2	A3	A3	A3	A3	A3	A3	A1	32	33	18.5	22.3	1.2	Poor value and high cost
B		B2	D1	B2	F2	B1	H1	B2	J1	B3	B1	M2	11	12	6.7	3.9	0.6	
C			D2	C1	F3	C1	112	C1	J3	C2	L1	M2	4	5	2.1	4.8	1.7	Poor value
D				D2	F2	D2	H1	D3	J1	D3	D2	N3	15	16	8.9	1.2	0.1	
E					F3	G2	H2	E1	J3	E2	L1	M2	3	4	2.2	4.6	2.0	External variable
F						F3	F2	F2	F1	F3	F2	M2	23	24	13.4	1.9	0.4	
G							H2	G2	J2	G3	G1	M2	9	10	5.6	1.4	0.2	
H								H3	J1	H3	H2	M2	16	17	9.5	21.9	2.3	External variable
I									J3	I2	L2	L3	2	3	1.7	2.0	1.2	Poor value
J										J3	J2	M3	19	20	11.2	9.5	0.8	
K											L1	M2	0	1	0.5	6.5	13	Poor value
L												M3	5	6	3.4	3.0	0.9	
M													26	27	15.6	14	0.9	

NOTES

Table 12.3. Function-cost matrix for a compass

Sr. No.	Component	Function	I (%)	C (%)	Value Index I/C
1.	Pencil leg	Contain marker	16	25	0.6
2.	Pencil lock	Apply leverage	5	4	1.3
3.	Lock rivet	Create fulcrum	1	1	1.0
4.	Handle	Access Assembly	0	9	0.0
5.	Screw	Connect Components	12	7	1.7
6.	Nut	Induce torque	7	3	2.3
7.	Washer	Maintain Friction	1	4	0.3
8.	Pinleg	Hold Pin	12	20	0.6
9.	Pin	Anchor Axis	21	4	5.3
10.	Pencil	Deposit graphite	25	23	1.1

(*iv*) **Creation Phase**

The objective of this phase is to create ideas for value alternatives to accomplish the functions defined in the previous phase. The first step is to try answering the question 'what else will do'? This phase requires creativity to be the focal point.

Brainstorming is a very effective way of promoting creativity. In brainstorming 'free wheeling' is permitted. Two powerful techniques to promote creativity are:

(*a*) **Establish positive thinking.** Here we divorce the judicial part of the mind from the creative part by insisting that we do not attempt to judge an idea simultaneously when it is being created.

(*b*) **Develop creative ideas.** This is done by cultivating uninhibited thinking and developing a multitude of ideas and approaches for accomplishing the defined functions. The desired thing at this point is a large number of ideas, no matter whether they look ridiculous. A number of check-lists and idea-stimulators could be used for the purpose.

(*v*) **Evaluation Phase**

The objective of this phase is to select for further analysis the most promising of the ideas generated during the creative phase and to subject the ideas to a preliminary screening to identify those which satisfy the following criteria:

- Will it work ?
- Is it less costly than the present design ?
- Is it feasible to implement ?

This phase of the Job Plan together with its supporting techniques must be undertaken with both care and diligence, for it is here that the judicial part of the mind is brought into active use. There are four-techniques associated with this phase:

(*a*) **Refine and combine ideas.** The ideas must be practicable and to make them so we may have to refine an idea or combine two or more than two ideas.

(*b*) **Establish cost on all ideas.** As an idea or combination of dieas is being refined, an estimated cost should be calculated. What are the potential costs of implementing the idea and what are the resultant savings implied ?

(*c*) **Develop function alternatives.** This makes further use of the information developed in the evaluation of functional relationships to mould the individual functional solutions into total solutions.

NOTES

(*d*) **Evaluate by comparison.** When these rough total solutions and their related estimates of costs have been established they are compared to determine which one will provide the greatest value advantage.

The evaluation of value alternatives may have to be done on multiplicity of attributes—both tangible and intangible. The decision matrix approach can be a very effective way of multi-criteria evaluation. Here each criterion is assigned a relative importance and a normalised value score is allocated to each alternative on each attribute. The total weighted score is obtained for each alternative and the greatest score determines the preferred alternative.

Example 4. For the compass of Example 3 suppose the criteria for evaluation are: Ease of use, Ease of manufacturing, Safety, Quality and Attractiveness with the relative percentage weightage of 15, 30, 20, 25 and 10, respectively. Then the four value alternatives can be compared by using decision-matrix approach as shown in Table 12.4. As can be seen value alternative A_2 is the best as it gives the greatest total weighted score.

Table 12.4. Decision-matrix to evaluate value alternatives for a compass

		Attributes					
Sr. No.	*Value Alternative*	*Ease of use (15)*	*Ease of Manuf. (30)*	*Safety (20)*	*Quality (25)*	*Attractive-ness (10)*	*Total Score*
1.	A_1	100	30	50	70	100	61.50
2.	A_2	80	100	100	50	50	79.50
3.	A_3	30	50	70	100	70	61.50
4.	A_4	50	60	80	50	60	57.00

(*vi*) **Investigation Phase**

The three techniques of this phase further refine the selected ideas into workable and acceptable solutions providing lower cost methods for performing the desired function. The three techniques are:

(*a*) **Use Company and Industrial Standards.** Within a standard lies tried and proven solution to a problem. We should try to use standards to the extent possible.

(*b*) **Consult Vendors and Specialists.** The vendor may prove to be invaluable source of help in VE programme because he knows more about his product and its potential capabilities than most of his customers. We may decide to buy an item from the vendor instead of making it within if it is a cheaper and better proposal. Suppliers should be asked for cost-reducing and quality improving ideas. The degree of VE assistance by vendors also varies directly with the types of rewards, such as giving more business to cooperating vendors. Specialists can also contribute by suggesting a better material substitute, for example, by virtue of vast and up-to-date knowledge they may have in their chosen area of specialisation. In VE philosophy the consultation with others is a strength rather than a sign of weakness.

(*c*) **Use Speciality Products, Processes and Procedures.** These in many cases provide a lower-cost way of acomplishing the function; but before being adopted these should be evaluated to ensure lower costs in relation to standard products, processes and procedures.

NOTES

(vii) **Recommendation Phase**

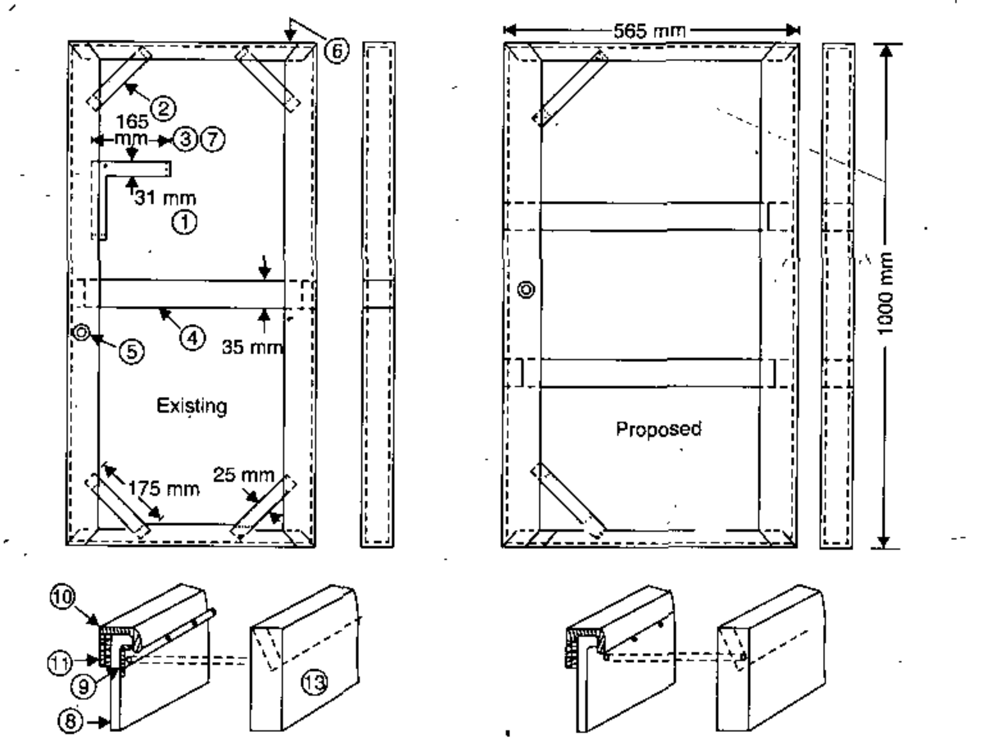
This is the final phase of the Job Plan in which the finally selected value alternative is recommended for acceptance and implementation. It is vital in the sense that the entire project of conducting VE would succeed only if the recommendation is accepted. Many a time the acceptance of the suggested alternative depends upon the way it is presented to the management. The two techniques associated with this phase are:

(a) **Present Facts.** Facts usually speak for themselves.

(b) **Motivate Positive Action.** The presentation of accurate, specific and detailed facts and costs will motivate positive action. This technique requires the follow-up to make sure that the action is taken for idea implementation.

The presentation of facts can be either verbal or written in standard format or in combined form. The combined strategy is the best. The final recommendation need not contain all the data but should contain sufficient information to enable decision makers to find the course of action to be taken.

Example 5. We take the same example as 'Door Assembly' of a refrigerator which was given for functional analysis phase. After successfully carrying out VE Job Plan, the improved design of the 'Door Assembly' was suggested. Figure 12.2 shows the existing design and the proposed design. Table 12.5 shows the comparison of costs of the existing design and the proposed design. It shows a saving potential of Rs. 37,15,200 per year without jeopardising the functions to be accomplished by such an assembly.



1. Outer Pan 2. Gusset Plates 3. Handle Reinforced 4. Centre Stiffner
5. Lock assembly 6. Sleeve door hinge 7. Handle
8. Liner 9. Gasket Retainer strip 10. Gasket
11. Magnetic strip 12. Decorative strip 13. Insulation glasswood

Fig. 12.2. Existing and Proposed Door Aseembly

NOTES

Table 12.5. Summary of savings through VE for the door assembly

Item	*Cost per unit (Rs.)*			*Savings (Rs.)*	
	Existing	*Proposed*	*Per unit*	*Per day*	*Per year*
Door Assembly	207.14	194.24	12.90	10.320	37,15,200

(B) DARSIRI is essentially similar to the Job Plan of Mudge described alone. *The seven steps involved are*—D (Data Collection), A (Analysis), R (Record of Ideas), S (Speculation), I (Investigation), R (Recommendation) and I (Implementation).

12.5. FAST DIAGRAM AS VALUE ENGINEERING TOOL

Basic Methodology of FAST Diagrams

FAST (Functional Analysis System Technique) was developed in 1965 by Charles W. *Bytheway. It visually represents the relationships* of functions performed by a product, service or system and identifies where the functions have the greatest impact on costs. It is useful in determining the function inter-relationship in analysing an entire system and gives a better understanding of the interaction of function and cost. FAST is like a network diagram. The steps involved in constructing the FAST diagram are as follows:

(*a*) Prepare a list of all functions of the product using verb and noun technique of functional analysis.

(*b*) Write each function on a small card. Select the card pertaining to Basic Function. Determine the position of the next higher and lower function by answering the following logical questions.

How is this function accomplished ?

Why is this function performed ?

When is this function performed ?

A critical function path may result from the logic sequence of the basic and secondary *functions. It is composed of only those functions* that must be performed to accomplish the functions. The FAST diagrams are usually bounded on both ends by the scope lines, which delineate the limits of responsibility of the study. For example, if one is value analysing an over-head projector, the FAST diagram will be expanded up to the point where current is conducted to the device.

Illustrative Example

The technique of drawing FAST diagram as applied to Refrigerator Packaging is shown in Figure 12.3. It shows the scope of the study and the entire logical relationship for its basic function 'Prevent Damage'. 'Prevent Damage' function is to support another function—'Facilitate Transportation' (beyond scope line) and is supported by 'Prevent *Corrosion' and 'Prevent Impact'*. Similarly, the entire network is completed.

The cost of each part is divided into different headings of functions in the ratio of its estimated contribution to perform this function. Thus total cost apportioned to perform that function is computed and entered in the FAST diagram outside the box describing the function. In Figure III the highest functional cost is Rs. 17 to accomplish the function 'Product Corners' in the Packaging. It thus identifies the high cost functions where potential for savings exist. In the proposed packaging, the total cost could be reduced to Rs. 77.96 per unit as compared to Rs. 87.84 per unit in the existing design, thus giving a saving potential of Rs. 69,78,240 per annum.

NOTES

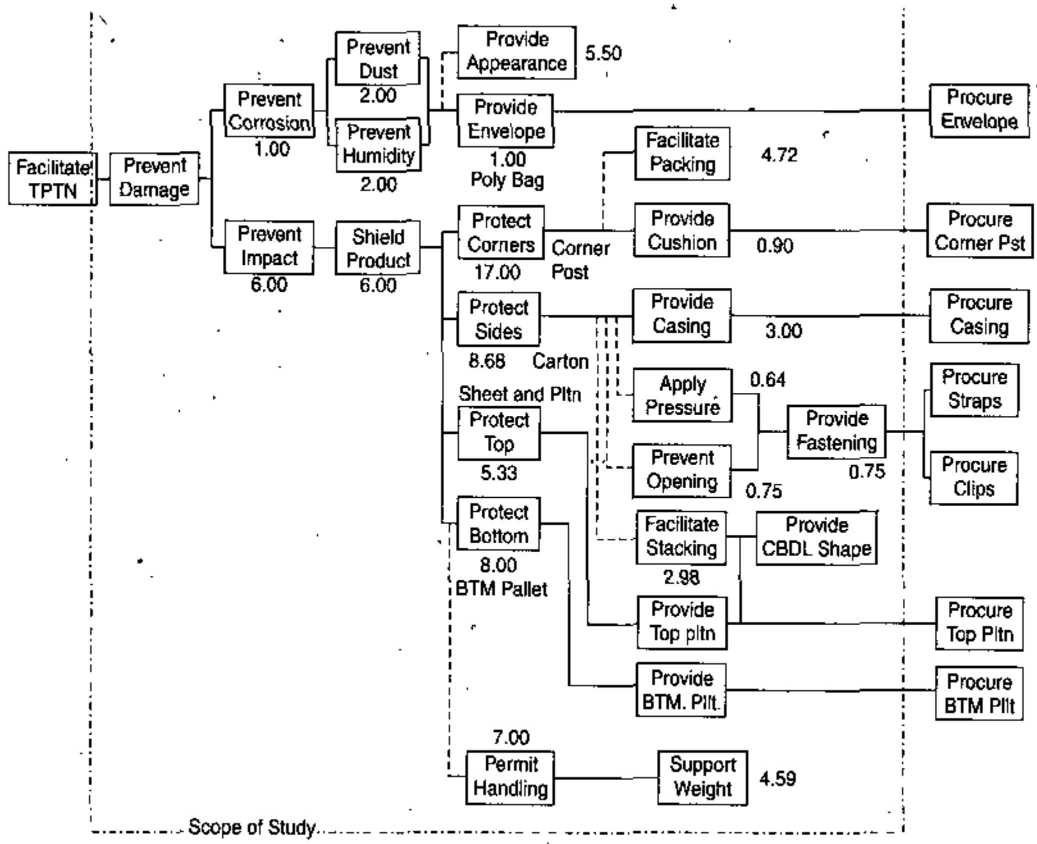


Fig. 12.3. Fast Diagram Refrigerator Packaging (Existing).

12.6. SOME CASE STUDIES IN VALUE ENGINEERING

Value engineering has been very extensively applied in product design, systems and procedures and a very large number of case studies have been reported in books and journals on Value Engineering. In many of these case studies large amounts of savings have been reported. In Indian industries value engineering applications have been reported from TISCO, Escorts, TELCO, Kelvinator, Railways and other units in public and private sectors. It is also known to have been applied in Indian Army and Navy.

Some very simple case illustrations are as follows:

(*i*) **Problem.** Make design changes to reduce the construction cost in a large garage for a trucking firm.

Function. Protect trucks

General explanations and Solutions: Company management had drawn plans to construct a large garage complex for its fleet of trucks. The value Analysis pointed out that trucks were on road on an average of 20 out of 24 hours. What was really needed was a large parking area and a small maintenance building.

NOTES

(ii) **Problem.** Reduce the number of guards by combining entrances to classified areas.

Function. Monitor doors

General Explanations and Solutions: *It was difficult to reduce the number* of doors to the classified areas. However, it was found that each guard could monitor and control two entrance doors by using CCTV and electric door locks.

(iii) **Problem.** Reduce the manufacturing cost of gasoline tanks for the landing aircrafts.

Function. Hold gasoline

General Explanations and Solutions: Initial design was inherently very costly. It was discovered that standard 55 gallon steel drums could be easily modified, coated and used.

(iv) **Problems.** Reduce the manufacturing cost of oil dipstick

Function. Measure oil

General Explanations and Solutions: It was discovered that standard dipstick used in large numbers could be more economically purchased from outside vendors instead of making.

12.7. BEHAVIOURAL AND ORGANISATIONAL ASPECTS OF VALUE ENGINEERING

Basic foundation of VE is structured around the effective use of people in teams. If team work is not properly harnessed it may not achieve major cost reductions. Some problems and roadblocks that are commonly encountered in the VE process are:

(i) Individuals involved in VE usually have other jobs and are already busy.

(ii) Teams may be inherently conservative, non-coherent and may avoid decisions and waste time.

(iii) Individual members of the team may have vested interests in resisting changes.

The success of VE study is enhanced if organisational and behavioural aspects are considered early in VE process. Hence the importance of the general phase of the VE Job Plan. Some important factors are:

(a) **Organising for VE:** *Organising of VE function itself is very important.* There are many alternative ways of doing it and there are many question to be answered. Size, composition, level of participation, leadership are some of the relevant issues. VE may be organised as a team of multidisciplinary areas coordinated by a value engineer/industrial engineer. It may be an independent cell in staff level or it may be visualised as a philosophy-conditioning of mind so that every individual be trained to be value conscious so that it gets reflected in his decisions and attitudes towards problem solving. The right choice is contingent upon various situational parameters.

(b) **Decision Making.** How are decisions to be made in a team? What are the external influences ? What are the processes of approval ? Are there some relevant issues that must be debated in the early stage of VE process ?

12.8. BENEFITS OF VALUE ENGINEERING AND CONCLUDING REMARKS

NOTES

Value Engineering helps in improving efficiency as well as effectiveness of products, systems and procedures. In general, VE,

(*i*) enables people to pinpoint areas that need attention and improvement.

(*ii*) provides a method of generating ideas and alternatives for possible solution to a problem.

(*iii*) provides a means of evaluating alternatives including intangible factors.

(*iv*) provides a vehicle for dialogue.

(*v*) documents the rationale behind decisions.

(*vi*) materially improves the value of goods and services.

In conclusion it must be re-emphasised that VE/VA is an extremely powerful methodology for cost reduction and value improvement and is becoming more and more popular. It is applicable to all ares: hardware, products, services, systems or procedures, and in all functional processes: purchasing, designing, producing, packaging physical handling and distribution.

NOTES

SUMMARY

1. Value Engineering/Value Analysis is a systematic and organised effort to identify the functions of a product, system or procedure and to attain that function with minimum cost without jeopardising quality, aesthetics, appearance etc. The Systematic procedure is known as VE Job Plan. Its phases include General Information, Function, Creation, Evaluation, Investigation and Recommendation. Each phase has a set of techniques associated with it. FAST diagram is another *powerful technique for VE. Other important techniques are functional analysis,* function-cost matrix, paired comparison and decision matrix. Value Engineering requires a good team spirit and an effective organisation. Benefits of VE in cost reduction and value improvement are tremendous. It is equally applicable to hardware and software projects.

KEY WORDS

Brainstorming. The process of generating creative ideas in a group by permitting free and uninhibited discussions among the team members.

Decision Matrix. A technique of evaluating finite number of alternatives against a multiplicity of factors.

Esteem Value. The properties, features or attractiveness which create a desire to possess the article.

Fast. Function Analysis System Technique; it looks like a network representation of various basic and secondary functions showing their inter-relationships.

Function. The term used to mean the purpose or use of a product.

Function Analysis. A technique to describe function of a product or system using two words—a verb and a noun.

Function Cost Matrix. A tool for identifying poor value areas by showing percentage importance of a function in a product and percentage cost spent in accomplishing that function.

Job Plan. A systematic procedure consisting of seven phases to carry out a Value Engineering Project.

Mental Roadblocks. Conditions of mind due to beliefs, resistance, fear etc. which retard creativity and idea generation.

Primary (Basic) Function. It is the basic or specific purpose for which the component or assembly was designed.

Paired-Comparison. A technique of determining relative importance of functions in Value Engineering by comparing two functions at a time.

Secondary Function. A function which does not directly contribute to the basic function or is only need to support the achievement of a primary function playing enabling role.

Scope-lines. Used in FAST diagram to delineate the scope of responsibility of VE study.

Unnecessary cost. Aslo termed as hidden or invisible cost which does not improve the quality, features required by customer or the product utility but only increase the cost; for example, materials handling cost.

NOTES

Use value. The properties which accomplish a use, work or service. The use value is equal to the value of the functions performed.

Value. A composite of product quality and cost consideration expressed as a ratio of quality to cost.

Value Engineering (Value Analysis). A systematic organised approach to determine the function of a product and system and find least cost ways of achieving it.

Value Index. Ratio of relative importance of a function to its relative cost.

Vendor. Supplier of materials, products or services who can play an effective role in cost reduction and value improvement.

Worth. Relative importance of a function.

TEST YOURSELF

1. Identify five products in your day-to-day life and determine reasons for poor value in them.
2. Applying the Function Analysis approach write down the basic functions of the following objects in two words:
   (*i*) Umbrella
   (*ii*) Ash Tray
   (*iii*) Paper Weight
   (*iv*) Wrist Watch
   (*v*) House.
3. Write true or false against the following statements :
   (*i*) Value engineering aims at reducing the cost by compromising on the desired quality.
   (*ii*) Basic functions can be many in a product.
   (*iii*) It is good for creativity if an idea is evaluated immediately after generating it.
   (*iv*) Value Engineering is equally applicable to products, systems, procedures, services.
   (*v*) L.D. Miles developed the FAST.
4. Choose the most appropriate answer from the following:
   (*a*) Value Analysis concepts were developed by:
      (*i*) Arther E. Mudge
      (*ii*) F.W. Taylor
      (*iii*) G.B. Dantzig
      (*iv*) Henry Gantt
      (*v*) Frank Gilbreth.
   (*b*) The basic function of a telephone is to:
      (*i*) transmit message
      (*ii*) provide status
      (*iii*) provide safety
      (*iv*) permit dialogue
      (*v*) allow discussion.

NOTES

(c) The tie clip as product is:

(i) primarily use value-oriented

(ii) primarily esteem value-oriented

(iii) substitutable by a paper clip.

(iv) not amenable to Value Engineering concepts

(v) too trivial for applying Value Engineering.

5. Suppose the following five attributes are identified to evaluate a value alternative initial cost; functional performance; reliability and maintainability ; product appearance; and dependence on supplier. Use paired comparison approach to determine the relative importance of these attributes.

6. Identify the basic and secondary functions of a typewriter and arrange them in a descending order of importance.

7. Write an essay on how to organise value engineering function in an electronic industry.

8. Why are suppliers sometimes helpful in value analysis programmes? How can they help ? Does it violate your concept of good business ethics to involve them in your problems ?

9. Critically examine the following statement: "Value Engineering is more of a human relations, team building and motivation programme than anything else".

10. Study the following situation and attempt to answer the questions raised.

Thomas is a purchasing manager of a company making do-it-yourself power tools. The president of the company entrusted him the task of cost reduction through value analysis.

Thomas organised a display of all bought out parts and sub-assemblies and the fancy Drill-A-Thon, made of castings, stampings and termings to draw the most attention. It had been designed and turned over to a supplier before purchasing became a separate profit centre under the president. In response to his queries to improve the assembly he got the following responses from three visiting salesmen.

The first company said that they would really gain price advantage if plastic instead of metal was accepted. The second company offered to make the product with fewer parts while the third company suggested that the best way was to assemble it within and they would supply parts at rockbottom prices.

Vice President of the Deen Dayal Industries Pvt. Ltd. who are the present suppliers rang up Thomas to express his concern in offering the products his company had been supplying for long to others and wondered whether these newcomers could make a better offer. He expressed a desire to be given a chance to reduce cost by trying value analysis. The chief design engineer also ridiculed the idea of going for plastic in place of metals and saw in it a conspiracy to cheapen their merchandise.

Thomas thus faces a conflict of view points. The president has given an ultimatum to reduce cost by at lest 5 per cent, and his company's design experts are uneasy about outside interference. Would-be-suppliers are anxious in re-designing Drill-A-Thon to fit their own shops Now:

(i) How can Thomas start a sound value analysis programme ?

(ii) How should he handle the reactions of his present supplier ?

(iii) In what way can he use the offered help of the would-be-suppliers who can be genuinely helpful ?