26 INVENTORY MANAGEMENT

26.1. INTRODUCTION

An effective management is necessary to ensure adequate supplies at optimum cost. The study of all the categories of inventory is carried out in detail with regard to its size and frequency of the various orders that must be placed. Additional controls must be exercised on higher value stocks.

Since inventory is money, and makes a heavy demand of working capital, it requires special attention to inventory control.

Inventory

Inventory can be defined as follows:

(*i*) Inventory is a detailed list of movable goods.

(*ii*) Inventory is a physical stock of items that a business or production enterprise keeps in hand for efficient running of affairs or its production.

(*iii*) Inventory is the quantity of goods, raw materials or other resources that are idle at any given point of time.

(*iv*) Usable but idle resource.

Inventories consist of raw materials, component parts, supplies or finished assemblies etc. which are purchased from an outside source, and the goods manufactured in the enterprise itself. In simple words, 'inventories' refer to stocks held by the firm.

When the demand for commodities increases, the inventory level decreases, while with the replenishment the inventory level increases. However changes in the demand for a commodity are not under the control of the firm, but the amount and time of replenishment is controllable.

Inventories are of following **types:**

1. **Production Inventories.** Raw materials, parts and components which enter the firm's product in the production process.
2. Maintenance, repair, and operating supplies which are consumed but do not become part of the product.
3. **In-process Inventories.** Semi-finished products found at various stages of the production operation.
4. **Finished Goods Inventories.** Completed products ready for shipment.

Inventory v/s Stores

The words, inventory and stores are some times confused, these must therefore be clearly understood. Stores means all those articles which are kept in store, while inventory comprises stores as well as materials in transit, materials in process, finished products and stock lying at company's show rooms and at distribution centres which have not been sold out.

Need for Inventory

Inventories in a business serve as the suspension system of an automobile. Ups and downs in sales are absorbed by inventory of finished goods. It enables a constant rate of production for the firm, even if the source of supply are not too reliable, may be due to power shortage, transport problem, labour unrest etc.

There are five reasons why a firm carries inventories :

(*i*) To gain economies in purchasing beyond current requirements.
(*ii*) To level out production cycles by producing to inventory.
(*iii*) To carry a reserve in order to prevent stock-out or lost sales.
(*iv*) To maintain service stocks while replacement stocks are in transit.
(*v*) Protection against variations in demand.

Thus an inventory helps in maintaining production rate and lowering manufacturing costs. A company can have substantial savings by using a rational procedure for inventory management. These savings are realised in several forms, depending on the particular situation. Some of the common sources of such savings are :

(*i*) lower purchase cost,
(*ii*) lower interest expenses,
(*iii*) increase in the availability of internal funds.
(*iv*) lower operating costs (clerical, expediting, transportation, receiving etc.),
(*v*) dependable delivery schedules, and
(*vi*) better customer service in the supply of goods.

But keeping inventory also leads to :

(*a*) Blocking working capital.
(*b*) Occupying space.
(*c*) Increasing risks of obsolescence, spoilage, theft, pilferage etc.
(*d*) Increasing maintenance and preservation costs.
(*e*) Increasing insurance premium etc.

26.2. TYPES OF INVENTORIES

Inventories can be classified in two ways, namely : (*i*) according to needs, (*ii*) according to the functions.

1. Classification According to Needs

(*a*) *Economic lot Inventories:* Since there is a fixed cost in ordering, hence it is economical to order beyond the immediate needs and divide the fixed ordering costs among a larger number of units. In addition, the manufacturer, from whom purchases are made, gains from producing and shipping in large quantities, and a portion of this gain can be passed on to the purchaser through quantity discount.

(*b*) *Fluctuation or Stabilizing Inventories:* Since it is not always possible to match the timing of production and sales, some inventories are accumulated due to the

time lag between production and sales. Since demand is also not accurately predicted, some reserve stocks are necessary. These safety stocks are fluctuation or stabiliz-ing inventories.

(c) *Anticipation Inventories:* These inventories are required to meet (*i*) seasonal demand and are produced and stocked throughout the year in order to meet high demand during the season, (*ii*) the high demand during promotion programmes launched by the firm, and (*iii*) the demand during temporary shut down of the plant for repair or maintenance.

(d) *Transportation Inventories:* These are also known as transit inventories. These are (*i*) raw materials and supply inventories which are in transit and have already been paid for, and (*ii*) finished goods despatched to buyer and payments of which not received.

2. **Classification As Per Functions**

(a) *Production Inventories:* Raw materials, parts, and components required during the production process are called production inventories.

(b) *Maintenance, Repair, and Operation (M.R.O.) Inventories:* These items are consumed in production process and do not become a part of product, *e.g.*, lubricating oils, fuels, spare parts etc.

(c) *Inprocess Inventories:* These are the items which are semi-finished and are waiting for their turn at work place for further processing.

(d) *Finished Product Inventories:* These are the finished goods and are completed products ready for sale.

(e) *Materials in transit Inventories:* As discussed at 1 (*d*) above.

26.3. SYMPTOMS OF POOR INVENTORY MANAGEMENT

Following are the symptoms of poor inventory management

1. High rate of order cancellations.
2. Excessive machine down-time due to materials shortages.
3. Periodic lack of adequate storage space.
4. Large scale inventories written-down because of price declines, distress sales, disposal of obsolete or slow moving items.
5. Widely varying rate of inventory losses.
6. Large written-downs at the time of physical inventory taking.
7. Continuous growing inventory quantities.
8. Inability to meet delivery schedules.
9. Uneven production rate.

26.4. A SYTEMS APPROACH FOR INVENTORY MANAGEMENT

This approach emphasises that inventory should be managed by developing and then following proper systems. The inventories should be viewed in terms of the total system of production and marketing. The aim of the systems approach is to reduce the size of inventories without destroying their effectiveness .

Following are some of the steps in this regard.

1. Better forecasting/material planning.
2. Fewer varieties.
3. Centralised inventories.
4. Developing a batch of reliable vendors to cater to the needs of a variety of items ensuring the right quantity, in right place and particularly at right time.
5. Effective follow up.
6. Control through reports at a regular frequency.
7. Effective budgetary control.
8. Following the scientific tools, like "Economic Order Quantity", "Selective Control Techniques" etc.

26.5. INVENTORY CONTROL

Inventory control is the means by which material of the corrent quantity and quality is made available as and when required with due regard to economy in storage and ordering costs, and working capital.

It may also be defined "as the systematic location, storage and recording of goods in such a way that desired degree of service can be made to the operating shops at minimum ultimate cost".

The Need of Inventory Control. The necessity of inventory control is to maintain a reserve (store) of goods that will ensure manufacturing according to the production plan based on sales requirements and the lowest possible ultimate cost. Losses from improper inventory control include purchases in excess than what needed, the cost of slowed up production resulting from material not being available when wanted. Each time a machine is shut down for lack of materials or each time sale is postponed or cancelled for lack of finished goods a factory loses money.

To promote smooth factory operation and to prevent piling up or idle machine time proper quantity of material must be on hand when it is wanted. Proper inventory control can reduce such losses to a great extent.

Functions of Inventory Control

Following are the most important functions of Inventory Control:

(*a*) To *run the stores effectively.* This includes layout, storing media (bins, shelves and open space etc.), utilization of storage space, receiving and issuing procedures etc.

(*b*) To ensure timely availability of material and avoid built up of stock levels.

(*c*) *Technical responsibility for the state of materials.* This includes methods of storing, maintenance procedures, studies of deterioration and obsolescence.

(*d*) *Stock Control System.* Physical verification (stock-taking), records, ordering policies and procedures for the purchase of goods.

(*e*) Maintenance of specified raw materials; general supplies, work in-process and component parts in sufficient quantities to meet the demand of production.

(*f*) Protecting the Inventory from losses due to improper handling or storing of goods and unauthorised removal from stores.

(*g*) Pricing all materials supplied to the shops so as to estimate material cost.

Essential Steps in Inventory Control

It is essential that the necessary materials shall be on hand when required and it is just as essential that no more stores shall be carried than is necessary. The maximum and minimum quantities of all stores should, therefore, be fixed with much care. In several cases, these limits can be set only by experience and careful observation. It is found that this results in a great reduction of inventory.

Advantage of Inventory Control

1. It creates buffer between input and output.
2. It ensures against delays in deliveries.
3. It allows for possible increase in output.
4. It allows advantage of quantity discounts.
5. It ensures against scarcity of materials in the market.
6. It utilizes the benefit of price fluctuations.

Hence, in conclusion with a good Inventory Control, a firm is able to make purchase in economic lots, maintain continuity of operations, avoid time consuming small orders, and guarantee prompt delivery of finished goods.

Objectives of Inventory Planning and Control

The objectives of Inventory Planning and Control are to ensure

1. Timely availability of required materials or acceptable quality (Planning)
2. To avoid build-up stock levels by inflow of materials much inadvance of requirements or accumulation of unwanted items which though ordered earlier, but not required now.

It is the duty of the Production Department to intimate Materials Management Department about the changes. In case, such information are not passed on to the material management department, the inventory build-up is unavoidable and it is difficult to take up preventive action in advance.

26.6. INVENTORY BUILD-UP

Inventory build-up starts because of the reasons, either (*i*) items get ordered in excess of the requirement or (*ii*) they do not get used at the same rate at which they are received.

To overcome the first possibility, orders should be placed after consulting the production department. Production and Materials Management departments must together work out the delivery schedules, which must be decided after considering the past performances of the suppliers. Sometimes inventories, get build-up because excessive quantities are received at a particular time. For example, receiving the years requirement spread over 4 quarterly deliveries, is different from receiving in one lot. In the second case the organisation isforced to carry inventory of 12 months at a time. The other danger is that such material deteriorates in storage or pilferred or damaged.

Now coming to the second aspect, stores inventory is consumed by the production department by drawing materials from stores and converting it into finished goods. If the consumption rate falls down, then inventory build-up takes place. The consumption rate may fall down because of any of the following reasons:

(*i*) Due to change in production plans.
(*ii*) Due to discontinuance of manufacture of a product.
(*iii*) Due to change in design for a particular assembly or set of components.

In such cases rescheduling of the deliveries or reducing the quantities of the pending order must be assorted to. In case the item is not required at all, the further supplies must be stopped and pending orders be cancelled.

Delivery Schedule

In order to control build-ups this aspect is most important. Production and material management departments must, together, workout delivery schedules. This must be done considering the past experiences. Inventories get build-up not only because excess quantities are ordered and received but also because excessive quantities are received at a particular time. For example, receiving the year's requirement spread over 6 bi-monthly deliveries is different from receiving a six-monthly lots. In second case 6 months inventory has to be carried at a time.

Next stage, while ordering and accepting the supplies is to ensure that material received only as per requirement. For this purpose following precautions are taken:

1. Availability of material into stock and material awaiting inspection from the past supply should also be taken into account.
2. Care should be taken to accept the supplies only as per delivery schedule since, the natural tendency on the part of suppliers is to take deliveries as early as possible and in as few lots as he can. Further, there is general belief in personnel, that timely supply means, it should not be late, may be early, whereas it should not be too early, i.e. much before its requirement.

Actions to be taken for Avoiding Inventory Build-up

1. Items with no issues and receipts in last one year should be identified in the beginning of the financial year. In consultation with production control and research and designs department, all the pending open-purchase orders, if any, items should be cancelled.
2. In the cases where, items have been received without any issues in the past, matter should be investigated. These investigations may reveal either of the following:
   (*a*) Items are for new project and utilisation is expected to be started in near future.
   (*b*) Items are received for the production planned a few months later.
   (*c*) The item is a replacement for an obsolete item, but will be issued only after existing stock of the obsolete item is exhausted.
   (*d*) The item is for a product whose production has been suspended or delayed due to a temporary slump in the demand.
   (*e*) Item is supplied much ahead of the requirement.
   (*f*) The item is not required.

   No action is required in the cases of (*a*), (*b*) and (*c*), whereas immediate action is called for in the case of (*d*) and (*e*), rescheduling the deliveries and reducing the total order quantities. In case of (*f*), immediate stoppage of further supplies and cancellation of pending purchase order has to be done.
3. A list of items which are in excess of predetermined levels should be prepared and investigation is to be done as to why the level has gone up and whether their supplies need to be slowed down.
4. Do not accept the following reasons for early supplies:
   (*a*) We need the material any way.
   (*b*) What difference does it make if we have a little extra stock.
   (*c*) Let us not harass the poor supplier. Taking back the material will mean a lot of extra expenditure to him.

(d) If we return the material today, he may not supply in time on the next occasion etc.

Therefore, at the risk of causing some inconvenience to the supplier, goods if received in advance of intimated delivery schedules should be returned back.

Disposal of Surplus Materials

A periodical study is necessary for finding obsolete or surplus (not being used from a considerable period) items. These items must then be re-examined for their alternative use. If they could not be used anywhere in the concern they must be disposed of. Mode of disposal must be decided in following priority.:

(a) Send it back on resale to the original supplier, if they are, interested, or otherwise.
(b) Sell them at the best possible price. If it is not possible then.
(c) Sell it at any available price even at scrap value. In case, if it could not be sold at scrap value or at any other rate, then.
(d) Give away free, as there is no use of preserving it year after year and blocking the space.

26.7. QUANTITY STANDARDS IN INVENTORY CONTROL

There are five important quantity standards used as tool to control Inventory. These are as follows (see Fig. 26.1)

1. The Maximum Stores.
2. The Minimum Stores.
3. The Standard Order.
4. The Ordering Point.
5. Lead or Procurement Time.

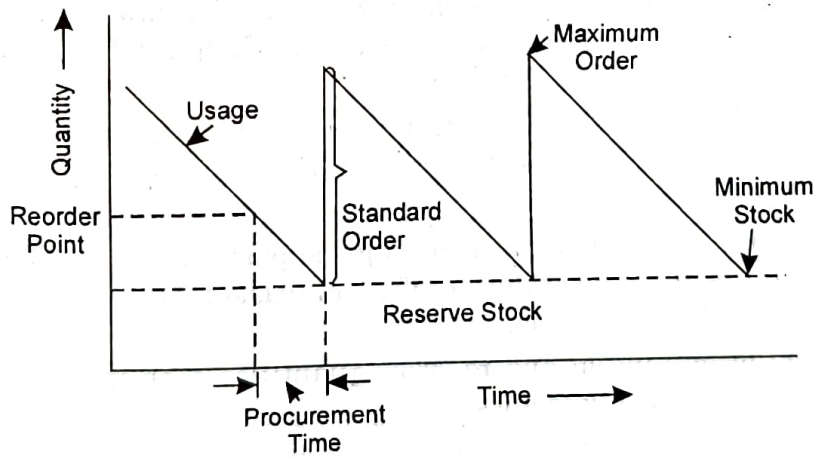

Fig 26.1

1. **The Maximum Stores.** This term is applied to designate the upper limit of the Inventory and represents the largest quantity which in the interest of economy should generally be kept in stores.
2. **The Minimum Stores.** This term is applied to designate the lower limit of the Inventory and represents a reserve or margin of safety to be used in case of emergency. When requirements have been abnormal it is intended that there must always be atleast this quantity available in stores.

3. **The Standard Order.** It is the quantity to be purchased at any time. Repeat order for a given product are always for this quantity until this is revised.
4. **The Ordering Point.** This represents the quantity required to ensure against exhaustion of the supply during the interval between the placement of an order and delivery. When the balance falls to this level, it is an indication that a new purchase order must be placed.
5. **Lead Time.** It is the time which takes the stock to reach from Re-order point to Minimum Stock level. It may also be defined as the time that elapses between the voicing of a need for anything and the time taken to satisfy the need. If one order is palced today and after 40 days it is fulfilled, then 40 days period is lead time. Hence, it shows that the order should be placed 40 days earlier. Load time determines the amount of material to be kept in reserve. As the lead time decreases, the reserve stock also decreases and *vice versa*. Therefore, the lead time analysis is very necessary, and the attempts should be made to reduce this period.

   Lead Time Includes:

   1. Requisitioning of materials.
   2. Time to process the enquiries and to place the order.
   3. Time to deliver the order to supplier.
   4. Time for the supplier to fulfil the order.
   5. Transportation time to reach the purchaser, inspection etc.
6. **Reserve (Safety or Buffer Stock).** If every thing goes as per programme, i.e., order is placed exactly at Reorder level, consumption rate remains same and material is received within lead time then there is no need for reserve or safety stock. But this seldom happens. Therefore to safeguard the production against uncertainties in consumption rate and lead-time, an extra stock is maintained all along and this is called as safety stock, reserve stock or buffer stock.

   Safety stock levels should be decided very carefully, as lower level may lead to stock-out positions and higher level means blockage of capital. The factors considered for this purpose are:

   1. Variation in consumption expected during the lead-time.
   2. Variation in lead-time expected considering the prevailing market conditions for that item.

Generally the safety stock is fixed considering the past data of maximum lead-time and normal lead-time. Safety stock should then be sufficient to last for the periodic difference between maximum and normal lead-time periods.

In setting maximum, minimum and re-order quantities each item should be considered separately in terms of the following factors :

(*a*) Economic size of each purchase order.
(*b*) Increased lock-up of capital.
(*c*) The time required to receive the goods after requisitioning.
(*d*) The probable depreciation and obsolescence.
(*e*) The rate of demand etc.

26.8. SELECTIVE CONTROL TECHNIQUES

'Selective Inventory Management' or 'Selective Control Techniques' are based on the priniciple that it is inpossible to manage and control every item in inventory holdings in the same way and skill so as to meet the two broad objectives of inventory control, *i.e.*, to reduce investment in inventories, and also to avoid stock-outs and shortages. This technique, therefore, concentrates on those items where it is justified either due to essentiality or amount of money involved.

Therefore, in other words the approach is to evaluate a trade off between the cost of inventories as against cost of control. For example, the inventory of high value items (in terms of annual usage) is to be controlled carefully, because a small percentage decrease in inventory can save a lot, while in case of low value items, the cost of control may be more than the possible savings.

Some of the common techniques used for exercising selective control are being described here under.

(1) A-B-C Control Policy

It is difficult and very costly to give equal attention to all the items of inventory. A-B-C analysis is meant for relative inventory control in which maximum attention can be given to items which consume more money and a fair attention can be given to medium value items, while the attention for low value items can be reduced to routine procedure only. This policy can also be applied in various other aspects of materials management.

If all the store items of an undertaking are analysed in terms of annual consumption of each item in rupees, it will be found that nearly 10 percent (sometimes even less) of the items are responsible for about 70 percent of total annual consumption cost, about 20 percent items will require about 25 percent of total consumption cost and rest 70 percent of the items require only 5 percent of the total annual consumption cost. The first category, small number of high consumption cost items, are called A items ; second category of medium consumption value items are known as *B* items; while the third category, *i.e.*, large number of items with small annual consumption cost are *C* items.

It is necessary to clear that *A-B-C* analysis does not depend on the unit cost of the items but on its annual consumption. Further it is also clarified that it does not indicate importance of any item or category, and every item is equally important. For example while installing a big machine of lacs of rupees, some foundation bolts (cost may be nearly Rs. 100 or 200 only) are not available in stores then this machine cannot be erected. Thus those bolts are equally important as that of machine although one is in category *A* and another in category *C*.

A-B-C analysis is a basic technique of materials management and can be applied over almost all the aspects of materials management such as purchase, sales, inspection, inventory control, store-keeping etc.

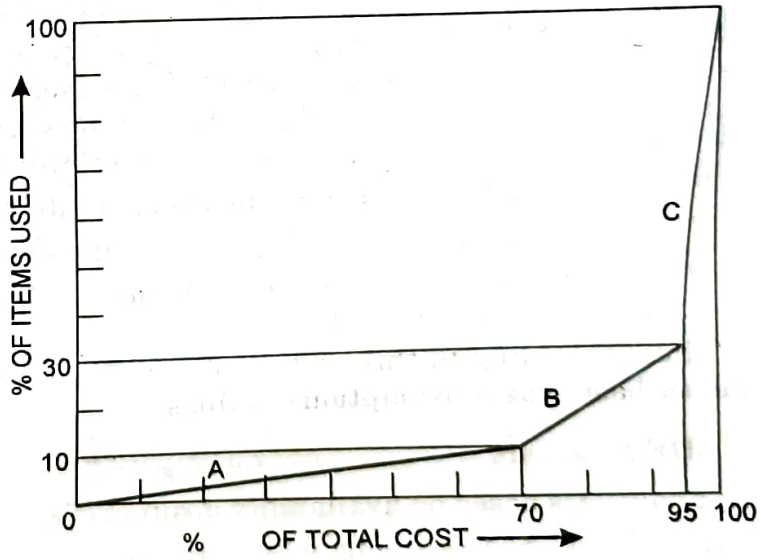

Fig. 26.2

Thus we see that control policies for *A*, *B* and *C* items are based on two principles, namely (*i*) to keep capital tied up inventories as low as practicable, (*ii*) to ensure that all the materials would be available when required. Control policies based on these two principles are described hereunder:

Policies for A items

(*i*) Since these items account for 70% of the total value hence they should be ordered more frequently, but in small quantities in order to reduce capital locked up at any time.

(*ii*) The requirement of such items must be planned in advance for expected future consumption, so that only the required quantities arrive a little before they are required for consumption.

(*iii*) Purchase of *A* items should be looked into by the top executives in purchasing department.

(*iv*) Since *A* items should be stocked as minimum as possible, maximum efforts should be made to expedite the delivery. Deliveries within a specified period of order must be adhered to.

(*v*) Two or more suppliers for each item may be engaged, so that dependence on one supplier is eliminated to safeguard against failure by one supplier.

(*vi*) Ordering quantities, re-order point and minimum stock level should be revised frequently.

Policies for B items

(*i*) The policies for *B* items, in general, are in between those for *A* and *C* items.

(*ii*) Order for those items must be placed less frequently than for *A* items. Generally 3 to 6 orders per year are placed for *B* items.

Policies for C items

(*i*) Since C items do not involve much capital tie up, the stock for such items may be kept liberally (*i.e.*, stock for 6 months to one year).

(*ii*) Annual or 6 monthly orders should be placed to reduce paper work and ordering costs and to get advantage of quantity discounts for bulk purchases.

(2) VED Analysis

The items can be classified according to their use, consumption, values etc. *A-B-C* classification is an oldest and commonly used method, but now-a-days *VED* and *SDE* analysis are also being used. *VED* analysis is done to consider essentiality of stocking spares.

V stands for Vital items, without which production would come to halt.

E is for Essential items, without which dislocation of production work occurs.

D is for Desirable items. Remaining items which do not cause any immediate loss in production fall under this category.

Thus, according to this system of analysis basis is criticality of items, whereas in *A-B-C* analysis basis was consumption of values.

(3) SDE Analysis

This analysis is based on availability position of each item. In this analysis,

S- refers to Scarce items, which are in short supply and their availability is scarce. This includes imported items.

D - refers to Difficult items, which cannot be procured easily.

E - refers to Easily available items.

(4) MNG Analysis

In this analysis,

M - refers to Moving items. These items are consumed from time to time.

N - refers to Non-moving items. These items are those items which are not consumed in last one year.

G - refers to Ghost items. These are those items which had nil balance, both at the beginning and at the end of the last financial year and there were no transactions (receipt or issues) during the year. These are non-existing items for which the store-keeper keeps bin-cards showing nil balance.

Above mentioned 4 control techniques are commonly used. However, following are some other methods which help the materials management to selectively control the large number of items and effectively channelise his energy to problem areas resulting in optimal use of his efforts.

S. No.	Title	Basis	Application
1.	F.S.N. (Fast, Slow, Non-moving)	Issues from stores	Obsolescence control
2.	H.M.L. (High, Medium, Low)	Unit price of material	To delegate purchasing powers
3.	V.E.I.N. (Vital, Essential, Important, Normal)	Equipment criticality	Maintenance
4.	F.A.N. (Failure Analysis)	Design and Issue of spares	Reliability Engineer-ing
5.	G.O.L.F. (Govt. Ordinary, Local, Foreign)	Source of origin of material	Purchase strategy
6.	S.O.S. (Seasonal Off-seasonal)	Nature of supply	To decide stock level

26.8. CODIFICATION

It is an effective tool of inventory control. Today it is used to properly classify equipments, raw materials, components and spares to suit the particular needs of any organisation. Codification is helpful to prevent duplication and multiplicity of stores and the mistakes which are caused by the normal practice of describing the material.

The main features of rationalised code are:

(*i*) It describes an article objectively

(*ii*) It is an all-numeric 8-digit code and

(*iii*) It describes an article progressively from general to particular.

For example :

(1) 03 01 15 15 — Radian 12 SWg (size)

First two digits 03 indicate — Arc Welding electrodes

Second two digits 01 Indicate — Manual electrodes (local-M.S.)

Third two digits 15 indicate — Radian

Last two digits 15 indicate — 12 SWg (size)

The code has got enough flexibility to absorb all the materials of the concern and has the provisions for unforeseen contingencies also.

First two digits indicate the main group, that is all the materials are divided into 100 main groups, say for instance 10 gases, 20 chemicals, 42 screws, 64 hand tools etc.

Third and fourth digit indicate the type of article. For example

21	XX	Iron and Steel
21	10	Steel-Mild
21	01	Steel- Alloy WJQ

Fifth and sixth digits indicate the shape and metallurgical conditions.

For example:

21	10	10	XX	Wire, Mild, steel
21	10	10	10	Wire, Mild, steel 0.116"

Thus, last two digits indicate the size.

In this way with the help of codification materials are specified at every stage that is in the main groups, types, shapes and metallurgical conditions and sizes. For all the materials, the code length is constant and is useful for the use of punched cards and computers.

Now codification is applied to all purchased items, *i.e.*, raw materials, semi-finished and finished products, saleable products and components.

26.10. ECONOMIC ORDERING QUANTITY (E.O.Q.)

The evaluation of the most economic quantity to bepurchased involves calculation of the following two costs:

(*a*) Procurement cost or buying cost. Set up cost in case of manufacturing.

(*b*) Inventory carrying cost.

A. Procurement Cost or Buying Cost:

This cost includes the expenditure made on :

(*i*) Calling quotations.

(*ii*) Processing quotations,

(*iii*) Placing purchase orders.

(*iv*) Receiving and inspecting.

(*v*) Verifying and payment of bills.

(*vi*) Other incidental charges etc.

Set-up cost in case of manufacturing:

It includes :

(*i*) Cost of setting up the process or equipment etc.

(*ii*) Cost of scrap which may occur at the beginning of new operation.

(*iii*) Cost of planning production and controlling.

(*iv*) Cost of machine idle time during set up etc.

(b) Inventory Carrying Cost

This consists of expenditure made for:

(*i*) Insurance.

(*ii*) Storage and handling.

(iii) Obsolescence and Depreciation.

(iv) Deterioration.

(v) Taxes.

(vi) Interest etc.

For manufacturing it will include, unit material, unit direct labour, all the unit burden excepting items affected by lot size.

This cost varies between 10 to 20% of the product cost.

The economic ordering quantity is obtained by the quantity whose procurement cost is equal to inventory carrying cost.

Let A = Total items consumed per year.

P = Procurement cost per order.

e = Annual Inventory carrying cost per unit.

= Unit cost × Inventory carrying charges = C × I

and Q = Economic order quantity.

Let y = Total cost of one year's requirement

Then, Total cost

= (number of lots) × procurement cost + (consumption quantity × variable cost per unit) + (average inventory cost × Inventory carrying charges).

$$\therefore \quad y = \frac{A}{Q} P + A \times C + \frac{Q}{2} \times C \times 1 \qquad \ldots (1)$$

This equation can be used to determine the total cost.

By differentiating w.r.t Q and equating equation (1) to zero, the economic purchase order is obtained.

Thus $$-\frac{AP}{Q^2} + \frac{C \times I}{2} = 0 \text{ or } \frac{AP}{Q^2} = \frac{C \times I}{2}$$

Therefore, $$C \times I = e$$

or $$Q^2 = \frac{2AP}{e}$$

or $$Q = \sqrt{\frac{2AP}{e}} = \sqrt{\frac{2AP}{C \times 1}} \qquad \ldots (2)$$

This formula was developed by Mr. F.W. Harris in 1915.

Thus using Equations (1) and (2), the most economical purchase order size and the minimum total cost for a given set of conditions can be obtained.

The Economic Ordering Quantity can be obtained by plotting the relevant cost against the order quantity, as below (Refer Fig 26.3)

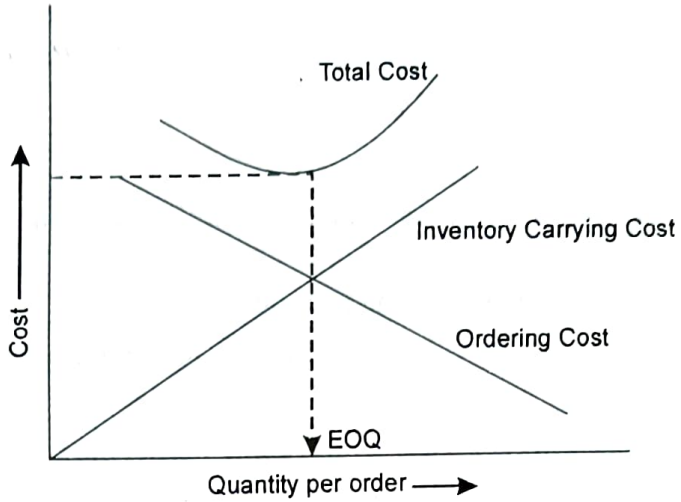

Fig. 26.3. Economic ordering quantity

Since the total cost curve is flat at the bottom we can deviate upto 25 percent on either side of the economic ordering quantity, without any significant extra cost, depending upon the circumstances. Therefore, for perishable items order can be reduced by 25 percent from E.O.Q, where quantity discount is available, we can enhance the order by 25 percent over the E.O.Q.

Important assumptions in applying the E.O.Q. model:

1. Demand is continuous and constant, and does not change with time.
2. Lead-time is constant.
3. Delivery of all the items is instantaneous.
4. Replenishment of one item has no effect on the replenishment of any other item of inventory.
5. Purchase price and their cost parameters, *i.e.*, P and C are constant.

Problem 26.1 *A plant producing a line of hydraulic valves can supply the factory warehouse at the rate of 750/ month. The warehouse ship, 3000 valves per year at a unit selling price of Rs. 250. Considering the plant's ordering and set up cost of Rs. 300 and the inventory carrying cost rate of 20%. What quantities should the warehouse order from the plant?*

Solution.

Let Q = the quantity, the warehouse should order from the plant.

A = No. of items consumed/year = 3000

P = Ordering and set up cost/order = Rs. 300

C = Annual inventory carrying cost/item

$$= \frac{\text{Total inventory carrying cost}}{\text{Total No. of items consumed}}$$

$$= \frac{3000 \times 250 \times 20}{3000 \times 100} = \text{Rs. } 50$$

Now

$$Q = \sqrt{\frac{2AP}{C}} = \sqrt{\frac{2 \times 3000 \times 300}{50}}$$

$$= \sqrt{30,000}$$

Q = 189.7 say **190 units Ans.**

Problem 26.2 *The rate of a particular raw material from stores is 20 units per year. The cost of placing and receiving an order is Rs. 40. The cost of each unit is Rs. 100. The cost of carrying inventory in percent/year is 0.16 and it depends on the average stock.*

Determine : (i) The economic ordering quantity (ii) If the lead time is 3 months, calculate order point.

Solution. Let

Q = Economic ordering quantity = ?

A = No.of units consumed/year = 20

P = Ordering and set up cost = Rs. 40

C = Annual inventory carrying cost per unit

$$= \frac{\text{Total annual inventory carrying cost}}{\text{Total items consumed in a year}}$$

$$= \frac{20 \times 100 \times 0.16}{20} = \text{Rs. } 16$$

$$\therefore \quad Q = \sqrt{\frac{2AP}{C}} = \sqrt{\frac{2 \times 20 \times 40}{16}}$$

$$= \mathbf{10 \text{ items. Ans.}}$$

(*ii*) To determine re-order point

Let Q_0 = Stock level at reorder point

a = Consumption rate

t_0 = Lead time

Them $Q_0 = a \times t_0$

Hence $$a = \frac{20}{12} \text{ items/month}$$

$$t_0 = 3 \text{ months}$$

$$Q_0 = a \times t_0$$

$$= \frac{20}{12} \times 3 = 5 \text{ units.}$$

That is, when stock level reaches to 5 units, Reorder should be sent.

Problem 26.3 *A company producing motors, decides to make a particular item in batches. The following information is available.*

Cost of setting–up machine and tools = Rs. 800

Annual rate of depreciation, interest etc. = 15%

Consumption of parts in assembly shop = 100/month

Processing of each item takes 8 hours on the machine

Labour rate = Rs. 10 per day (Assume 8 hours in a day)

Material cost = Rs. 3 per kg Weight of each item = 15 kg.

Overhead expenses on each part is allocated at 100% of the duration of machine run, assuming that machine loading factor is about 80%.

Solution.

Material cost of each part $= 3 \times 15 =$ Rs. 45

Labour cost of each part $= \frac{10}{8} \times 8 =$ Rs. 10

Prime cost of each part $= 45 + 10 =$ Rs. 55

Overhead = 100% of 55 = Rs. 55

$\therefore$ Manufacturing cost = Rs. 45 + 10 + 55 = Rs. 110

Now Economic lot size, $Q = \sqrt{\frac{2AP}{C}}$

A = Annual items to be consumed
$= 100 \times 12 = 1200$

P = Set up cost = Rs. 800

C = Inventory carrying cost/unit
$= 110 \times 0.15$

$$= Q = \sqrt{\frac{2 \times 1200 \times 800}{110 \times 0.15}}$$

$$= \mathbf{341\ Ans.}$$

Running hours of machine $= \frac{341 \times 8}{0.80} =$ **3410 hours. Ans.**

Problem 26.4. *A factory is manufacturing Hubs in batches. The following details are available.*
Cost of setting–up machine and tools = Rs. 1400
Annual rate of depreciation, interest etc. = 18%
Consumption of parts in assembly shop = 120/month
Processing of each item takes 6 hours on the machine
Labour rate = Rs. 20/ day for 8 hours
Material cost = Rs. 5/ kg
Weight of each item = 4 kg.
Overhead on each item is allocated at 120% of the prime cost. Find out:
(*i*) Economic batch size for machining and
(*ii*) *Duration of machine run, assuming that the machine loading factor is about 90%.*

Solution.

Material cost = $5 \times 4 =$ Rs. 20

Labour cost = Time for producton of each unit × hourly rate

$$= 6 \times \frac{20}{8} = \text{Rs. } 15.$$

$\therefore$ Prime cost = Rs. 20 + 15 = Rs. 35

Now overheads = 120% of prime cost
$= 1.20 \times 35 =$ Rs. 42

$\therefore$ Unit cost = Prime cost + Overheads

$$= \text{Rs. } 35 + 42 = \text{Rs. } 77/\text{ unit}$$

$\therefore$ $N = 120 \times 12 = 1440$

As, $C = 77$ Rs./unit, A = Rs. 1440, I = 0.18

$\therefore$ $$Q = \sqrt{\frac{2 \times 1440 \times 1400}{77 \times 0.18}}$$

$\therefore$ $$Q = \sqrt{\frac{144 \times 4000 \times 100}{11 \times 18}}$$

$\therefore$ $$= \sqrt{\frac{144 \times 40 \times 10^4}{11 \times 18}}$$

$$= 534 \text{ (say)}$$

Runnig hours of the machine

$$= \frac{534 \times 6}{0.90} = \textbf{3560 hours Ans.}$$

Problem 26.5. *Determine the economic order quantity for a product whose average daily consumption rate is 80 units. The cost of each unit is Re. 0.50 and the inventory carrying charges is 0.20. The cost of placing and receiving the order is Rs. 10. Assuming total working days in a year as 300, obtain the annual inventory capital also.*

Solution.

(*i*) No. of units consumed/year,

$$A = 80 \times 300$$
$$= 24{,}000 \text{ units}$$

Ordering cost, $P = \text{Rs. } 10$

Annual Inventory carrying charge/unit,

$$C = \text{Re. } 0.20$$

$\therefore$ Economic ordering quantity,

$$Q = \sqrt{\frac{2AP}{C}}$$

$$= \sqrt{\frac{2 \times 24{,}000 \times 10}{0.20}} = 1549.2$$

$$= \textbf{say 1550 units. Ans.}$$

(*ii*) Annual Inventory capital = Cost of units consumed per year + Procurement cost/year + Inventory carrying cost per year.

$$= 24{,}000 + 0.50 + \frac{A \times P}{Q} + \frac{Q \times C}{2}$$

$$= 12{,}000 + \frac{24{,}000 \times 10}{1550} + \frac{1550 \times 0.20}{2}$$

$$= 12{,}000 + 155 + 155 = \textbf{Rs. 12,310 Ans.}$$

Problem 26.6.

(*a*) *Explain the term economic order quantity.*

(*b*) *The total annual demand for an Inventory item is 2,000 units. The Inventory carrying cost per rupee purchase value of Inventory per year is 10 paise. The order cost per order is Rs. 5. The purchase price of the unit consists of two elements Rs. 2 per unit and Rs. 40 as fixed charges per order.*

(*i*) *Determine the economic order quantity and the order quantity per year.*

(*ii*) *If 100 more units are ordered over and above the economic order quantity per order, what is the difference in total annual costs?*

Solution. (*i*) Here

$$Q = \sqrt{\frac{2AP}{C}}$$

Q = Economic ordering quantity

A = 2000 units

P = Order cost per order = Rs. 5

C = Inventory carrying cost

$$= \text{Rs.} \left(2 + \frac{40}{Q}\right) \times 0.1 \text{ (given in the question)}$$

n = No. of orders placed per year

$$Q = \sqrt{\frac{2 \times 2000 \times 5}{\left(2 + \frac{40}{Q}\right)0.1}}$$

or
$$Q = \sqrt{\frac{2 \times 10^5 Q}{2Q + 40}}$$

Squaring both the sides,

$$Q^2 = \frac{2 \times 10^5 Q}{(2Q + 40)}$$

or $2Q^2 + 40Q - 2 \times 10^5 = 0$

or $Q^2 + 20Q - 10^5 = 0$

This is a quadratic equation

$\therefore$ $Q = 306.5$ or -326.5

Taking $Q = 306.5$ say 307

$\therefore$ $n = \frac{2000}{307} = 6.5$ say 7

$\therefore$ Economic ordering quantity, Q = 307 **Units Ans.**

$\therefore$ No. of units ordered 307×7 = **2149. Ans.**

(*ii*) Total annual cost in first case,

Cost of units + Procurement cost + Inventory carrying cost.

$$= 2149\left(2+\frac{40}{307}\right) + 5 \times 7 + 0.1\left(2+\frac{40}{307}\right) \times 2149$$

$$= 4578 + 35 + 457.80 = \text{Rs. } 5070.80$$

Total annual cost in 2nd case

Here $Q_1 = 307 + 100 = 407$

$n = 7$

$\therefore$ Annual demand $= 407 \times 7 = 2849$

$\therefore$ Procurement cost $= 5 \times n = 5 \times 7 = 35$

and Inventory carrying cost

$$= 0.1\left(2+\frac{40}{407}\right) \times 2849 = 597.80$$

$$\text{Cost of units} = \text{Rs. } 2849\left(2+\frac{40}{407}\right)$$

$$= \text{Rs. } 5978$$

$\therefore$ Total cost $= 5978 + 35 + 597.80$

$= \text{Rs. } 6610.80$

$\therefore$ Difference in the total annual cost

$= 6610.80 - 5070.80 = \textbf{Rs. 1540 Ans.}$

26.11. INVENTORY MODELS

The inventory models identify the relationship to quantify the order size which minimises the total cost. Before going into details of inventory models, we shall first discuss, the meaning of models.

Models

Models aim at creating a set of relationship which approximate the real world situation. These are simple from the point of view of computation and gives satisfactory results. Models are very helpful in decision-making. "Models are structures involving relationships among- concept."

Economic theory deals with the scientific approach for selecting a best alternative, and constructs a simplified model of reality on the basis of which laws describing regularities in economic behaviour are derived. A model deals with the relationship of a given dependent variable with one or more independent variables.

Examples of models are : Quantitative models, Allocation models, Queuing or waiting line models, Simulation models, Inventory models. Network or scheduling models.

Complex problems of the practical world thus can be solved by concentrating only on some key features insted of every detail. This approximation of reality, which we may construct in various forms are called as 'model'. Models exist in many forms, and the particular form selected depends upon the purpose. The decision-making through models is (*a*) economical to construct as compared to actual situation and its modification, if required, (*b*) Convenient to analyse and

experiment as compared to those with complex situations, and (*c*) decision-making with these models is quick.

Types of Models

Models are of different types, some of them are:

(*i*) Predicitive
(*ii*) Descriptive
(*iii*) Nominative
(*iv*) Inconic
(*v*) Analog
(*vi*) Symbolic
(*vii*) Deterministic
(*viii*) Probabilistic

(*i*) **Predictive Models.** This indicate that "If this occurs, then that will follow".

(*ii*) **Descriptive Models.** These provide descriptive picture of a situation and do not predict or recommend e.g. organisation chart.

(*iii*) **Nominative Models.** These provide the best answer to a problem, e.g. economic lot size model.

(*iv*) **Inconic Models.** These retain some of the physical characteristics of the things they represent, *e.g.*, Three dimension scale models.

(*v*) **Analog Model.** These employ one set of properties to represent some other set of properties which the system being studied possesses, e.g., frequency distribution charts, flow charts etc.

(*vi*) **Symoblic Model.** These use symbols to descibe the real world, e.g., quantitative models, allocation models, queuing models, inventory models, simulation models and network or scheduling models.

(*vii*) **Deterministic Models.** These determine the output (representing the solution) from a set of input values, e.g., Profit = Revenue – Costs.

(*viii*) **Probabilistic Models.** These involve probability distributions for inputs and provide a range of values of atleast one output variables with a probability associated with each value. These models assist decision-making under conditions of risk (uncertainty).

Inventory Models

Inventory models mainly deal with two decisions, namely :

1. How much to order at one time, and
2. When to order this quantity to minimise total cost.

These models are suitable both for (*a*) buying items for production purposes from outside, and (*b*) producing them with in the firm to meet the demand of customers. It is extremely difficult to formulate one common model which takes into account all variations in real systems. Even if such a model is developed, it will be difficult to solve it. Therefore, inventory models are developed for specific purposes only. Inventory models, some times known as 'Economic Ordering Quantity Models', are of following two types:

(1) Deterministic models.
(2) Probabilistic (Stochastic) models.

26.12. DETERMINISTIC MODELS (MODELS ASSUMING CERTAINTY)

These models while determining 'Economic Ordering Quantity', which some times known as 'Economic Lot Size' or 'Optimum Lot Size' make following assumptions:

(*i*) Exact demand is known for given period.

(*ii*) Demand is uniform and constant (finite) over a period of time.

(*iii*) Cost of order is same regardless of size.

(*iv*) Price of raw materials are stable.

(*v*) Holding cost is proportional to the amount of inventory as well as the time for which inventory is held. E.O.Q. models under different situations are explained hereunder :

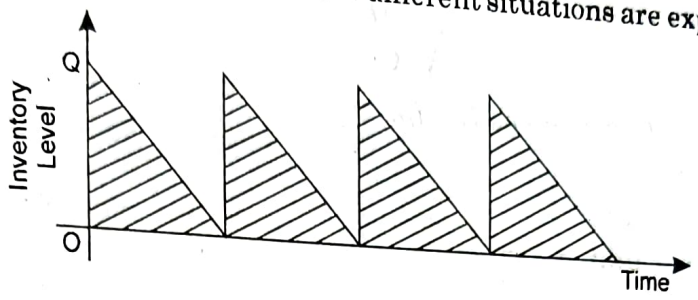

Fig. 26.4

26.13. INSTANTANEOUS REPLENISHMENT MODELS

In this situation supply is received instantaneously. All other assumptions as mentioned above hold good.

26.13.1. No Shortage Situation

In this type of instantaneous replenishment model, no shortages are allowed.

Let A = Annual consumption rate.

P = Procurement cost per order.

C = Annual Inventory carrying cost per item.

and Q = Economic ordering quantity.

Then,

Procurement cost/year = No. of orders placed in a year × Cost per order

$$= \frac{A \times P}{Q} \qquad \ldots (1)$$

and Inventory carrying cost/year

= Average value of Inventory in a year × Annual inventory carrying cost/item

$$= \frac{Q}{2} \times C \qquad \ldots (2)$$

$$\therefore \quad \text{Total cost} = \frac{A \times P}{Q} + \frac{Q \times C}{2} \qquad \ldots (3)$$

This total cost will be minimum, when

$$\frac{A \times P}{Q} = \frac{Q \times C}{2}$$

or $$Q^2 = \frac{2AP}{C}$$

or $$Q = \left(\frac{2AP}{C}\right)^{1/2}$$

Hence most economic ordering quantity

$$= \sqrt{\frac{2AP}{C}} \quad \text{... (4)}$$

Note1 : Some times, C is given as $H + ip$.

Where, H = Holding cost.

i = Interest rate.

p = price per unit of item.

Note 2 : If

L = Lead-time in days.

R = Inventory consumption rate in units per day.

$\therefore$ Reorder Point = LR.

Note 3 :

If B is the buffer stock which is required to be maintained,

$\therefore$ Reorder point = $B + LR$

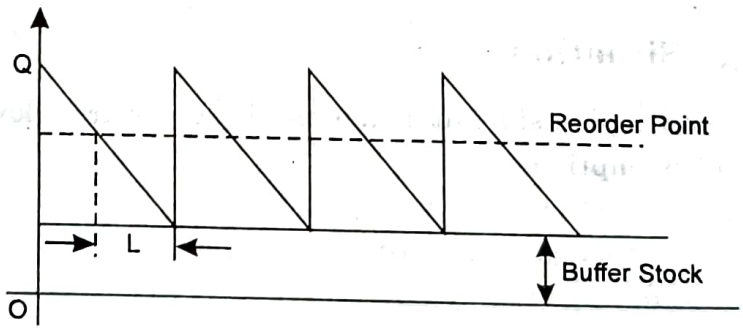

Fig. 26.5.

Example 26.7. *Calculate E.O.Q. for an item, if its annual usage rate is 600 units, procurement cost is Rs. 20 per order, cost per piece is Rs. 100, and inventory carrying cost is 10%.*

Solution. As we know that,

$$Q = \sqrt{\frac{2AP}{C}}$$

where, $A = 600$

$P = 20$

and $C = 10\%$ of $100 = 10$.

$$\therefore \quad Q = \sqrt{\frac{2 \times 600 \times 20}{10}} = 48.98$$

Since the size of order is preferred to be same, each time therefore, first we calculate the number of orders per year

$$= \frac{600}{48.98} = 12 \text{ (Say) (rounded)}$$

$$\text{Hence E.O.Q} = \frac{600}{12} = \mathbf{50} \text{ units. } \mathbf{Ans.}$$

Example 26.8. *Requirement of an item in a manufacturing concern is 250,000 per year, the price of which is Rs. 20 per thousand, the cost of holding stock is 10% per annum, and the cost of ordering is Rs. 12 per order. Determine E.O.Q.*

Solution. $\text{Since E.O.Q} = \sqrt{\frac{2AP}{C}}$

where, considering one unit of material as 1000 pieces for simplifying the calculations;

$A = 250$

$p =$ Rs. 12

$C = 10\ \%$ of $20 =$ Rs.2

$$\therefore \quad \text{E.O.Q.} = \sqrt{\frac{2 \times 250 \times 12}{2}}$$

$$= 54.77 \text{ or } 54770 \text{ items}$$

$$\text{Therefore number of orders} = \frac{250{,}000}{54770} = 4.56$$

$$= \text{Say } 5 \text{ (rounded).}$$

$$\therefore \quad \text{E.O.Q.} = \frac{250{,}000}{5} = \mathbf{50{,}000.\ Ans.}$$

Example 26.9. *A manufacturer is required to purchase 2500 pieces of an item per year. The price of each item is Rs. 10. Ordering cost is Rs. 60 and inventory carrying cost is 20% per year, find out*

(a) *What should be ordering quantity?*

(b) *Number of orders issued per year.*

(c) *Order interval, considering 300 working days in a year.*

Solution. $\text{Since E.O.Q} = \sqrt{\frac{2AP}{C}}$

where, $A = 2500$

$P =$ Rs. 60

$C = 20\ \%$ of Rs. $10 =$ Rs. 2

$$\therefore \quad \text{E.O.Q.} = \sqrt{\frac{2 \times 2500 \times 60}{2}}$$

$= 387.2$. **Ans.**

(*b*) Number of orders/year $= 2500/387.2 = 6.46$

$=$ say **6 Ans.**

(*c*) Ordering interval $= \dfrac{300}{6} =$ **50 days. Ans.**

Note : Quantity to be ordered/order $= \dfrac{2500}{6}$

$= 416.6$ or between **410 to 420** (rounded)

Example 26.10. *A manufacturing concern buys 60,000 items each year. The cost of each item is Re 1.00 and the ordering cost is Rs. 80 per-order. Holding cost per year is Re 0.20. Taxes, insurance and interest togather are charged at the rate of 15%. Determine*

(*a*) *Order quantity*

(*b*) *Number of orders placed in a year*

(*c*) *Time between orders if working days per year are 300.*

Solution. Since, $\text{E.O.Q} = \sqrt{\dfrac{2AP}{C}}$

where $A = 60{,}000$ items

$P = 80$

$C = H + ip$

$= 0.20 + .15 \times 1 = 0.35.$

$\therefore \quad \text{E.O.Q.} = \sqrt{\dfrac{2 \times 60{,}000 \times 80}{0.35}} = 5237$

In order to have full number of orders $\dfrac{60{,}000}{5237}$

$= 11.46$, i.e. 12

(*a*) Order quantity $= \dfrac{60{,}000}{12} =$ **5000 items Ans.**

(*b*) Number of orders $=$ **12 Ans.**

(*c*) Order interval $= \dfrac{300}{12} =$ **25 days Ans.**

Example 26.11. *A manufacturing concern has a demand of 10,000 pieces of a particular item. Each item costs Rs. 2, ordering % cost is Rs. 80 per order and inventory carrying cost is 25%. Past lead times are 15 days, 13 days, 25 days, 12 days and 10 days. Calculate*

(*a*) *E.O.Q.*

(*b*) *Safety stock.*

(*c*) *Normal lead-time consumption.*

(*d*) *Average inventory.*

(*e*) *Reorder level.*

Solution. As we know that,

$$\text{E.O.Q} = \sqrt{\frac{2AP}{C}}$$

Where, A = 10,000 items
P = Rs .80
$C = 0.25 \times 2 = 0.50$

(a) $\therefore$ $$\text{E.O.Q} = \sqrt{\frac{2 \times 10{,}000 \times 80}{0.50}} = 1788$$

say **2000** considering full number of orders (5) in a year **Ans.**

(b) Safety stock = (Maximum lead time – Normal lead-time) × monthly consumption.

$$\text{Normal lead–time} = \frac{15+13+25+12+10}{5} \times \frac{1}{30}$$

$$= \frac{15}{30} \text{ months.}$$

$\therefore$ $$\text{Safety stock} = \left(\frac{25}{30} - \frac{15}{30}\right) \times \frac{10{,}000}{12}$$

$$= 278$$

say = **280 to 300 units Ans.**

(c) Normal lead-time consumption

$$= \frac{15}{30} \times \frac{10{,}000}{12}$$

= **417 units Ans.**

(d) Average inventory

$$= \frac{\text{Maximum} + \text{Minimum}}{2}$$

$$= \frac{(2000+300)+300}{2}$$

= **1300** units **Ans.**

(e) Reorder level

= Normal lead time consumption + safety stock
= 417 + 300 = 717 **unit ans.**

Example 26.12. *A particular item in a factory has a demand of 10,000 units per year. Cost of one order is Rs. 150 and the holding cost is Rs. 2 per unit per year. If replacement is instantaneous and no shortages are allowed, determine :*

(a) *E.O.Q.*

(b) *Total cost per year if the cost of one unit is Re 1.*

Solution. Since,

$$\text{E.O.Q.} = \sqrt{\frac{2AP}{C}}$$

where, A = 10, 000 units/year
P = Rs. 150
C = Rs. 2 per unit per year

$$\therefore \quad \text{E.O.Q} = \sqrt{\frac{2\times 10{,}000\times 150}{2.00}}$$

$$= \textbf{1225 units Ans.}$$

Total cost per year = (cost of material consumed) + (Procurement cost + Inventory carrying cost)

$$= (10{,}000 \times 1) + \left(\frac{10{,}000}{1225}\times 150 + 2\times\frac{1225}{2}\right)$$

$$= 10{,}000 + 1225 + 1225$$

$$= \textbf{Rs. 12450. Ans.}$$

Here, Procurement cost = No of orders × ordering cost and
Inventory carrying cost = Holding cost/unit/year × Average inventory.

26.13.2. Instantaneous Replenishment Model with Shortages:

In this type of model shortages are allowed, some times the temporary stock out positions are allowed, if the customer/user is willing to wait until it is replenished. In such situations, extra expenditure is incurred on expediting and extra communication. In some cases it is economical to wait rather than keeping in stock, *e.g.*, in high value irregularly required items. The stock out situations become serious when sales are lost. Therefore, as a policy and on economical reasons management can allow shortages in limited items and for limited periods.

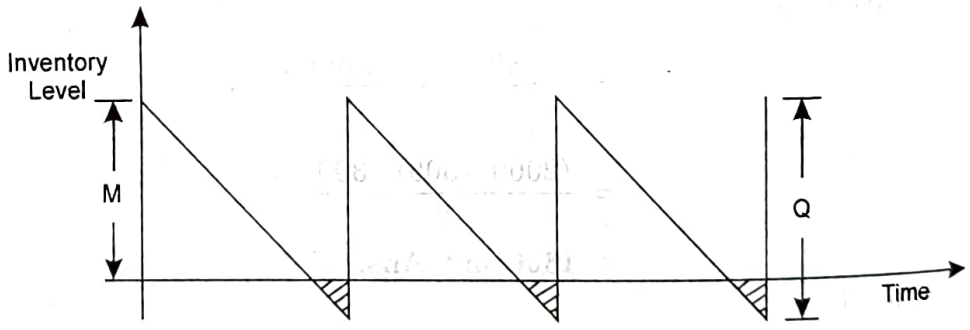

Fig. 26.6. E.O.Q model with shortage allowed.

In the cases when shortages are allowed, Economic Ordering Quantity.

$$Q = \sqrt{\frac{2AP}{C}} \times \sqrt{\frac{C+S}{S}}$$

and Maximum Inventory, $M = \dfrac{Q.S}{C+S}$

where, S = Shortage cost and M = Maximum inventory all other terms remain same.

Example 26.13. *In a factory having annual demand of 10,000 units of a particular item, ordering cost is Rs. 100 per order, cost of item is Rs. 10.00 per unit, inventory carrying cost is 15% of the cost of product for an year, and shortage cost is Rs. 20 per unit per year. Determine Economic Ordering Quantity and Maximum inventory.*

Solution. Since, Economic Ordering Quantity,

$$Q = \sqrt{\frac{2AP}{C}} \cdot \sqrt{\frac{C+S}{S}}$$

Where,

A = 10,000 units
P = Rs. 100 per order
C = 15% of 10 = Rs. 1.5.
S = Rs. 20.

$$\therefore \quad Q = \sqrt{\frac{2 \times 10000 \times 100}{1.5}} \sqrt{\frac{1.5+20}{20}}$$

$$= 1155 \times 1.037 = 1197.5$$

Say **1250** (with 8 orders per year) **Ans.**

Maximum Inventory, $M = \frac{Q.S}{C+S} = \frac{1197.5 \times 20}{1.5+20} = 1114$ Ans.

26.14. REPLENISHMENT OF STOCK WITH FINITE RATE

26.14.1. Shortages not allowed

When a particular item of supply is manufactured on order rather than purchasing them from market in lots, these models are applicable. In this case items are despatched continuously as being manufactured. Therefore, during replenishment periods, the items are received, as well as consumed, but when maximum inventory level is reached, production is stopped temporarily. This inventory is then used. Such a model is shown in Fig. 26.7. This shows that in the beginning, inventory increases at a constant rate of (K-A) during replenishment period, until it reaches maximum level. During no replenishment it decreases at a constant rate of A. In this case, Economic Ordering Quantity,

$$Q = \sqrt{\frac{2AP}{C}} \cdot \sqrt{\frac{K}{K-A}}$$

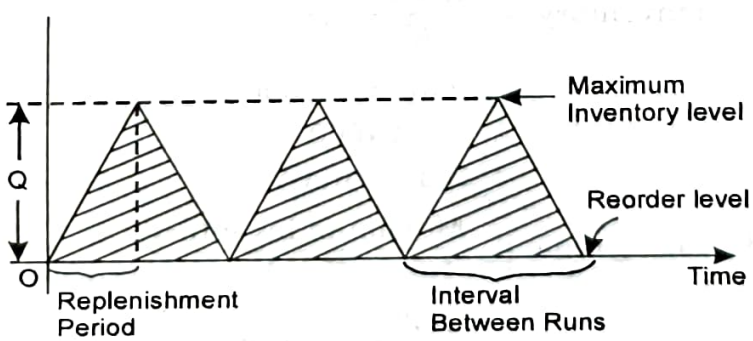

Fig . 26.7.

Where,

K = Number of items produced in a unit time.

P = Set-up cost per run.

Rest all other abbreviations remain same.

Example 26.14. *A manufacturing company has a demand of 12000 units of a particular item in a year, and can manufacture this item at the rate of 2000 units per month. If cost of each set-up is Rs. 400, holding cost per unit per month is Re. 0.15. Determine*

(*a*) *Optimum lot size*

(*b*) Total cost per year, assuming cost of each unit as Rs. 4.

(*c*) *Maximum inventory*

(*d*) Manufacturing time

(*e*) Number of cycles in a year

(*f*) *Total cycle time*

Solution, (*a*) Since,

$$E.O.Q.Q = \sqrt{\frac{2AP}{C}} \cdot \sqrt{\frac{K}{K-A}}$$

where,

A = 12000 units per year

P = Rs. 400/set up

$C = 0.15 \times 12$ = Re. 1.8/ unit/year.

$K = 2000 \times 12 = 24000$ unit/year.

$$\therefore \quad Q = \sqrt{\frac{2 \times 12000 \times 400}{1.8}} \cdot \sqrt{\frac{24000}{24000 - 12000}}$$

$$= \textbf{3265 units Ans.}$$

(*b*) Since, Total cost per year = cost of items consumed + cost of set up/year+ inventory carrying cost.

For Optimum value of Q,

$$\text{Set up cost/year} = \text{Inventory carrying cost.}$$

$$\therefore \quad \text{Total cost} = 12000 \times 4 + 2 \times \frac{12000}{3265} \times 400$$

$$= 48000 + 2940 = \textbf{Rs. 50940 per year Ans.}$$

(*c*) $$\text{Maximum inventory} = \frac{K-A}{K} \times Q$$

$$= \frac{24000 - 12000}{24000} \times 3265$$

$$= \textbf{1632 Units Ans.}$$

(*d*) $$\text{Manufacturing time} = \frac{\text{Maximum inventory}}{K-A}$$

$$= \frac{1632}{12000} = \textbf{0.136 year Ans.}$$

(e) Number of cycles/year

$$= \frac{12000}{3265} = 3.675 \text{ Ans.}$$

(f) Total cycle time

$$= \frac{1}{3.675} = 0.272 \text{ year Ans.}$$

26.14.2. Replenishment of stock with finite rate–shortages allowed:

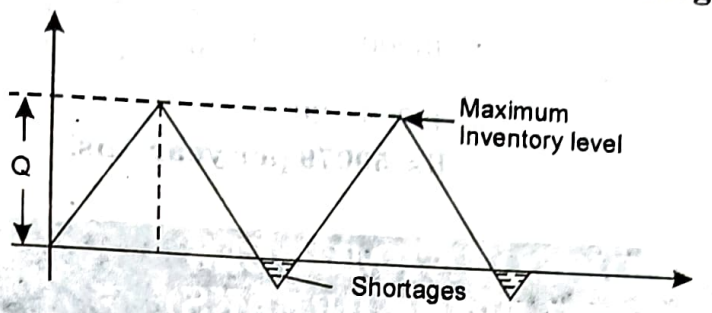

Fig. 26.8

Similar to previous model replenishment is done at finite rate in this model, except that in this model shortages are also permitted. In this model, Economic Ordering Quantity,

$$Q = \sqrt{\frac{2AP}{C}} \sqrt{\frac{K}{K-A}} \cdot \sqrt{\frac{C+S}{S}}$$

with abreviations as mentioned in earlier formulae.

Example 26.15. *Let us take data of example 26.14, except that shortage cost of one unit is Rs. 25 per year.*

Solution.

(a) Since, economic ordering quantity

$$Q = \sqrt{\frac{2AP}{C}} \cdot \sqrt{\frac{K}{K-A}} \sqrt{\frac{C+S}{S}}$$

$$= \sqrt{\frac{2 \times 12000 \times 400}{1.8}} \times \sqrt{\frac{24000}{24000 - 12000}} \times \sqrt{\frac{1.8+25}{25}}$$

$$= \mathbf{3880 \text{ units Ans.}}$$

(b) Maximum Inventory

$$= \sqrt{\frac{2 \times 12000 \times 400}{1.8}} \times \sqrt{\frac{12000}{24000}} \times \sqrt{\frac{25}{26.8}}$$

$$= \mathbf{1577 \text{ units Ans.}}$$

(c) Manufacturing time $= \frac{3380}{24000} = \mathbf{0.1408 \text{ year Ans.}}$

(*d*) Number of Cycles in a year $= \dfrac{12000}{3380}$

$= \mathbf{3.55\ Ans.}$

(*e*) Total cycle time $= \dfrac{1}{3.55} = \mathbf{0.2817\ year\ Ans.}$

(*f*) Total cost per year $= 12000 \times 4 + 2 \times \dfrac{12000}{3380} \times 400 \times \sqrt{\dfrac{K-A}{K}} \cdot \sqrt{\dfrac{C+S}{S}}$

$= 48000 + 2840 \times \dfrac{1}{2} \cdot \sqrt{\dfrac{1}{2}} \times \sqrt{\dfrac{26.8}{25}}$

$= 48000 + 2079$

$= \mathbf{Rs.\ 50079\ per\ year\ Ans.}$

26.15. QUANTITY DISCOUNT MODELS (MODELS WITH PRICE BREAKS)

In the inventory models described so far, production or purchase cost per unit was assumed as constant. Some times the cost depends upon the quantity manufactured or purchased. Usually suppliers offer discount for the purchase of large quantities. This price discount factor is being considered in this model.

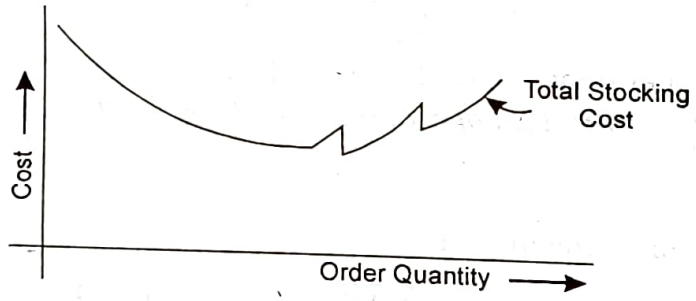

Fig. 26.9.

In these models, quantities are calculated considering the normal model, then it is confirmed whether it is really optimum. This process starts with the maximum discounted price. This will be clear from the following example :

Example 26.16. *A manufacturing concern consumes 200 items per month working for 30 days in a month. The cost of item is Rs. 1000. For a lot of more than 50, the price is Rs. 950. Find out optimum purchase quantity, if ordering cost is Rs. 10,000 and handling charges are 1% of unit cost/month.*

Solution. As a first step, let us calculate quantity considering rate of Rs. 950.

$$Q = \sqrt{\frac{2AP}{C}}$$

$$= \sqrt{\frac{2 \times 200 \times 10,000}{950 \times 1}}$$

(*d*) Number of Cycles in a year $= \frac{12000}{3380}$

$= 3.55$ **Ans.**

(*e*) Total cycle time $= \frac{1}{3.55} = 0.2817$ **year Ans.**

(*f*) Total cost per year $= 12000 \times 4 + 2 \times \frac{12000}{3380} \times 400 \times \sqrt{\frac{K-A}{K}} \cdot \sqrt{\frac{C+S}{S}}$

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$= 48000 + 2079$

$=$ **Rs. 50079 per year Ans.**

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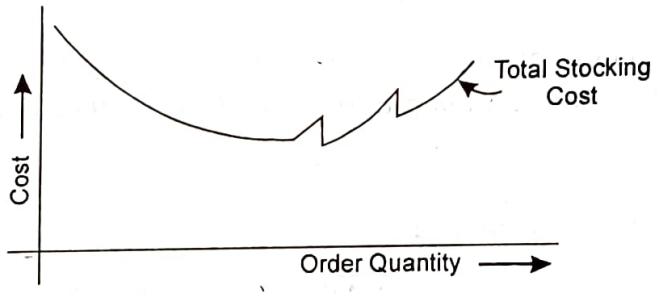

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Solution. As a first step, let us calculate quantity considering rate of Rs. 950.

$$Q = \sqrt{\frac{2AP}{C}}$$

$$= \sqrt{\frac{2 \times 200 \times 10,000}{950 \times 1}}$$

$= 64.9 = 65$ **say.**

Since for 65 items the price is least, hence this is optimal quantity $\therefore$ **E.O.Q. = 65 Ans.**

QUESTIONS

1. What is A-B-C control policy? Describe it in detail.
2. What is material handling? Suggest some steps to reduce the material handling cost.
3. Describe the procedure for disposing the surplus and obsolete items.
4. What is Inventory control? Explain its importance in an industrial undertaking.
5. Describe various functons of Inventory control.
6. What are the quantity standards and how they can be used as a tool to Inventory control?
7. What is the purpose of stock-taking? How stock taking of a large concern is done?
8. Discuss any difference in inventory planning for jobing and mass production industries.
9. Explain how the standard order quantity is determined and point out how it helps in inventory control?
10. Write short notes on :
    (*i*) Economic lot size,
    (*ii*) *ABC* analysis in inventory control and
    (*iii*) Perpetual inventory control.
11. Describe briefly the different elements of inventory carrying costs.
12. The rate of use of a particular raw material from stores is 20 units per year. The cost of placing and receiving an order is Rs. 40. The cost of each unit is Rs. 100. The cost of carrying inventory in per cent per year in 0.16 and it depends upon the average stock. Determine the economic order quantity. If the lead time is 3 months, calculate the reorder point. [10.5 units]
13. Find economic order quantity from the following data :

    Average annual demand = 30,000
    Inventory carrying cost = 12% of the unit value per year 7.
    Cost of placing an order = Rs. 70
    Cost/unit = Rs.2 [4, 834,500 (Rounded of)]
14. A factory uses two pieces per of a rod 6 mm dia and 150 mm length in one of their manufacturing processes. The rod costs Rs. 3 each and the total expenses involved in purchasing and receiving them are Rs. 50 per order. The annual inventory carrying cost per item is Re. 1. The procurement period is 3 days and minimum stock kept is 8 pieces. Find out:
    (*i*) Standard ordering quantity
    (*ii*) Reorder point and
    (*iii*) Maximum stock [(*i*) 245, 200, (*ii*) 14, (*iii*) 280]
15. Determine the economic order quantity from the following data :

    Average annual demand = 10,000 units.
    Inventory carrying cost = 20% per rupee value/year
    Cost of placing order = Rs. 100
    Cost per unit = Rs. 5

Determine the most economical lot size for the following conditions :

Fixed cost per lot = Rs. 75

Various costs per unit = Rs. 0.25

Peicentage charge for interest, taxes, insurance and storage etc. 40%

Production rate = 80,000 units/year.

Demand rate = 15,000 units/year.

16. (a) What are the four basic components of the inventory system? Discuss the significance of each component.
    (b) In what ways can inventories serve to reduce the cost and to increase the cost?
    (c) Determine the economic order quantity for a prouct whose average daily consumption rate is 8 units. The cost of each unit is Rs. 0.50 and the inventory carrying charge is Rs. 0.20. The cost of placing and receiving the order is Rs. 10.00. Assuming total working days in year as 300, obtain the annual inventory capital also.
17. Machine parts are produced at the rate of 200 units per day. The cost of each unit is Rs. 15 and the storage cost Re 0.0005 per unit per day. If preparation and set up cost is Rs. 500 for the production run and assembly by using 50 units per day, determine the minimum cost, batch size and length of production run assuming 10% interest charges and 300 days per year.
18. Deduce an expression for 'economic order quantity' assuming that the cost of managing inventory is composed of two parts (*i*) ordering cost and (*ii*) carrying cost. The rate of use of a particular raw material from stores is 20 units per year. The cost of placing and receiving an order is Rs. 4000. The cost of each unit is Rs. 100.00. The cost of carrying inventory in percent per year is 0.16 and it depends on the average stock. Determine the Economic Order Quantity. If the lead time is 3 months, calculate the order point.
19. What functions do inventories serve in a manufacturing concern? Discuss both the advantages and disadvantages.
20. "Inventories are necessary evil." What is your view? Discuss.
21. How will you classify different types of inventories?
22. Explain what is meant by the terms (*a*) "inventory carrying costs" and (*b*) "inventory acquisition cost"?
23. List and discuss the main limitations of E.O.Q theory.
24. Write down symptoms of poor inventory management.
25. What are the quantity standards, and how they can be used as a tool to inventory control.
26. Explain how the standard order quantity is determined, and point out how it helps in inventory control?
27. What is inventory built-up? How it can be avoided? How codification help in reducing inventory build-up?
28. What do you understand by a model? Name various types of models. Explain how deterministic type of models are used in inventory control?
29. Explain the following terms relating to materials, and state on what basis they are fixed?
    (*a*) Minimum stock level.
    (*b*) Maximum stock level.
    (*c*) Reorder level
    (*d*) Buffer stock
    (*e*) Lead-time