Planning of Ordering Policy for Logistics Department of a Barge Mounted Power Plant.

By

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Declaration

This is to certify that the thesis work entitled " Planning of Ordering Policy for Logistics Department" has been carried out by Bhola Nath Roy in the Department of Industrial Engineering and Management, Khulna University of Engineering & Technology, Khulna, Bangladesh. The above research work or any part of the work has not been submitted anywhere for the award of any degree or diploma.

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Abstract

Today, material management has gained acceptance in all developing economies. As material is nothing but money in the form of goods, each industry uses materials for its smooth running. A Power Plant is a public-interest company. Electricity plays a very important role in regulating modern life. Therefore, any interruption in the supply of this vital item of energy puts the whole system out of gear and paralyses our life. It uses various types of materials for smooth running. Raw materials and consumables are being converted into work-in-progress and finally produce electricity for national grid. Spare parts and components are utilized for the smooth functioning of the production machineries. This necessitates the involvement of the finance executives with the policy-making of the materials function. So, an appropriate management system of spare parts for schedule maintenances is developed in this research.

This research work is an outcome of scientific spare parts management policy required for schedule maintenance of a Barge Mounted Power Plant, Bangladesh. The materials department accounts for over 60 percent of the cash outflows and 90 percent of working capital in the Plant [4]. The Logistics Department is responsible for managing all types of materials in the Plant. The functions of procurement, materials management, business logistics, inventory control and warehousing are being carried out in the Plant under the scope of integrated materials management. The Plant follows various procedures to manage its materials. But the management does not follow any analytical procedure in setting up reorder points. As a result, the Plant faces over-stocking of spare parts in the warehouse. This situation acts as a catalyst to increase the total expenditure of the Plant. By applying scientific materials management method it has been calculated reorder points, safety stock and order quantity of spare parts of schedule maintenance which eventually reduced overstocking as well as overall cost.

The Plant gets an idea of annual power demand from BPDP. Based on BPDP's power demand, Operation department determines annual plant factor and Maintenance department makes annual maintenance schedule depending on plant factor. Logistics converts number of schedule maintenance into annual spare parts demand and review period spare parts demand and places orders accordingly. The strategy of logistics department is to review the inventory position in the first week of every month (i.e. review period R=one month=30 days) and places order of those items which are at or below the reorder point depending on the demand of planning period (lead time + review period). If the position is above reorder point, nothing is done until the next review period. So, the Plant more or less follows (R,s,S - Periodic-review, recorder point, order-up-to-level) system. Theoretically, (R,s,S) system is appropriate when tight control is necessary, e.g. for class A items. Reorder point is the base-stock of the system. Relying on a reorder point replenishment actions are taken. But the Plant uses the (R,s,S) system for all type of spare parts to show a high degree of responsiveness to meet demand rate. Reorder point answers the question when to order in the system. Applying (R,s,S) system actual reorder points, safety stock and ordered quantity of schedule maintenance parts are determined in this thesis (chapter 4).

Lead time is an important factor in placing an order. The order quantity depends on lead time. The Plant's calculated lead time is 90 days (chapter 3) and review period is 30 days. So, the Plant can place maximum three orders in a year. For lengthy lead time, it has to place order of large quantity. In the obtained data of previous year, it has been observed that the Plant's tendency is to bring yearly demand by placing two or a single order. In this research work, it has been shown that three orders can meet yearly variable demand easily. It reduces holding cost but increases ordering cost in the Plant. As ordering cost mostly depends on the salary of the employee of the purchase department, so ordering cost per order is almost constant in the Plant. If for a given period actual demand is less than expected, extra inventory is left over, which increases the holding cost. Therefore, there is no reason in decreasing ordering cost. The calculated holding cost in the Plant is 66% of unit value of an item and ordering cost is $25/order/item (chapter 3). Holding cost plays a vital role in increasing or decreasing of total incremental cost. The objective of this research was to reach a balance between the extra holding cost and the ordering cost.

In the obtained data, it is observed that 122 (one hundred twenty two) items are required to execute all schedule maintenances. ABC classification has been carried out in this research to find out key components (chapter 3). Out of 122 (one hundred twenty two) items only 14(fourteen) items are graded as class A items. But all items are equally important from maintenance point of view. With shortage of any item the maintenance task cannot be done successfully. So, from maintenance point of view all 122 (one hundred twenty two) items are regarded critical. In the thesis work, annual demand, lead time demand and review period demand of various spare parts required for schedule maintenance are determined based on maintenance schedules to be carried out in whole year. Demand is the output of inventory control system. So it is more emphasized on demand calculation. After demand calculation, reorder point, safety stock and ordering quantities have been analytically calculated.

Calculated total incremental cost is compared with the data of previous year (chapter 4), it is found that most of the low valued (class C) items are having lower holding cost than ordering cost. So, total incremental cost of these items becomes lower. Again, there is no benefit in decreasing ordering cost for C class items in the Plant. On the contrary, reducing holding cost, it is shown in this research that the total incremental cost of 2006 is 1.70% lower than previous year after covering extra 5% plant factor and more 19 schedule maintenance (in 2006 plant factor was 75% with 222 maintenance and in 2005 plant factor was 70% with 203 maintenance) of which (19 maintenance) total incremental cost is USD 21,938.08. If this value is deducted from existing figure then it becomes 10.12% lower in comparison with previous year. Total inventory cost is not compared because it is largely influenced by purchase cost.

The Materials Requirement Planning (MRP) may act as a bridge between Logistics and Maintenance department. But, the Plant does not maintain MRP. As a result, it has to face communication gap among the departments. MRP of 1500hrs. maintenance is shown in this research as a sample.

All the data available in the Plant are deterministic. It may change due to the change of power demand of BPDP.

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Nomenclature

HR	Running hour
Maint.	Maintenance
C_H	Holding cost
C_R	Ordering cost
C_B	Purchase cost
D	Annual demand
L	Lead time
R	Review period
$\bar{D}$	Average demand during (L+R/2) interval
D_m	Maximum demand during (L+R/2) interval
$\bar{x}$	Average lead time demand
ss	Safety stock
s	Reorder point
Q	Order quantity
Q_1	First time order quantity
Q_2	Second time order quantity
Q_3	Third time order quantity
S	Maximum desired inventory

CHAPTER 1

Introduction

1.1 General

Manufacturing as well as service industries hold inventories. In any organization, a large number of departments strive to attain the organizational final objectives. All these departments have various duties and responsibilities. Within the materials department, the manager must ensure smooth cooperation between the functions of purchasing, stores, inventory control, information flow, transportation etc. The material / logistics manager exists in the organization to serve the user and must have maximum interaction with the production executives for prompt supply of quality materials. Internally, almost everyone in the organization is interested in the materials functions while suppliers, bankers, carriers, insurers and customers are the external agencies interested in the company's materials management. The finance department wants the releasing of funds or working capital commitment to be minimum, while the customer complains about the non-availability of the items. The banker is interested in the inventory as the company's inventory has been mortgaged to the commercial bank. The supplier is interested in supplying more items, the transporter desires a full wagon load, Government department like imports, sales tax, excise and customs are interested in the accuracy of figures to collect taxes.

Under the integrated materials management, the material manager can control the materials significantly and can increase profitability and hence improve return on investment. The integrated materials management, which is conceived as a comprehensive supply system, can substantially contribute to company's profit, through its systematic influence on materials cost and overhead expenses. In most of the industries, the incoming materials cost including fuel and utilities constitute over 60% cost of the final product [4]. Reducing the materials cost through proper management can increase the profitability. There is a Japanese slogan – "we live by sales, but make our profit from materials." The major objective of an organization is to improve the return on investment. The return on investment can be increased by decreasing the working capital, bulk of which is in the form of inventory. Some research has shown that in more than 90% of the cases, improved materials management would lead to cost savings of at least 20% without sacrificing customer service [1].

The materials management, in fact, deals with the design of an entire system consisting of ordering functions, warehousing systems and the servicing of customer demand.

1.2 Introduction of the Barge Mounted Power Plant

The Power Plant is owned by Global Power Company Ltd., a private sector power company. The Power Plant is located near the port city Narayangonj, Bangladesh. The Power Plant is situated on the bank of the Shitalakhya river and is near to the Siddirgonj power station.

The Barge Mounted Power Plant utilizes Wartsila model 18V46 duel-fuel engines as a prime mover. These engines are capable of burning both liquid and gaseous fuels and are equipped with Wartsila latest low nitrogen oxides (No_x) combustion control technology. The power barge Tiger-I and Tiger-III consist of 19 engines capable of producing 120 MW of electricity when operating with heavy fuel oil (HFO). The engines are installed on two floating power barges, with nine engines installed on one barge, ten on the other. Each barge is 91.5 meter long and 24 meter wide. The barges are moored in the pool (a small body of still water) and edges are secured with steel sheet piles. The level of the pool is controlled by means of electric pump. The land area is protected with high solid wall equipped with barbed wire on the top. Store, Administration building, Maintenance facilities, Bunker storage tanks and cooling water pump building are installed inside the boundary. The engines are water-cooled using a single pass system. Raw cooling water is drawn from the river and filtered to reduce the concentration of fine silt particles. Biological fouling within the system is controlled by using a copper ion anti-fouling system. No significant amounts of chemicals are added to the water that will be discharged from the barges. Main fuel storage tanks are located at the shore. Day tanks are located at barges where liquid fuel is stored. There are plenty of trees and flowers around the site area. The Power Plant is generating electricity for the national grid. The Plant sells it's generated power to Bangladesh Power Development Board (BPDP) under power purchase agreement. Wartsila Bangladesh Limited operates this Plant under Operation and Maintenance (O & M) agreement with the owner. Wartsila Bangladesh Limited is a subsidiary of Wartsila Finland Oy.

The Company under its social goodwill programs provides school bus, computer and educational aids to different educational institutions, ambulance, hospital equipment and financial grants to different charitable organizations and hospitals to render improved medical care to the local people.

As corporate philosophy and commitment, the company attaches highest attention to the environmental quality of the area. The Plant operation has achieved highest degree of environmental awareness and as recognition LRQA (Lloyd's Register Quality Assurance) of UK awarded to the Plant operators with ISO 14001.

1.3 Materials Management system of the Plant

The Plant uses various types of materials for smooth running of engines. Material are purchased and stocked for future use. Logistics department is responsible for Plant's materials management. Materials Management in the Plant is maintained and controlled by MAMA (Maintenance Management) software. Materials management starts before receiving an item in the warehouse. Materials management includes purchasing, arrangement for storage, generating reorder point report, creating purchase orders, receiving & inspection of items, codification and allocation of location, items checked-out and return, physical counting and generation of inventory reports. The Logistics Manager gets an idea of material requirements from the concern department. On the basis of this requirements, further actions are taken. The major logistics functions are Purchasing and Warehousing.

1.3.1 MAMA (Maintenance Management)

It is a computerized maintenance management system software application invented by Datastream System Inc., 50 Datastream Plaza, Greenville, SC 29605, USA. It is designed to control maintenance operations. With MAMA, one can do the following functions-

Labour: Track the number of labour hours and the cost of labour for each maintenance task in two ways- by craft or by employee of its own. Keep tracking of employee attendance exceptions like overtime, vacation, employee training and skill levels.

Equipment: Create records of equipments for each of the facility so that one may keep track of equipment maintenance and cost.

Task: Schedule tasks (by meter or by date) that the facility perform repeatedly, and MAMA automatically generates work orders for due tasks.

Work orders: Create work orders for unscheduled works, or generate work orders for due tasks. One may print work orders for reference while completing the work and also specify parts and labour used for the works.

Inventory: Create inventory records for all parts used for maintaining the equipment. Store parts at multiple locations and check out parts to employees, equipment, work order, cost center and location.

Purchasing: Create quotation to request items price from vendors, and then generate purchase orders from selected quotations or from items in inventory which have reached their reorder points. Receive ordered items to stock.

Reports and Graphs: Prints reports and graphs to view and compare maintenance information. One can select records and fields to print reports, customize the format and lay out of reports and graphs.

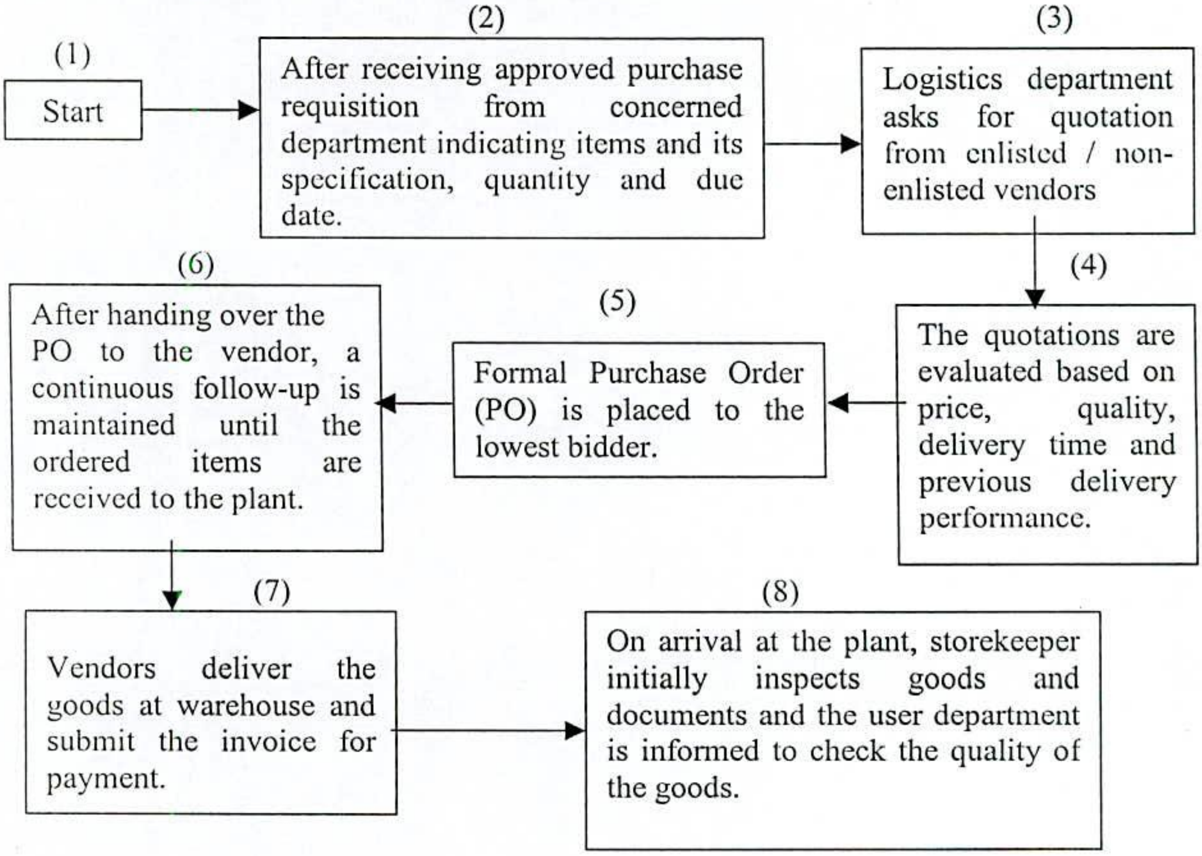
MAMA stores all maintenance information in a database, a collection of related information stored in tabular forms. Each table contains records, which consists of fields containing individual information of items. The equipment data is in one table, the inventory data is in second table and the due date in a third table. Within a work order table, each work order is a record. The work order record consists of a work order number in one field, an equipment number in a second field and the due date in a third field. One who has access permission can access the database at any time, and can add, change or delete information in any record in the table.

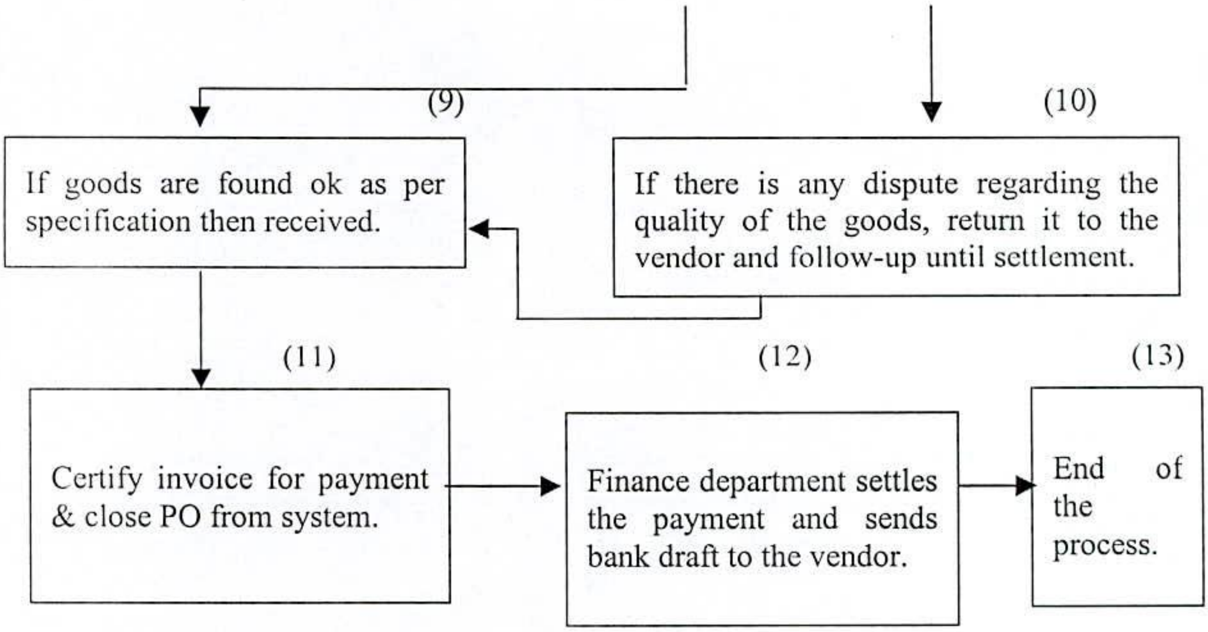
1.3.2 Purchasing

The Plant purchases its needed materials from local and foreign sources. Materials that are purchased from local market are known as local purchase and materials that are purchased from abroad are known as foreign purchase.

1.3.2.1 Local purchase

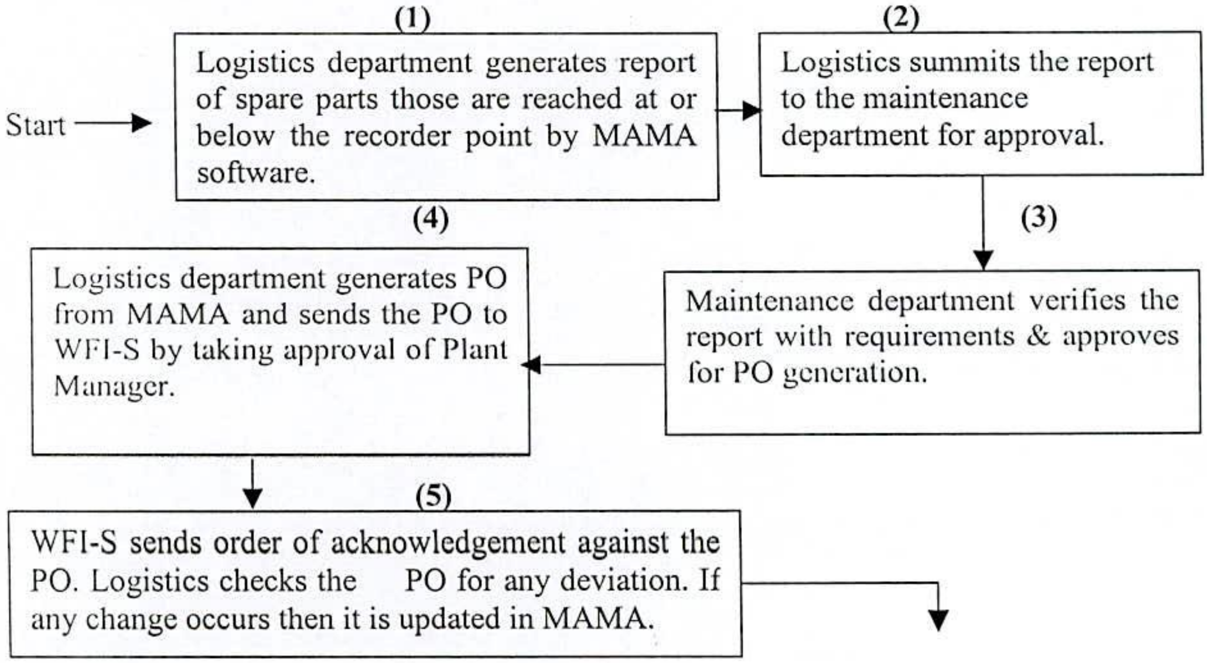
The local purchase of materials is done according to the following flow chart.

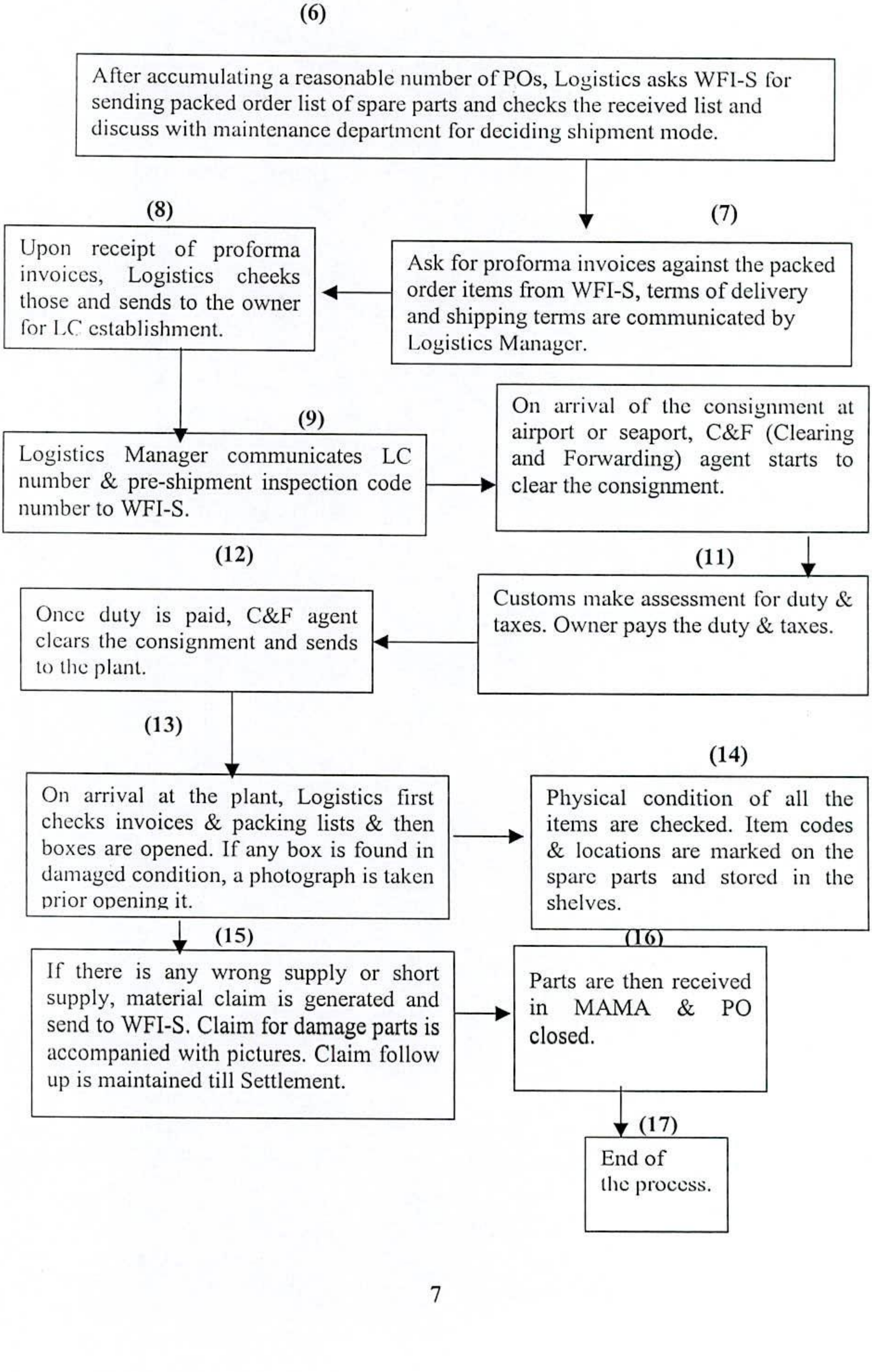




1.3.2.2 Foreign Purchase

The Plant procures spare parts only from abroad. Wartsila Finland Oy supplies spare parts of the Power Plant under Operation & Maintenance (O&M) agreement. Under the scope of this agreement the Plant places order for all types of spare parts to Wartsila Finland service (WFI-S). The owner pays local customs and other applicable taxes. The flow chart below indicates spare parts procurement process.




(6)
After accumulating a reasonable number of POs, Logistics asks WFI-S for sending packed order list of spare parts and checks the received list and discuss with maintenance department for deciding shipment mode.
(7)
Ask for proforma invoices against the packed order items from WFI-S, terms of delivery and shipping terms are communicated by Logistics Manager.
(8)
Upon receipt of proforma invoices, Logistics cheeks those and sends to the owner for LC establishment.
(9)
Logistics Manager communicates LC number & pre-shipment inspection code number to WFI-S.
On arrival of the consignment at airport or seaport, C&F (Clearing and Forwarding) agent starts to clear the consignment.
(11)
Customs make assessment for duty & taxes. Owner pays the duty & taxes.
(12)
Once duty is paid, C&F agent clears the consignment and sends to the plant.
(13)
On arrival at the plant, Logistics first checks invoices & packing lists & then boxes are opened. If any box is found in damaged condition, a photograph is taken prior opening it.
(14)
Physical condition of all the items are checked. Item codes & locations are marked on the spare parts and stored in the shelves.
(15)
If there is any wrong supply or short supply, material claim is generated and send to WFI-S. Claim for damage parts is accompanied with pictures. Claim follow up is maintained till Settlement.
(16)
Parts are then received in MAMA & PO closed.
(17)
End of the process.

1.3.3 Operation and Maintenance Agreement Regarding Spare Parts

The owner has an agreement with Wartsila Finland Oy. Under the scope of this agreement Wartsila Bangladesh Limited operates the Plant and Wartsila Finland Service (a sister concern of Wartsila Finland Oy) provides all required supports and spare parts.

The terms and conditions of spare parts supply are as follows:

(1) The Plant shall not make or collect any spare parts internally from any other sources.

(2) The Wartsila Finland Service shall supply all spare parts.

(3) No discounts in either the unit purchase cost or the unit transportation cost shall be given.

(4) Shortages are not allowed.

(5) The entire order quantity of an order shall be delivered in a single consignment.

1.3.4 Warehousing

Warehousing is a part of materials management, which includes codification and allocation of locations, checked-out and return, receiving, inspection and physical counting.

1.3.4.1 Codification and allocation of locations

Prior to ordering of an item a unique code is given to it. For engine part it is same as Wartsila's code. For auxiliary parts the first two/three letter designates the manufacturers name than the numerical serial numbers. Example, say the item belongs to Alfa Laval, than the code is AL-001, if it is Asia Brown Broveri, than ABB-001, so on.

Location of the items are arranged in a unique way. Engine parts, auxiliary parts, electrical parts, gaskets, o-rings, filters etc. are arranged separately. Relatively heavier parts are kept in the lower compartment of the shelves. Chemicals are stored in a separate store.

1.3.4.2 Receiving and Inspection

Spare parts are received as per invoice and packing list and compared with the orders, prior to opening, if a package is found in broken or in damaged condition a photograph is taken for future reference. If any spare is found defective or damaged or short supply, a formal material claim is made. A good inspected report is certified during inspection and receiving of spare parts.

1.3.4.3 Checked-out and return

Each and every item from the warehouse is checked out against valid materials requisition form. Once the item is issued then it is being checked out from the system. Spare parts or materials that are not used on a job but withdrawn from warehouse by material requisition form are to be returned to the warehouse by filling the material return form. Returned items are updated in the system.

1.3.4.4 Physical counting

Quarterly physical counting of all items in the warehouse is carried out to minimize difference between quantity in the shelves and that are in the system. In physical counting if there is any deviation between records & shelf quantity that is adjusted in the stock with remarks.

1.4 Drawbacks of existing Plant's materials management system

Materials enter into the Plant as raw materials, components, spare parts, or as consumable items. Raw materials and consumables are get converted into work-in- progress and finally produce electricity for national grid. Spare parts and components are utilized for the smooth functioning of the production machineries. The budgeting figure against the Plant's spare parts for the year 2006 was 2.5 million dollar which was 80 percent of total maintenance budget [Ref. Finance Manager]. It can be seen that if the materials cost is reduced by 5 percent of the existing figure using scientific materials management techniques, then the new materials cost would become 2.475 million dollar which will save 125 thousand dollars with other things remaining the same.

The Plant follows many procedures to manage its materials. In the preliminary studies, it seems that the management does not follow analytical procedure in setting reorder points. As a result, sometimes the Plant faces shortages or over stocking of spare parts in the warehouse. Both the situations act as a catalyst to increase the total expenditure of the

Plant. Therefore, there is a room for improvement in setting up reorder points of spare parts that will eventually lead overall cost reduction.

1.5 Objectives

The identified objectives are mentioned below-

(1) Setting up reorder points of spare parts by analytical procedure: As reorder point is the base of ordering of an item, so, it's selection should be based on scientific methods. Without proper selection of reorder point, it is not possible to order an item at the right time, right quantity or maintain the stock level for satisfying user/customer demands.

(2) Determining the ordering interval: Order is to be placed considering the planning period demand (lead time demand plus review period demand). If order is not placed timely than it will delay the availability of stock in the warehouse and will hamper maintenance schedule.

(3) Determination of ordering quantity: It is evident that the more the lead time the higher will be the stock level which increases holding cost. So, proper ordering quantity should be determined for satisfying spare parts requirement for schedule maintenance.

(4) An MRP (Material Requirements Planning) schedule for selected spare parts will be developed.

(6) At last but not the least recommendations will be made for the management for smooth functioning of spare parts.

CHAPTER 2

Theoretical Consideration

Some theoretical terms are closely related in spare parts management system in the Plant. These terms are brought in light before analytical calculation.

2.1 Plant Factor

The amount of energy that have been generated in a time period in comparison to how much could have been generated.

$$\text{Plant Factor} = \frac{\text{MWh produced in time period}}{\text{Site output x Running hrs in time period}}$$

Plant factor is the Plant's output and all efforts are taken to comply the budgeted plant factor. To meet the plant factor proper maintenances are done to keep the engines in running condition.

2.2 Maintenance

The purpose of maintenance is to ensure the trouble free and economical service of the equipment in the Plant. Maintenance causes costs, as it needs manpower and spare parts to carry out. It has to be considered on one hand how often and how thoroughly should the maintenance be carried out. On the other hand which kind of risks will be taken in case some of the measures were postponed or not carried out at all is also to be decided. There are two types of maintenance such as schedule maintenance and unscheduled maintenance.

2.2.1 Schedule Maintenance

The common category of spare parts, used for repetitive routine maintenance purpose is called the schedule maintenance. It is possible to collect the failure data over a period of time. The Plant plans maintenance schedules on the basis of running records obtained from the engine under normal operation. Such operating data may be:

- Exhaust gas temperature
- Maximum firing pressures.
- Turbocharger speed.
- Charged air cooler pressure and temperature.
- Fuel rack position of injection pumps.
- Pressure drop over charged air cooler.
- Pressure in the crankcase.

The information given by these data is valuable and gives a good picture of the engine condition, provided that they really are needed for maintenance.

Maintenance strategies of the Power Plant: The Power Plant, like in most other companies implements three levels responsibility in the maintenance:

- The strategic level, setting the targets of maintenance for a considerable length of time. Important decisions regarding the resources, methods and goals of the plant are done at this level.
- The Tactical level, which should be able to carry out plans according to target set and in this process use information gained from the operative level.
- The Operative level, which should have the skills and instructions to carry out the daily tasks in the Plant.

2.2.2 Unscheduled Maintenance

It is difficult to forecast failure but every failure needs not require replacement. Under this maintenance, it is difficult to generate exact consumption data and procure the spare parts. The failure of maintenance spares is similar to the mortality rate of human beings. During infancy, the mortality rate is high, during adolescence and middle age, the rate is low, but during old age the mortality rate increases. A similar phenomenon is also observed in the case of spare parts with increased failure rate due to wear and tear. By better scientific management techniques like condition monitoring, the Maintenance Engineer can increase the life of engines in the third phase.

2.3 Spare Parts

Spare parts are defined as a part, identical to the part of the machinery, which needs replacement due to wear and tear as the life of the part is less than the operating life of the equipment. These are idle resources stocked for future use. It has been considered as important, to a power plant, as the blood of human body. Some times the engine is out of service until spare parts have been supplied from service station or from the manufacturer. The engine manufacturer is often asked to give a recommendation for spare parts, which should be kept on stock in a power plant. The stock of spare parts depends on costs associated with it, lead time, safety stock, reorder point and management policy.

2.3.1 Different types of stocks

On-hand stock: This is stock that is physically on the shelf. It can never be negative.

Net stock: It is on hand stock minus on order stock. It can be negative.

On order stock: This is ordered but not yet received at the site. It is also called pipeline stock.

2.3.2 Ordering cost or set up cost of an item

The cost per order is known as ordering cost and is determined by considering only the incremental or variable costs of placing an order or setting up equipment and it is almost related to the overhead cost of the purchasing department. It generally includes:

- Cost of order generation
- Postage (Negligible when order is sent through web site)
- Telephone calls / E-mail cost
- Documentation cost (follow – up cost)
- Inspection cost
- Handling cost of vendor invoices etc.

All these cost are mainly treated as salary of staff engaged for procurement.

2.3.3 Purchase cost

It is simply the price (including freight paid) of an item. If the price per unit is the same regardless of the size of the order (Q), the purchase cost becomes

$$C_B = b.D \quad [3]$$

D= demand per unit time.
b=price per unit.

However, some suppliers offer discounts for large order to encourage their customers to buy in greater amounts. Here, the price depends on the lot size and hence the purchase cost now is variable and depends on the inventory decision of how much to order. Thus-

$$C_B = b(Q).D$$

b=price per unit when lot size Q.

2.3.4 Holding cost of an item in inventory

This cost is incurred to maintain surplus inventory is the sum of a variety of costs, i.e. cost of capital tied up, storage or warehouse cost, depreciation or deterioration, insurance, handling, taxes etc. [3] and expressed as C_H. The break down of holding cost is mentioned as below:

- The opportunity cost of the money invested in inventory
- Expenses in running warehouse (including handling and counting cost)
- Insurance
- Depreciation or deterioration of stock.
- Taxes
- C & F (Clearing and Forwarding) agent commission etc.

2.3.5 Lead time

It is the time that elapses from the moment at which it is decided to place an order, until it is physically on the shelf ready to satisfy customer demands. It is denoted by L. Lead time is made up of five distinct components. Such as-

- Administrative time at the stocking point (order preparation time).
- Transit time to the supplier.
- Time at the supplier

- Transit time back to the stocking point.
- Time from order receipt until it is available on the shelf.

2.3.6 Safety stock

It is the amount of extra inventory needed to satisfy maximum reasonable demand for a given service level during the lead-time. The random variability in the demand rate, the supply time and the production rate represents one of the most difficult yet real problems in inventory management. In order to meet random variability in demand during lead-time inventory systems rely on safety stocks. Safety stock reduces the risk of running out of stock. The greater is the safety stock maintained the less is risk of experiencing storage. However, such an increase in safety stock raises the holding cost. To reach a balance between the extra holding cost resulting from safety stocks and expected cost of shortage, an optimum amount of safety stock would be one that makes the sum of these costs a minimum. If the management accepts a reasonable service level and then determines the size of safety stock necessary then it may balance the risk of stock out within a prescribed limit. For example, suppose a company is committed to maintain the service level 90%, then the company should maintain adequate safety stock to satisfy actual demand 9 times out of 10.

The determination of the required safety stock to support a given service level depends on the type of inventory management system i.e. whether orders are to be placed at fixed interval or in fixed amounts.

The safety stock desired for (R,s,S) system when the lead time is longer than review period must provide protection for a time interval equal to R/2 + L. Thus,

$$ss = (D_m - \bar{D})(R/2 + L) = Z_\alpha S_D \sqrt{R/2 + L} \qquad [3]$$

Where,

ss = Safety stock
D_m= Maximum reasonable demand during (R/2+L) period
$\bar{D}$= Average demand during (R/2+L) period
S_D = Standard deviation of demand during (R/2+L) period

L= Lead time
R= Review period
Z_u= Number of standard deviation from mean for specific service level.

2.3.7 Reorder point

It corresponds to the maximum reasonable demand during the lead-time at the specified service level. Thus-

Reorder point, s= $\overline{x}_L$ + ss (safely stock) [1]

$\overline{x}_L$ = average lead-time demand

∴ Reorder point = average lead-time demand + safely stock.

2.3.8 ABC Classification

The Power Plant handles thousands of items to meet all maintenance tasks. It is not sound managerial practice to exercise the same degree of control over all such items. To determine the proper degree of control for various items held in the stock, it is necessary to classify the items on the basis of their value or critical nature. The resulting categories are then ranked according to the desired degree of control, which reflects the size of investment in each and critical nature of an item in securing smooth and economical operation. The most effective and widely used approach for establishing the various control categories is a procedure known as ABC analysis. After completion of the ABC analysis, an inventory-management system is set up so that items in class A are placed under tight control, items in class B under intermediate control and class C items under loose control. An ABC analysis can also be used to evaluate which inventory items are profitable, which suppliers or consumers are most important and so on. A material management system then answers the questions, which items when to and how much to order.

2.4 Materials Management Systems

To determine ordering quantity (how much to order) and when to order- it requires to select materials management system. There are four types of materials management system [1], such as-

(1) (s,Q) ⟶ Reorder-point, order quantity (fixed quantity) system.

This is a continuous review system. A fixed quantity Q is ordered whenever the inventory position drops to the reorder point s or lower. Here inventory position means on hand stock plus on order stock and takes proper account of the materials which are ordered but not yet received from the supplier. The (s,Q) system is often called a two- bin system because of it's physical form of implementation. Two bins shall be used for storage of an item. As long as units remain in the first bin, demand is satisfied from it. The amount in the second bin corresponds to the reorder point. Hence, when this second is opened, replenishment is triggered. When the replenishment arrives, the second bin is refilled and the remainder is put into first bin. The physical two-bin system will operate properly only when no more than one replenishment order is outstanding at any point in time. Thus, to use the system, it may be necessary to adjust Q upward so that it is appreciably larger than the average demand during a lead time.

The (s,Q) system is widely used in practice, even though it seems to be the most demanding and expensive from the point of view of record keeping. It is primarily recommended for items of low value per unit i.e. C class items. The advantages of this system are:

- Quite simple for the stock clerk to understand
- Fewer errors.
- Production requirements for the supplier are predictable.

The limitation of the system:

- May not be effective in situation when transaction is so large that replenishment of size Q would not even raise the inventory position above the reorder point s.

(2) (s,S) ⟶ Reorder-point, order-up-to-level (variable quantity) system

It is like the (s,Q) system, a replenishment is made whenever the inventory position drops at or below the order point s. However, in contrast to the (s,Q) system, a variable replenishment quantity is used in ordering enough to raise the inventory position to the order up-to-level S. If all demand transaction are unit sized, the two systems are identical because the replenishment requisition will always be made when the inventory position is exactly at s, that is, $S = s + Q$. If the transactions are larger than unit size the replenishment quantity in the (s,S) system becomes variable. The (s,S) system is frequently referred to as a min- max system because the position is always between a minimum value of s and a maximum value of S except momentary drop of inventory position below reorder point s. The advantage of the system:

- Best when total incremental cost of the (s,S) system is lower than (s,Q) system.

The limitations of the system:

- More computation efforts are required to find the best value of (s,S) pair.
- Order quantity is variable
- More frequent errors from supplier, and they certainly prefer predictability of fixed order quantity.

(3) (R,S) ⟶ Periodic-review, order-up-to-level (variable quantity) system

Instead of ordering a fixed amount at variable time intervals it is possible to operate an inventory system in the opposite way. The system is also known as a fixed-order-interval or periodic review system. The system, also known as replenishment cycle system and commonly used in companies where computer is not utilized to control the inventory. Every R units of time (weekly, biweekly, monthly etc.) enough is ordered to raise the inventory position to the level S, and frequently used in situation:

- When items are ordered from same supplier
- When the item requires resource sharing
- Coordinated replenishments of related item especially in the case of filling shipping container.

The Advantages of the system:

- Coordination can provide significant savings.
- The system offers regular opportunity (every R units of time) to adjust the S (especially time varying demand).
- The clerical cost is lower than (s,Q) system.

The limitation of the system:

- Carrying costs are higher than the continuous review system.

(4) (R,s,S) ⟶ Periodic-review, recorder point, order-up-to-level (variable quantity) system.

This is combination of (s,S) and (R,S) system. The inventory position is reviewed in every R units of time. If the inventory position is at or below a reorder point s, an order is placed to bring the inventory up to a desired maximum level S. If the inventory is above the reorder point, the replenishment decision is postponed until at least the next review. The (s,S) system is the special case of (R,s,S) system where R=0 and the (R,S) is the special case where s=0. Alternatively, one can think the (R,s,S) system is a periodic version of the (s,S) system. The system is appropriate when tight control is necessary that is for class A items.

The Advantages of the system:

- Best total for relevant cost (R,s,S) lower than any other system
- Requires less safety stock than the periodic review system.

The limitations of the system:

- Intense computation effort is required to obtain the best value of (R,s,S). However, reasonable values rather than optimal, are often searched with simplified method.
- More difficult for a clerk to understand.

Rules of thumb for selecting the form of inventory:

Items	Continuos review	Periodic review
A	(s,S)	(R,s,S)
B	(s,Q)	(R,S)

For C items, Firms generally use a more manual and simple approach (which can be equivalent to simple (s,Q) or (R,S) systems)

2.5 Material Requirement Planning (MRP)

It is a method which, starting with a forecast for the independent demand of the finished product, determines, the dependent or derived demand for (1) the kinds of components (materials, parts, or ingredients) needed (2) the exact quantities required and (3) the time phasing of the above orders to satisfy a production plan. The MRP emphasizes more on when-to-order than on the how-much-to order in respect to the problem. In these sense, MRP might be viewed more as a scheduling than as an inventory management technique. For items with dependent demand, inventories are held to support production smoothly. The paramount problem in the management is not monitoring the inventory levels but ensuring the availability in desired quantities at the proper time and at the right place. In order to run an MRP program a company must provide three key inputs:

- A master production schedule
- A bill-of-materials
- An inventory record file

The master production schedule specifies what end item is to be produced, when, and in what amounts. For each time period in the planning horizon management must specify the total demand for each end item. This usually consists of two parts, an amount determined by orders received from known customers and estimate of the uncertainty demand for the period, obtained by forecasting. The bill-of-materials file is a "recipe" of how a finished product is made from raw materials, or purchased components. In the recipe, each component is listed showing only it's parents and the number of units required for each product unit. When all identical components are listed at the same level of each end item, the computer can easily scan across each level and determines total the number of units required for each items.

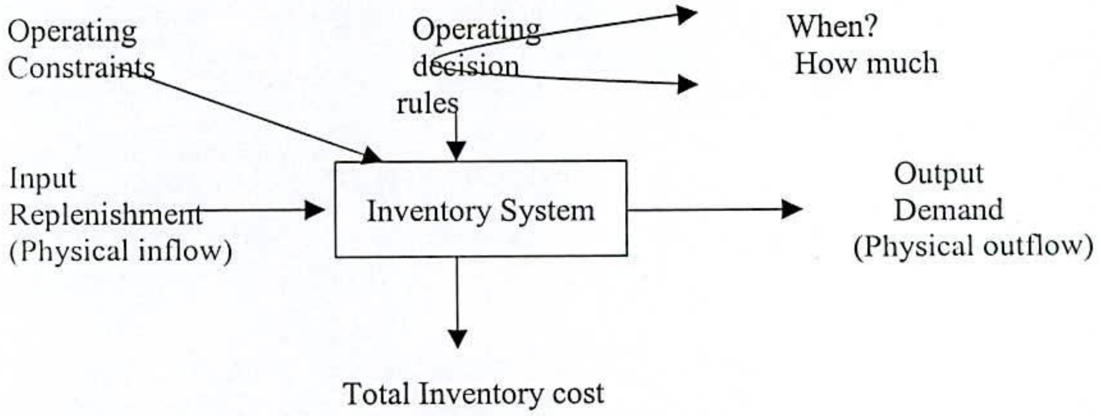
The inventory-records file covers each item separately, indicating its inventory status as a period-by-period basis. It also includes many other details about the item i.e. supplier, lead time, lot size etc. From a feasible master production schedule for a specific end item, the next step is to translate the period-by-period demand into requirements for parts needed to complete the tasks. This translation is performed with the bill-of-materials file. Once total requirements for the parts are calculated from master production schedule and the bill-of-materials file. MRP proceeds to determine the net requirements in conjunction with the inventory records file.

CHAPTER 3

Background of Research

3.1 Demand generation of the Plant

The materials management system can be shown with the following input-output representation:



The demand is the system's output. It is usually a physical outflow. The demand is the most critical and uncontrollable. Again without demand there would be no need for maintaining inventory. On the basis of demand, materials are categorized as-

- Fast moving items.
- Slow moving items.
- Non-moving items.

The Power Plant handles more than four thousand items to keep smooth running of its nineteen diesel engines. Of those, owner is responsible to supply the fuel (working fluid). The spare parts, lube oil and chemicals are managed by the plant itself. The ultimate goal of the Plant is to satisfy the demand of power.

3.2 Demand of power

Power is generated as per demand of BPDP (Bangladesh Power Development Board). Our country is not an industrialized country. So, industrial load is very little in Bangladesh, the power demand is predominantly made of commercial and household loads. Demand from 5p.m. to 11p.m. is the highest and it is known as evening peak load demand. The evening peak load demand is twice the off peak load demand. Considering this uneven load profile the Plant is designed with 19 dual fuel diesel generators each having 6.0 MW capacities to meet BPDP's widely varying dispatch request. On the basis of power demand maintenance works are scheduled. Due to hot weather and irrigation, power demand from February to June is highest. From July to October power demand is medium because of rain in these periods. From November to January power demand is lowest due to cold weather. So, demand of spare parts varies at different time. The Plant gets the yearly demand of power from BPDP and according estimates the plant factor for each month. As per demand of BPDP the average plant factor for year 2006 was 75%. The monthly graphical presentation of variable plant factors for year 2006 is shown in below.

ESTMATED PLANT FACTOR (PF) FOR YEAR 2006

Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
PF in %	68.10	72.89	83.16	83.16	83.16	83.16	76.32	72.89	69.47	68.10	66.05	64.68

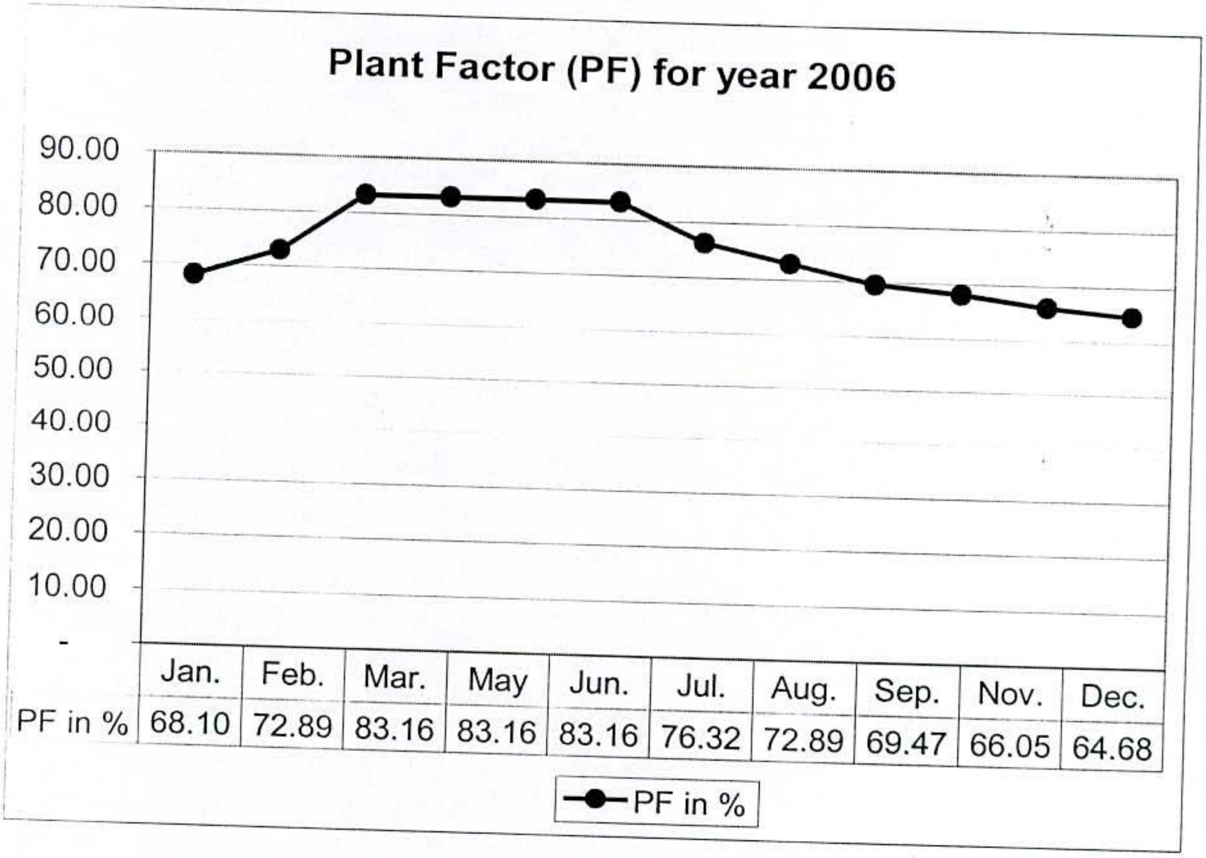


Fig. 3.1 Plant factor for year 2006

Plant factor is the Plant's output and all efforts are taken to comply the budgeted plant factor. Since for year 2006 the budgeted plant factor was 75%. On the basis of this budgeted plant factor maintenance schedules are setup and based on maintenance schedules, spare parts ordering processes are done to meet the demand of maintenance. Maintenance is carried out based on engine running hours. The Plant's schedule maintenances are 1500hrs, 2000hrs, 3000hrs, 4000hrs, 6000hrs, 9000hrs, and 12000hrs maintenance. These maintenances are done in due time to ensure trouble free and economical service of the engines. The plant factor fluctuates in accordance with demand variation. In order to satisfy budgeted plant factor, the Plant makes an operation schedule in which six EGB (Exhaust Gas Boiler) would run with 90% plant factor and thirteen non EGB engines would run with 67% plant factor. Spare parts are the prime requisite to execute the maintenances in due time.

Based on budgeted plant factor annual maintenance projection, review period maintenance projection are planned which are shown in appendix table No.3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8, 3.9, 3.10, 3.11, 3.12, 3.13, 3.14 & 3.15. The graphical presentation of schedule maintenance for year 2006 against budgeted plant factor are shown as below:

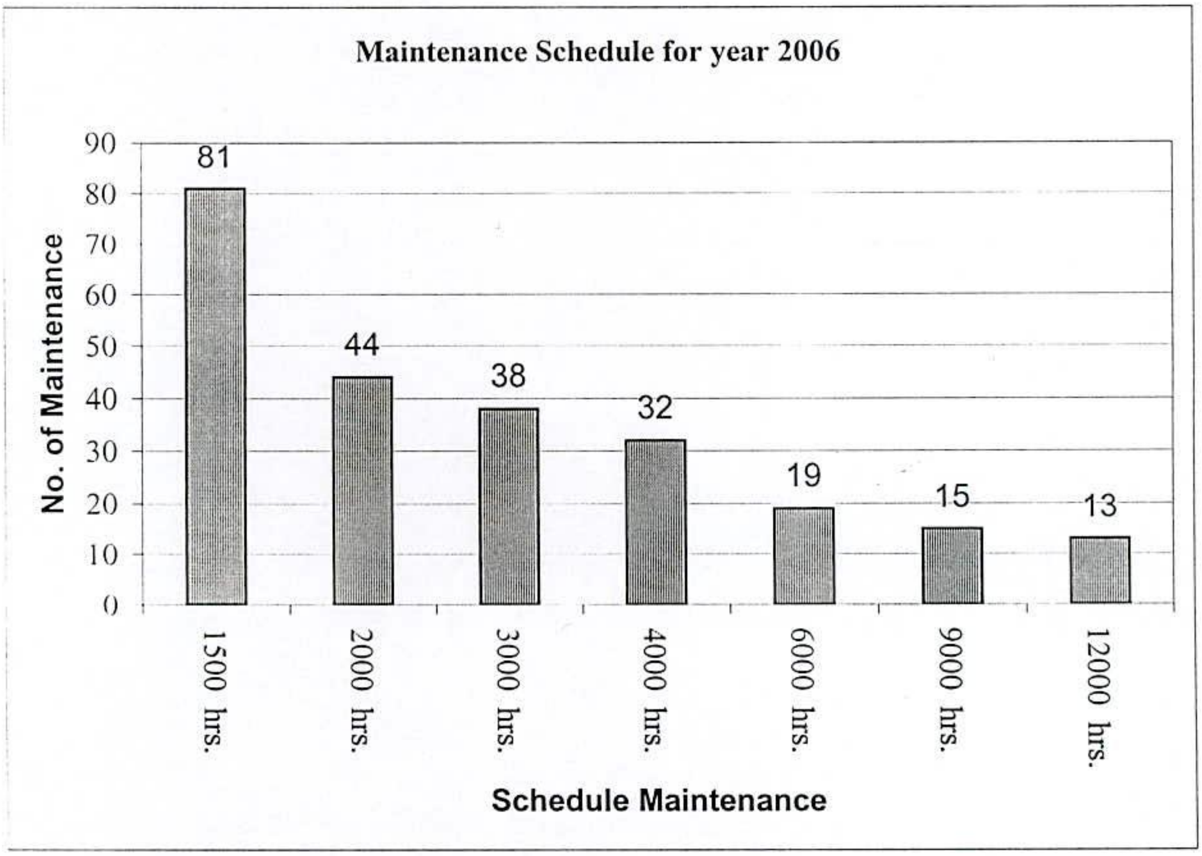


Fig. 3.2 Graphical presentation of schedule maintenance for year 2006

3.3 Needs of Spare Parts in the Plant

Maintenance department is the sole consumer of spare parts. So the demand of spare parts depends on maintenance schedules. Spare part constitutes 90% of plant's handled materials and up to 80% of maintenance budget. According to Finance department, spare parts budget for year 2006 was 2.5 millions dollar. Spare parts are needed for maintenance purpose. Spare parts to be replaced are determined based on maintenance schedule suggested by manufacturer.

A Power Plant is a public interest industry and modern civilization entirely depends on electricity. So, it is important to run the Plant continuously. To keep running condition of 19 engines, right quantity of spares should be provided at the right time. For healthy living, a man is required timely fooding. Like human, safe running of an engine depends on its routine maintenance. Spare parts are required for maintenance purpose. So, stock out of spares will delay the routine maintenance that indirectly reduce the life of the engines or may cause serious breakdown. Stock out of spare parts is an unusual phenomenon and the engine will remain idle until its availability.

As the Plant is owned by a private power generating company. One of the major objectives of the Plant is to improve Return on Investment. The Plant sells it's generated power to the BPDP (Bangladesh Power Development Board) under power purchase agreement. Power is sold in kwh (Kilowatt hour). One engine produces 6000 KW per hour. So, if one engine fails to generate power only one hour due to shortage of spare parts than the company will loose the monetary value of 6000 units. So, it is evident that determination of spare parts requirement for schedule maintenance is an important factor. The Plant's annual spare parts demand, (L+R/2) period (lead time + review period/2= 90 + 30/2 =105days) demand and review period demand against projected schedule maintenance for year 2006 are shown in appendix table No. 3.16, 3.17, 3.18, 3.19, 3.20, 3.21, 3.22, 3.23, 3.24, 3.25, 3.26, 3.27, 3.28, 3.29 & 3.30.

After calculation of demand, three key issues become evident:

- How often the inventory status should be determined?
- When a replenishment order should be placed?
- How large the replenishment order should be?

The Plant's strategy is to review the inventory status at first week of every month by maintenance management software MAMA (a data base software) and generates a report of items those are dropped to the reorder point or lower. On the basis of report, replenishment orders of spare parts are placed. The placing of a replenishment order depends on planning period demand. The main objective of spare parts storage is to satisfy demand of maintenance. A proper materials management can answer the above three key issues in which cost, review period demand, planning period demand, lead time, reorder point, safety stock and ordered quantity are related. To keep all engines in running conditions, it h requires to maintain a large volume of investment on spare parts. Again, if a placed order is too large, ordering costs are reduced, but holding costs go up conversely. If the orders are too small, spare parts must be ordered frequently to avoid running out of stock. So, the best order quantity should be ordered at the right time. The performance of an inventory management system is evaluated in terms of the total inventory cost.

- Total Inventory cost = Holding cost + Ordering cost + Shortage cost + Purchase cost.

Under the scope of Operation and Maintenance agreement, shortage cost is not allowed and no price discounts are offered. So, the shortage cost = 0 and the purchase cost remains constant regardless of when and how much to order. Thus, total inventory cost becomes:

- Total Incremental Cost (TIC) = Holding cost + Ordering cost.

3.4 Holding cost calculation of the Plant

The break down of Plant's holding costs are mentioned below.

- The opportunity cost of the money invested in inventory = 15% of the value invested in the inventory
- Expenses in running warehouse (including handling and counting cost) = 4% of the value invested in the inventory.
- Insurance = 1% of the value invested in the inventory.
- Depreciation or deterioration of stock = 0% because all are iron and rubber parts and kept in a air conditioned warehouse.
- Taxes-

(a) Customs duty (CD) = 25% of the value invested in the inventory

(b) Value added Tax (VAT) = 15% of the value invested in the inventory

(c) Supplementary Duty (SD) = 0% of the value invested in the inventory

(d) Advanced Income Tax (AIT) = 0% of the value invested in the inventory

(e) Development Surcharge (DSC) 4% of the value invested in the inventory

(f) Pre-shipment inspection (PSI)= 1% of the value invested in the inventory

- C & F (clearing & Forwarding) Agent commission = 1% of the value invested in the inventory
- Total holding Cost of the Plant, C_H = 66% of the value invested in the inventory.

3.5 Ordering cost or set up cost calculation of the Plant

- All these cost are treated as salary of staff engaged for procurement.
- As per finance department, ordering cost of the Plant C_R = $ 25/order/item.

3.6 Lead time calculation of the Plant

The break down of lead time of the Plant is given below.

(a) Administrative time at the stocking point

- Verification of items those are below reorder point: 2 days
- Approved purchase requisition from maintenance with approval from PM: 1 day
- Generation of PO (purchase order) from MAMA software: 1day
- Generated PO is approved by PM - 1day

(b) Transit time to the supplier

- Sending items of PO through web site – 1 day.

(c) Time at the supplier

- Sending A/O (Acknowledgement of order) against PO – 1week.
- Collecting parts from various manufacturers – 3 week.
- Picking, packing & handling time – 1 week.

(d) Documentation time

- Proforma Invoice generation -1 Week
- Letter of credit establishment - 1 Week
- Pre-shipment inspection - 3 Week

(e) Transit time back to the stocking point (plant site)

- Transportation time: Air freight 4 days, Sea freight 5 Week

- Customs clearance: 1 week

(f) Time for order received until it is available on the shelves

- Inspection time - 1 day
- Handling time - 1 day
- Order receive - 1 day

So, the plant's lead time becomes **90 days for Air freight**
& **121 days for Sea freight**

Scheduled maintenance parts are always imported through airfreight.

3.7 Determination of Key Parts for Analysis

Spare parts held in the warehouse are classified according to the unit value. The specific unit of stock in the Plant's Warehouse is called a Stock-Keeping Unit (SKU). An SKU is defined by an item of stock that is completely specified its function, size, coding and usually location. Table 3.31 illustrates 122 SKUs which are used schedule maintenance and are classified them in A-B-C categories.

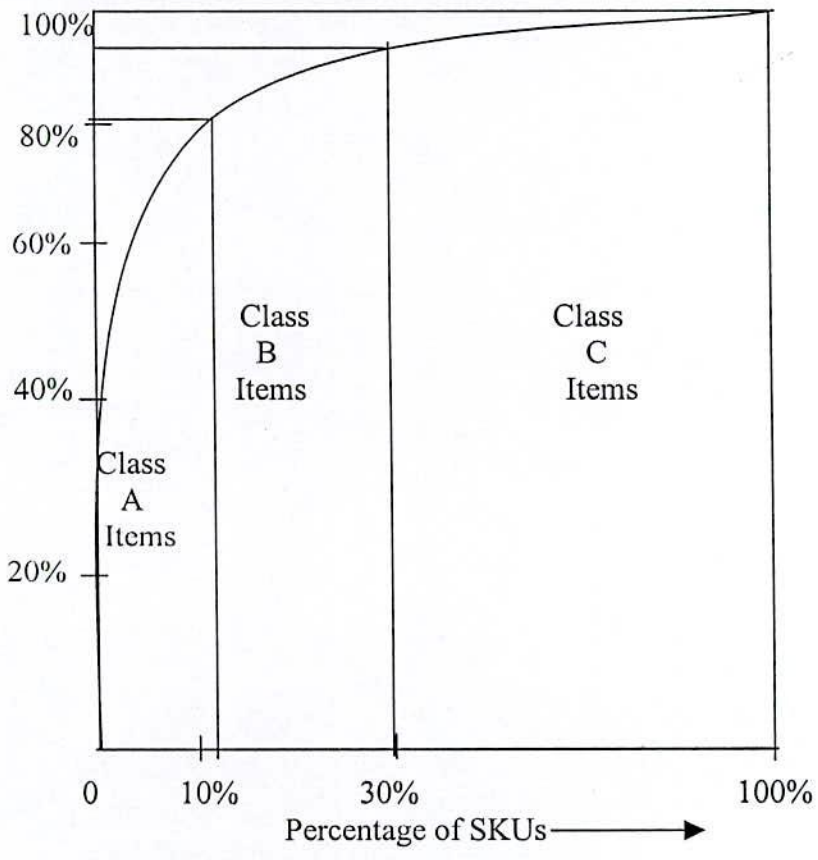


Fig. 3.3 A-B-C classification curve of schedule maintenance parts

The fig.3.3 is developed by using table 3.31 where the value v, in dollar per unit, and annual usage (demand) D, of each SKUs are identified. Then, the product Dv is calculated for each SKU, and Dv values for all SKUs are ranked in descending order, starting with the largest value as in the table 3.31. The corresponding values of the cumulative percentage of total dollar usage and cumulative percentage of the total number of the SKUs in the table are plotted on a graph fig.3.3. The table 3.31 is one of the most valuable tools for handling the diversity of disaggregate inventories because it helps to identify the SKUs that are the most important. These SKUs are assigned a higher priority, for control and rated A (most important), B(moderate importance) and C (least important).

Class A items: The first 11.48% percent of the SKUs that account for 81.96% percent of the dollar usage. Typically, valued items that require tight control.

Class B items: These are secondary importance in relation to class A because of their Dv values or considerations, rated moderate but significant amount of attention needed. The 29.52% percent of the SKUs that account for 14.85% percent of the annual dollar usage fall in this group.

Class C items: The largest group 59% of the SKUs that account for 3.19% percent of the annual dollar usage fall in this group. Typically, low-valued items so that the Plant shall try to keep relatively large number of units on hand to minimize the amount of inconvenience that could be caused by a stock out of such insignificant parts.

The power producing industry gives attention on dollar usages of materials to reduce cost of the unit power generation. So A-B-C classification is done on the basis of conventional ABC analysis. After completion of the A-B-C analysis, an inventory-management system may be set up so that items in class A are placed under tight control, items in class B are placed moderate control, and items in class C are under loose or normal control.

Table: 3.31

LIST OF SKUs BY DECENDING DOLLAR USAGE

Sl no	SKU I.D.	SKU Description	Req. Qty./ Maint	Annual demand (D)	unit cost in dollar (v)	Annual Usage, (Dv)	Cumulative percentage	Percentage of total use	Class
1	113001	Piston Crown 32LN	4	52	3,127.19	162,613.88	0.82	12.54	A
2	121006	Exhaust Valve Nim.	18	234	645.00	150,930.00	1.64	11.63	
3	113013	Piston Ring Set 32LN	18	234	535.66	125,344.44	2.46	9.66	
4	111019	Shim	18	234	493.00	115,362.00	3.28	8.89	
5	32100	Bearing unit	2	26	3,560.00	92,560.00	4.1	7.14	
6	167020	Nozzle	18	792	101.00	79,992.00	4.92	6.17	
7	34100	Bearing unit	2	26	2,157.00	56,082.00	5.74	4.32	
8	120009	Seat Ring, Exhaust	8	104	476.76	49,583.04	6.56	3.82	
9	100156	Antipolishing ring	18	234	205.87	48,174.36	7.38	3.71	
10	111004	Big end bearing upper	18	234	165.83	38,804.22	8.2	2.99	
11	111005	Big end bearing lower	18	234	165.83	38,804.22	9.02	2.99	
12	120065	Sealing set	18	234	154.61	36,178.74	9.84	2.79	
13	471196	Lube oil filter	8	648	53.67	34,778.16	10.66	2.68	
14	470200	Fuel Filter	9	729	46.76	34,088.04	11.48	2.63	
15	100096	Main bearing, upper	10	130	168.92	21,959.60	12.3	1.69	B
16	100097	Main Bearing, Lower	10	130	168.92	21,959.60	13.12	1.69	
17	121033	Disk	20	260	59.40	15,443.43	13.94	1.19	
18	100112	Thrust washer	4	52	213.21	11,086.92	14.76	0.85	
19	100111	D- Seal	36	468	23.18	10,848.24	15.58	0.84	
20	120022	Valve Guide	8	104	101.26	10,531.04	16.4	0.81	
21	165175	Limiter	18	342	28.33	9,688.86	17.22	0.75	
22	AL-01E	Gasket	16	208	42.81	8,903.70	18.04	0.69	
23	Chem-034	Cleaning Chemical	1	81	101.21	8,198.01	18.86	0.63	
24	121010	Inlet valve	4	52	156.02	8,113.14	19.68	0.63	
25	165173	Spring	18	342	20.00	6,840.00	20.5	0.53	
26	165280	Telfon ring	18	342	18.96	6,484.32	21.32	0.50	
27	350018	O-ring	72	2304	2.10	4,838.40	22.14	0.37	
28	191015	Shaft seal	2	30	146.78	4,403.40	22.96	0.34	
29	100113	Thrust bearing	2	26	168.92	4,391.92	23.78	0.34	
30	191009	Bearing RHW 33	2	30	144.00	4,320.00	24.6	0.33	
31	148011	Camshaft Bearing	2	26	159.09	4,136.36	25.42	0.32	
32	76040	Gasket ring	2	26	155.68	4,047.68	26.24	0.31	
33	476004	Gasket	2	162	24.11	3,905.82	27.06	0.30	
34	476005	Gasket	2	162	24.11	3,905.82	27.88	0.30	
35	476006	Gasket	2	162	24.11	3,905.82	28.7	0.30	
36	131007	Bush	2	26	126.69	3,293.94	29.52	0.25	
37	200014	Two-part ring	1	13	227.63	2,959.19	30.34	0.23	

Sl no	SKU I.D.	SKU Description	Req. Qty./ Maint	Annual demand (D)	unit cost in dollar (v)	Annual Usage, (Dv)	Cumulative percentage	Percentage of total use	Class
38	200011	Gasket	12	156	18.70	2,917.88	31.16	0.22	
39	165105	O-ring	18	342	7.60	2,599.20	31.98	0.20	
40	51019	Hex.headed screw	12	156	15.42	2,405.47	32.8	0.19	
41	51015	Hex.headed screw	12	156	15.42	2,405.47	33.62	0.19	
42	165014	O-ring	18	342	5.40	1,846.80	34.44	0.14	
43	165200	Supporting ring	36	684	2.70	1,846.80	35.26	0.14	
44	350421	Screw	24	768	2.10	1,612.80	36.08	0.12	B
45	156015	Gasket	2	64	24.10	1,542.40	36.9	0.12	
46	165004	O-ring	18	342	4.40	1,504.80	37.72	0.12	
47	191010	Bearing NU 209	2	30	47.60	1,428.00	38.54	0.11	
48	165267	Sealing Ring	18	342	3.90	1,333.80	39.36	0.10	
49	200138	Stud12x90mm	5	65	19.25	1,251.37	40.18	0.10	
50	52801	Gasket	8	104	12.00	1,248.00	41	0.10	
51	165003	O-ring	18	342	3.50	1,197.00	41.82	0.09	
52	228279	Repair Kit	1	13	81.40	1,058.20	42.64	0.08	
53	165020	Sealing Ring	36	684	1.50	1,026.00	43.46	0.08	
54	354001	Gasket	6	486	2.10	1,020.60	44.28	0.08	
55	191054	Flinger	2	30	31.40	942.00	45.1	0.07	
56	200015	Allen Screw	24	312	2.99	932.88	45.92	0.07	
57	476001	Screw	5	405	2.10	850.50	46.74	0.07	
58	167003	O-ring	18	342	2.44	834.48	47.56	0.06	
59	121062	Ball	30	390	2.10	819.00	48.38	0.06	
60	191013	Radial seal	2	30	26.60	798.00	49.2	0.06	
61	165174	Shot	18	342	2.30	786.60	50.02	0.06	
62	167265	O-ring	12	384	1.82	698.88	50.84	0.05	
63	200026	Allen Screw	12	156	4.43	691.08	51.66	0.05	
64	350184	O-ring	10	320	2.10	672.00	52.48	0.05	
65	167012	Cylindrical pin	10	440	1.50	660.00	53.3	0.05	
66	131033	Allen screw	24	312	2.10	655.20	54.12	0.05	C
67	131034	Allen Screw	24	312	2.10	655.20	54.94	0.05	
68	200016	Nut10mm	24	312	2.10	655.20	55.76	0.05	
69	191043	Dry Lock screw	8	120	5.40	648.00	56.58	0.05	
70	100088	O-ring	22	286	2.10	600.60	57.4	0.05	
71	148013	Allen Screw	34	442	1.27	562.55	58.22	0.04	
72	167008	O-ring	6	264	2.10	554.40	59.04	0.04	
73	165031	O-ring	6	114	4.14	471.96	59.86	0.04	
74	191044	Pair of friction rings	2	30	15.20	456.00	60.68	0.04	
75	191045	Pair of friction rings	2	30	15.20	456.00	61.5	0.04	
76	148014	Allen Screw	15	195	2.10	409.50	62.32	0.03	
77	354100	Gasket	2	76	4.65	353.40	63.14	0.03	
78	167264	O-ring	6	192	1.82	349.44	63.96	0.03	
79	145008	O-ring	8	104	3.25	338.00	64.78	0.03	
80	476012	Sleeve	2	64	5.15	329.60	65.6	0.03	

Sl no	SKU I.D.	SKU Description	Req. Qty./ Maint	Annual demand (D)	unit cost in dollar (v)	Annual Usage, (Dv)	Cumulative percentage	Percentage of total use	Class
81	131032	Allen Screw	12	156	2.10	327.60	66.42	0.03	
82	51049	Locking plate	12	156	2.00	312.00	67.24	0.02	
83	51020	Locking plate	12	156	1.96	305.76	68.06	0.02	
84	355011	Gasket	4	52	5.40	280.90	68.88	0.02	
85	200139	Lock Nut12mm	5	65	3.83	249.09	69.7	0.02	
86	123001	O-ring	9	117	2.10	245.70	70.52	0.02	
87	123025	Seal Ring	9	117	2.10	245.70	71.34	0.02	
88	165122	Retaining ring	6	114	2.10	239.40	72.16	0.02	
89	354064	Gasket	1	38	5.57	211.66	72.98	0.02	
90	131030	O-ring	3	96	2.10	201.60	73.8	0.02	
91	131031	O-ring	3	96	2.10	201.60	74.62	0.02	
92	354102	Gasket	1	38	5.29	201.02	75.44	0.02	
93	165037	Sealing Ring	6	114	1.57	178.98	76.26	0.01	
94	156016	Gasket	1	32	5.30	169.60	77.08	0.01	
95	228042	O-Ring	2	26	5.60	145.60	77.9	0.01	
96	378002	O-ring	2	64	2.10	134.40	78.72	0.01	C
97	125447	Sealing Set	2	26	5.04	131.04	79.54	0.01	
98	352245	O-ring	1	13	9.58	124.54	80.36	0.01	
99	191052	O-ring	1	38	2.99	113.62	81.18	0.01	
100	228003	Hex. Screw	4	52	2.10	109.20	82	0.01	
101	355002	Gasket	4	52	2.10	109.20	82.82	0.01	
102	121063	Retainer ring	6	78	1.28	99.64	83.64	0.01	
103	167011	Push rod	1	44	2.00	88.00	84.46	0.01	
104	120028	Allen Screw	4	52	1.59	82.68	85.28	0.01	
105	145003	O-ring	4	52	1.50	78.00	86.1	0.01	
106	224040	Lock Nut12mm	4	52	1.50	78.00	86.92	0.01	
107	352460	O-ring for flap	2	26	2.91	75.69	87.74	0.01	
108	352013	O-ring	1	13	5.20	67.61	88.56	0.01	
109	350479	O-ring	1	32	2.10	67.20	89.38	0.01	
110	228032	Spring	1	13	4.74	61.68	90.2	0.00	
111	355025	O-Ring	2	26	2.10	54.70	91.02	0.00	
112	181160	Gasket	1	13	4.10	53.30	91.84	0.00	
113	145010	O-ring	4	52	1.00	52.19	92.66	0.00	
114	357012	O-ring	1	32	1.57	50.24	93.48	0.00	
115	357007	O-ring	1	32	1.28	40.96	94.3	0.00	
116	357018	Gasket	2	26	1.27	33.09	95.12	0.00	
117	228046	Gasket	1	13	2.37	30.84	95.94	0.00	
118	228204	Male Stud, 6mm	1	13	2.10	27.30	96.76	0.00	
119	352459	O-ring	1	13	1.57	20.41	97.58	0.00	
120	228043	O-Ring	1	13	1.28	16.61	98.4	0.00	
121	211016	O-ring	1	13	1.27	16.55	99.22	0.00	
122	76022	Locking washer	2	26	0.11	2.86	100.0	0.00	

CHAPTER 4

Analysis

The Plant's strategy is to review the inventory position first week of every month (i.e. review period R=one month=30 days) and places order of those items which are at or below the reorder point depending on the demand of planning period (lead time + review period). If the position is above reorder point, nothing is done until at least the next review period. So, the Plant more or less follows (R,s,S) system. But, the management does not follow analytical procedure in setting reorder point and order quantity at a time. The tendency of management is to order excess quantity than needed. As a result, the Plant has to bear more holding cost, because holding cost increases linearly and ordering cost decreases almost with the order quantity. Reorder point is the basis to place a replacement order. So, our objective is to find out actual reorder point and determine right order quantity, which in turn reduces total incremental cost. To maintain plant's 98% service level it also maintains safely stock. So, safely stock, reorder point and order quantity are to be determined to control Plant's inventory.

From obtained data, it is observed that 122 items are required to execute all schedule maintenance. Most of the class A items are required for 12000hrs. maintenance. 3000hrs maintenance requires low valued items that are in class C.

4.1 Sample Calculation for Different Spare Parts

Name of the method: (R,s,S) with lead time =90days and review period = 30days (lead time > review period)

For 47200 Fuel filter (class A item)

Annual demand, D = 729 pcs (Table No. 3.16 in appendix)

Unit price = $46.79

Maximum reasonable demand during (L+R/2) period, D_m = 234 pcs

(Table No. 3.23 in appendix)

Average demand for (L+R/2) period, $\overline{D}$ = 729/365 *105= 209.71 pcs

S = Maximum desired inventory

Safety stock, ss = $(D_m-\overline{D})(R/2 + L)$

= $(D_m-\overline{D})$ for (R/2 + L) period

= 234 - 209.71
= 24.29pcs
≈ 24pcs

Reorder point, s = $\overline{x}_L$ + ss
$\overline{x}_L$ = Average lead time(90 days) demand
= 729/365*90
= 179.75

So, reorder point, s = 179.75 + 24.29
= 204.04
≈ 204 pcs

Since, lead time 90 days (three month) and review period 30 days (one month). So normally 3 (three) orders can be placed in a year. Thus,

- Average order size, Q = 729/3 = 243 pcs.
- But the Plant always places an order depending on planning period (R+L) demand.
- Planning period demand = lead time demand + review period demand
- Since lead time 90 days so lead time demand contains three review period demand. Thus, planning period demand contains four review period demand.

(Ref. Table No.3.23 in appendix)

Event	Quantity Per Maint.	Number of Maint. during lead time	Lead time demand	Number of Maint. during planning Period	Planning period Demand/ order quantity
1	9	19	171	31	279
2	9	21	189	29	261
3	9	18	162	21	189

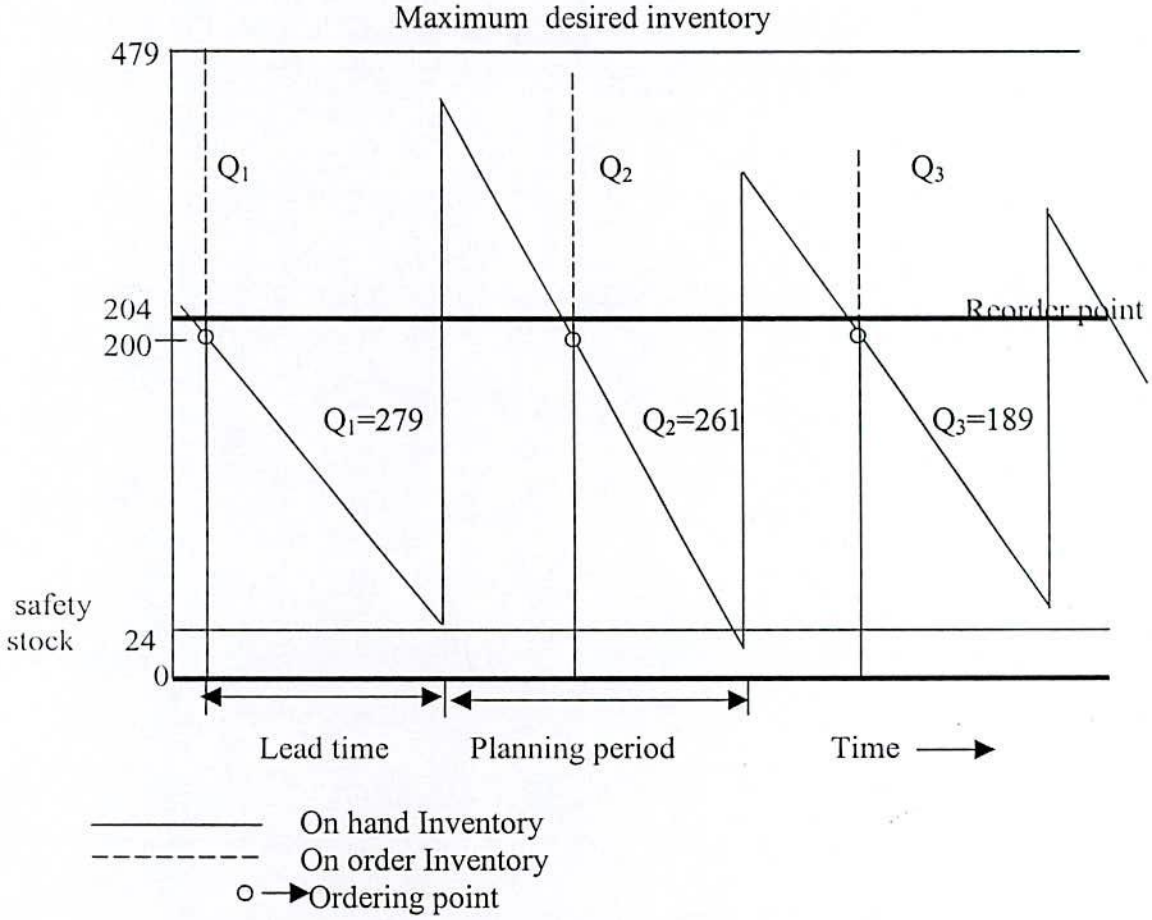


Fig. 4.1 **Inventory Fluctuation at different time**

Q_1, Q_2, Q_3 indicates order quantity at various time interval

Inventory cost:
Ordering cost, C_R = $ 25/order/item
Holding cost, C_H = 0.66* price per unit
Price per unit = $ 46.76
Desired Maximum Inventory S= on hand Inventory + maximum on order Inventory
Thus,
S = 200 + 279 [fig.4.1]
= 479 pcs
Total incremental cost = Holding cost + Ordering cost
= C_H (S - ss)/2 + C_R D/ Q
= 0.66*46.76(479 - 24)/2 + 25(No. of orders placed)
[As D/Q= annual no. of orders placed]
= $7,021.01 + $75.00
= $ 7,096.01

Total Inventory cost = Total incremental cost + Purchase cost

= Total incremental cost + unit price* annual demand

= \$7,096.01 + 46.76*729

= \$41,184.05

- Comparison with the data of previous year of existing system:
- Total incremental cost = C_H (S - ss)/2 + C_R D/ Q (Ref. Table No. 4.1 page 40)

= 0.66*46.76(735- 9)/2 + 25(No. of order placed)

= \$11,202.76 + \$25.00

= \$11,227.76

- Total incremental cost was about double in previous year due to the plant placed only one order to bring annual demand.
- By similar calculation rest of the items are calculated and listed in result sheet.

4.2 Results of Different Spare Parts for year 2006

The analytically calculated results are summarized in below.

s_1 = Existing reorder point

s = Proposed reorder point

Q_1 = First time ordered quantity

Q_2 = Second time ordered quantity

Q_3 = Third time ordered quantity

ss_1 = Existing safety stock

ss = Proposed safety stock

S = Maximum desired inventory

TIC= Total Incremental Cost

Item No.	Description	s_1	s	Q_1	Q_2	Q_3	ss_1	ss	S	Unit Value USD	TIC in USD
470200	Fuel Filter	400	204	279	261	189	9	24	479	46.76	7,096.01
471196	Lube oil Filter	360	181	248	232	168	8	22	423	53.67	7,177.15
476004	Gasket	50	45	62	58	42	2	5	106	24.11	878.59
476005	Gasket	50	45	62	58	42	2	5	106	24.11	878.59
476006	Gasket	50	45	62	58	42	2	5	106	24.11	878.59
476001	Screw	200	113	155	145	105	15	14	265	2.10	248.94
354001	Gasket	150	136	186	174	126	12	16	316	2.10	282.90
Chem-34	Cleaning chemical	24	23	31	29	21	3	3	54	101.21	1,778.36
167011	Cylindrical Pin	20	13	17	15	12	3	2	23	2.00	88.86

Item No.	Description	s_1	s	Q_1	Q_2	Q_3	ss_1	ss	S	Unit Value USD	TIC in USD
167020	Nozzle	300	237	306	270	216	18	42	526	101.00	16,206.72
167008	O-Ring	100	79	102	90	72	18	14	172	2.10	184.49
167012	Cylindrical Pin	100	132	170	150	120	18	23	290	1.50	163.11
191052	O-Ring	20	25	26	30	200	2	6	37	2.99	108.54
354100	Gasket	20	25	26	30	20	4	6	54	4.65	148.65
354064	Gasket	20	12	13	15	10	2	3	37	5.57	137.50
354102	Gasket	20	12	13	15	10	2	3	37	5.29	134.35
350421	Screw	150	233	336	264	168	24	44	566	2.10	436.75
131030	O-Ring	20	29	42	33	21	6	5	60	2.10	113.12
131031	O-Ring	20	29	42	33	21	6	5	60	2.10	113.12
167264	O-Ring	100	61	84	66	42	18	14	144	1.82	153.08
350184	O-Ring	50	39	56	44	28	12	7	94	2.10	135.29
357007	O-Ring	20	10	14	11	7	5	2	24	1.28	84.29
357012	O-Ring	20	10	14	11	7	5	2	24	1.57	86.40
350018	O-Ring	500	697	1008	792	504	72	129	1688	2.10	1,155.39
378002	O-Ring	20	19	28	22	14	6	4	46	2.10	104.11
476012	Sleeve	20	19	28	22	14	6	4	46	5.15	146.38
156015	Gasket	20	19	28	22	14	6	4	46	24.10	409.03
156016	Gasket	20	10	14	11	7	5	2	24	5.30	113.48
350479	O-Ring	20	10	14	11	7	2	2	24	2.10	90.25
167265	O-Ring	200	116	168	132	84	12	22	284	1.82	232.36
165003	O-Ring	200	112	162	90	90	18	28	262	3.50	345.27
165004	O-Ring	200	112	162	90	90	18	28	262	4.40	414.77
165014	O-Ring	200	112	162	90	90	18	28	262	5.40	491.99
165020	Sealing-ring	300	224	324	180	180	36	55	524	1.50	307.16
165031	O-Ring	50	37	54	30	30	6	9	88	4.14	182.93
165037	Sealing-ring	50	37	54	30	30	6	9	88	1.57	115.93
165105	O-Ring	200	112	162	90	90	18	28	262	7.60	661.87
165122	Retainer Ring	50	37	54	30	30	6	9	88	2.10	129.75
165173	Spring	200	112	162	90	90	18	28	262	20.00	1,619.40
165174	Shot	200	112	162	90	90	18	28	262	2.30	241.11
165175	Limiter	200	112	162	90	90	18	28	262	28.33	1,440.83
165200	Supporting Ring	300	224	324	180	180	36	55	524	2.70	492.88
165267	Sealing-ring	200	112	162	90	90	18	28	262	3.90	396.84
165280	Teflon-ring	200	112	162	90	90	18	28	262	18.96	1,444.29
167003	O-Ring	200	112	162	90	90	18	28	262	2.44	263.42
191009	Bearing	15	9	14	12	6	2	2	23	144.00	784.92
191010	Bearing	15	9	14	12	6	2	2	23	47.60	404.87
191013	Radial Seal	15	9	14	12	6	2	2	23	26.60	206.14
191015	Shaft Seal	15	9	14	12	6	2	2	23	146.78	798.62
191043	Dry lock Screw	50	35	48	48	24	8	6	83	5.40	169.01

Item No.	Description	s_1	s	Q_1	Q_2	Q_3	ss_1	ss	S	Unit Value USD	TIC in USD
191044	Friction ring	15	9	14	12	6	2	2	23	15.20	149.94
191045	Friction ring	15	9	14	12	6	2	2	23	15.20	149.94
191054	Flinger	15	9	14	12	6	2	2	23	31.40	229.80
32100	Bearing Unit	10	11	8	10	8	2	5	18	3665.00	15,797.85
34100	Bearing unit	10	11	8	10	8	2	5	18	2157.00	9,328.53
51019	Hex, headed screw	36	66	48	60	48	4	27	110	15.42	497.35
51015	Hex, headed screw	36	66	48	60	48	4	27	110	15.42	497.35
51020	Locking plate	36	66	48	60	48	4	27	110	1.96	128.68
51049	Locking plate	36	66	48	60	48	4	27	110	2.00	129.78
52801	Gasket	50	44	32	40	32	9	18	72	12.00	288.84
76022	Locking washer	6	11	8	10	8	2	5	18	2.10	84.01
76040	Gasket ring	6	11	8	10	8	2	5	18	155.68	725.18
AL-01E	Gasket	100	87	64	80	64	16	36	140	46.20	1,585.58
100088	O-ring	100	120	88	110	88	18	50	168	2.10	156.77
100096	Main bearing shell	40	55	40	50	40	10	23	90	174.00	3,922.14
100097	Main bearing shell	40	55	40	50	40	10	23	90	174.00	3,922.14
100111	D- Seal	200	197	144	180	144	27	81	334	23.18	2,010.30
100112	Thrust washer	20	22	16	20	16	3	9	35	213.21	1,904.34
100113	Flywheel bearing	10	11	8	10	8	2	5	18	168.92	799.67
100156	Antipolishin g ring	36	98	72	90	72	18	24	168	205.87	9,857.94
111004	Big end bearing	36	98	72	90	72	18	24	168	165.83	7,955.24
111005	Big end bearing	36	98	72	90	72	18	24	168	165.83	7,955.24
111019	Shim	36	98	72	90	72	18	24	168	493.00	23,504.36
113001	Piston Crown	10	22	16	20	16	3	9	35	3127.00	26,904.66
113013	Piston Ring Set	36	98	72	90	72	18	24	168	565.00	26,923.80
120009	Exhaust Seat	50	44	32	40	32	8	18	72	476.76	8,570.86
120022	Valve Guide	50	44	32	40	32	8	18	72	101.28	1,879.81
120028	Allen Screw	10	22	16	20	16	3	9	35	1.59	88.64
120065	Sealing set	36	98	72	90	72	18	24	168	154.61	7,422.07
121006	Exhaust Valve	36	98	72	90	72	18	24	168	645.00	30,725.40
121010	Inlet valve	10	22	16	20	16	3	9	35	156.02	1,413.65

Item No.	Description	s_1	s	Q_1	Q_2	Q_3	ss_1	ss	S	Unit Value USD	TIC in USD
121033	Disk	100	109	80	100	80	20	45	180	69.07	3,152.07
121062	Ball	200	164	120	140	120	30	68	260	2.10	208.05
121063	Retainer ring	50	33	24	30	24	6	14	54	1.28	91.90
123001	O-ring	50	49	36	45	36	9	20	81	2.10	117.27
123025	Seal Ring	50	49	36	45	36	9	20	81	2.10	117.27
125447	Sealing Set	6	11	8	10	8	2	5	18	5.04	96.62
131007	Bush	6	11	8	10	8	2	5	18	126.69	618.50
131032	Allen Screw	50	66	48	60	48	4	27	110	2.10	132.52
131033	Allen Screw	150	141	96	120	96	24	64	216	2.10	180.33
131034	Allen Screw	150	141	96	120	96	24	64	216	2.10	180.33
145003	O-ring	10	22	16	20	16	3	9	35	1.50	87.87
145008	O-ring	50	44	32	40	32	8	18	72	3.25	57.92
145010	O-ring	10	22	16	20	16	3	9	35	2.10	93.02
148011	Camshaft bearing	6	11	8	10	8	2	5	18	159.09	757.50
148013	Allen Screw	100	186	136	178	136	34	77	306	2.10	233.70
148014	Allen Screw	10	82	60	75	60	15	34	135	2.10	144.99
181160	Gasket	10	5	4	5	4	1	2	9	4.10	81.77
200011	Gasket	36	66	48	60	48	4	27	110	18.70	587.19
200014	Two-part ring	10	5	4	5	4	1	2	9	227.63	600.81
200015	Allen Screw	100	141	96	120	96	24	64	216	2.99	125.16
200016	Nut 10mm	100	141	96	120	96	24	64	216	2.10	180.34
200026	Allen Screw	36	66	48	60	48	12	27	110	4.43	196.34
200138	Stud	40	27	20	25	20	5	11	45	19.25	290.99
200139	Lock Nut	40	27	20	25	20	5	11	45	3.83	117.97
211016	O-ring	10	5	4	5	4	1	2	9	2.10	79.85
224040	Lock Nujt	10	22	16	20	16	3	9	35	2.10	93.02
228003	Hex. Screw	10	22	16	20	16	3	9	35	2.10	93.02
228032	Spring	10	5	4	5	4	1	2	9	4.74	85.95
228042	O-Ring	6	11	8	10	8	2	5	18	5.60	99.02
228043	O-Ring	10	5	4	5	4	1	2	9	5.60	87.94
228046	Gasket	10	5	4	5	4	1	2	9	2.37	80.47
228204	Male stud,	10	5	4	5	4	1	2	9	2.10	79.85
228279	Repair kit	10	5	4	5	4	1	2	9	81.40	263.03
352013	O-ring	10	5	4	5	4	1	2	9	5.20	87.01
352245	O-ring	10	5	4	5	4	1	2	9	9.58	97.13
352459	O-ring	10	5	4	5	4	1	2	9	1.57	78.63
352460	O-ring for flap	6	11	8	10	8	2	5	18	2.91	87.48
355002	Gasket	10	22	16	20	16	3	9	35	2.10	93.02
355011	Gasket	10	22	16	20	16	3	9	35	5.40	121.33
355025	O-Ring	6	11	8	10	8	2	5	18	2.10	84.01
357018	Gasket O-ring	6	11	8	10	8	2	5	18	1.57	81.74

Total: **256,329.19**

4.3 Total incremental cost (TIC) comparison

Total incremental cost is compared with year 2005 to show the benefits of follow-up scientific methods in managing Spare parts. From obtained data, it has been observed that in 2005 budgeted plant factor was 70% and total schedule maintenances were 203 (1500hrs. 68, 2000hrs. 36, 3000hrs. 33, 4000hrs. 25, 6000hrs. 16, 9000hrs. 13 and 12000hrs. 12). So, comparison is carried out TIC against 70% plant factor with 203 schedule maintenances for 2005 and 75% plant factor with 222 maintenances for 2006.

Table 4.1
List of spares for TIC comparison

D = Annual demand in year 2005
D/Q = No. of order placed during the year 2005.
ss_1 = Safety stock in year 2005
S_1 = Maximum desired inventory in year 2005
TIC = Total Incremental Cost

Item No.	Description	D	D / Q	ss_1	S_1	Unit Value USD	TIC in USD for year 2005	TIC in USD for year 2006
470200	Fuel Filter	612	1	9	735	46.76	11,227.76	7,096.01
471196	Lube oil Filter	544	1	8	600	53.67	10,509.97	7,177.15
476004	Gasket	136	2	2	62	24.11	527.38	878.59
476005	Gasket	136	2	2	62	24.11	527.38	878.59
476006	Gasket	136	2	2	62	24.11	527.38	878.59
476001	Screw	340	3	15	225	2.10	220.53	248.94
354001	Gasket	408	3	12	185	2.10	194.89	282.90
Chem-34	Cleaning chemical	68	2	3	50	101.21	2,428.44	1,778.36
167011	Cylindrical Pin	36	2	3	50	2.00	81.02	88.86
167020	Nozzle	648	2	18	512	101.00	16,515.02	16,206.72
167008	O-Ring	216	3	18	95	2.10	103.36	184.49
167012	Cylindrical Pin	360	2	18	150	1.50	115.36	163.11
191052	O-Ring	33	2	2	48	2.99	95.39	108.54
354100	Gasket	66	2	4	60	4.65	135.93	148.65
354064	Gasket	33	2	2	48	5.57	134.55	137.50
354102	Gasket	33	2	2	48	5.29	130.30	134.35
350421	Screw	600	2	24	390	2.10	303.64	436.75
131030	O-Ring	75	2	6	55	2.10	83.96	113.12
131031	O-Ring	75	2	6	55	2.10	83.96	113.12
167264	O-Ring	150	2	18	120	1.82	111.26	153.08
350184	O-Ring	100	2	12	85	2.10	100.59	135.29

Item No.	Description	D	D / Q	ss_1	S_1	Unit Value USD	TIC in USD for year 2005	TIC in USD for year 2006
357007	O-Ring	25	2	5	32	1.28	61.40	84.29
357012	O-Ring	25	2	5	32	1.57	63.99	86.40
350018	O-Ring	1800	2	72	1400	2.10	970.30	1,155.39
378002	O-Ring	50	2	6	40	2.10	73.56	104.11
476012	Sleeve	50	2	6	40	5.15	107.78	146.38
156015	Gasket	50	2	6	40	24.10	320.40	409.03
156016	Gasket	25	2	5	32	5.30	97.22	113.48
350479	O-Ring	250	2	2	200	2.10	181.67	90.25
167265	O-Ring	300	2	12	220	1.82	174.92	232.36
165003	O-Ring	288	2	18	370	3.50	456.56	345.27
165004	O-Ring	288	2	18	370	4.40	561.10	414.77
165014	O-Ring	288	2	18	370	5.40	677.26	491.99
165020	Sealing-ring	576	3	36	475	1.50	292.31	307.16
165031	O-Ring	96	2	6	88	4.14	162.03	182.93
165037	Sealing-ring	96	2	6	88	1.57	92.48	115.93
165105	O-Ring	288	2	18	370	7.60	932.82	661.87
165122	Retainer Ring	96	2	6	88	2.10	106.82	129.75
165173	Spring	288	2	18	370	20.00	2,373.20	1,619.40
165174	Shot	288	2	18	370	2.30	241.27	241.11
165175	Limiter	288	2	18	370	28.33	3,340.81	1,440.83
165200	Supporting Ring	576	3	36	475	2.70	466.15	492.88
165267	Sealing-ring	288	2	18	370	3.90	503.02	396.84
165280	Teflon-ring	288	2	18	370	18.96	2,252.39	1,444.29
167003	O-Ring	288	2	18	370	2.44	333.43	263.42
191009	Bearing	26	2	2	24	144.00	1,095.44	784.92
191010	Bearing	26	2	2	24	47.60	395.58	404.87
191013	Radial Seal	26	2	2	24	26.60	243.12	206.14
191015	Shaft Seal	26	2	2	24	146.78	1,115.62	798.62
191043	Dry lock Screw	104	2	8	85	5.40	187.21	169.01
191044	Friction ring	26	2	2	24	15.20	160.35	149.94
191045	Friction ring	26	2	2	24	15.20	160.35	149.94
191054	Flinger	26	2	2	24	31.40	277.96	229.80
32100	Bearing Unit	24	2	2	16	3665.00	16,982.30	15,797.85
34100	Bearing unit	24	2	2	16	2157.00	10,015.34	9,328.53
51019	Hex, headed screw	144	2	4	102	15.42	548.68	497.35
51015	Hex, headed screw	144	2	4	102	15.42	548.68	497.35
51020	Locking plate	144	2	4	102	1.96	113.37	128.68
51049	Locking plate	144	2	4	102	2.00	114.68	129.78
52801	Gasket	96	2	9	88	12.00	362.84	288.84
76022	Locking washer	24	2	2	16	2.10	59.70	84.01
76040	Gasket ring	24	2	2	16	155.68	769.24	725.18
AL-01E	Gasket	192	2	16	140	46.20	1,940.50	1,585.58
100088	O-ring	264	2	18	140	2.10	134.55	156.77
100096	Main bearing	120	2	10	90	174.00	4,643.60	3,922.14

Item No.	Description	D	D / Q	ss_1	S_1	Unit Value USD	TIC in USD for year 2005	TIC in USD for year 2006
100097	Main bearing shell	120	2	10	90	174.00	4,643.60	3,922.14
100111	D- Seal	432	3	27	300	23.18	2,138.29	2,010.30
100112	Thrust washer	48	2	3	30	213.21	1,949.70	1,904.34
100113	Flywheel bearing	24	2	2	16	168.92	830.41	799.67
100156	Antipolishing ring	216	2	18	140	205.87	8,338.33	9,857.94
111004	Big end bearing	216	2	18	140	165.83	6,726.31	7,955.24
111005	Big end bearing	216	2	18	140	165.83	6,726.31	7,955.24
111019	Shim	216	2	18	140	493.00	19,898.18	23,504.36
113001	Piston Crown	48	2	3	30	3127.00	27,911.57	26,904.66
113013	Piston Ring Set	216	2	18	140	565.00	22,796.90	26,923.80
120009	Exhaust Seat	96	2	8	80	476.76	11,377.81	8,570.86
120022	Valve Guide	96	2	8	80	101.28	2,456.41	1,879.81
120028	Allen Screw	48	2	3	30	1.59	64.17	88.64
120065	Sealing set	216	2	18	140	154.61	6,274.60	7,422.07
121006	Exhaust Valve	216	2	18	140	645.00	26,017.70	30,725.40
121010	Inlet valve	48	2	3	30	156.02	1,440.14	1,413.65
121033	Disk	240	2	20	220	69.07	4,608.62	3,152.07
121062	Ball	360	2	30	380	2.10	292.55	208.05
121063	Retainer ring	72	2	6	80	1.28	81.26	91.90
123001	O-ring	108	2	9	100	2.10	113.06	117.27
123025	Seal Ring	108	2	9	100	2.10	113.06	117.27
125447	Sealing Set	24	2	2	16	5.04	73.28	96.62
131007	Bush	24	2	2	16	126.69	635.31	618.50
131032	Allen Screw	144	2	4	102	2.10	117.91	132.52
131033	Allen Screw	288	2	24	230	2.10	192.76	180.33
131034	Allen Screw	288	2	24	230	2.10	192.76	180.33
145003	O-ring	48	2	3	30	1.50	63.36	87.87
145008	O-ring	96	2	8	90	3.25	137.95	57.92
145010	O-ring	48	2	3	30	2.10	68.71	93.02
148011	Camshaft bearing	24	2	2	16	159.09	784.99	757.50
148013	Allen Screw	408	2	34	300	2.10	234.34	233.70
148014	Allen Screw	180	2	15	180	2.10	164.35	144.99
181160	Gasket	12	2	1	14	4.10	67.59	81.77
200011	Gasket	144	2	4	102	18.70	654.76	587.19
200014	Two-part ring	12	2	1	14	227.63	1,026.53	600.81
200015	Allen Screw	288	2	24	230	2.99	253.26	125.16
200016	Nut 10mm	288	2	24	230	2.10	192.76	180.34
200026	Allen Screw	144	2	12	102	4.43	181.57	196.34
200138	Stud	60	2	5	65	19.25	431.15	290.99
200139	Lock Nut	60	2	5	65	3.83	125.83	117.97
211016	O-ring	12	2	1	14	2.10	59.00	79.85
224040	Lock Nujt	48	2	3	30	2.10	68.71	93.02
228003	Hex. Screw	48	2	3	30	2.10	68.71	93.02
228032	Spring	12	2	1	14	4.74	70.33	85.95
228042	O-Ring	24	2	2	16	5.60	75.87	99.02

Item No.	Description	D	D / Q	ss_1	S_1	Unit Value USD	TIC in USD for year 2005	TIC in USD for year 2006
228043	O-Ring	12	2	1	14	5.60	74.02	87.94
228046	Gasket	12	2	1	14	2.37	60.17	80.47
228204	Male stud,	12	2	1	14	2.10	59.10	79.85
228279	Repair kit	12	2	1	14	81.40	399.21	263.03
352013	O-ring	12	2	1	14	5.20	72.31	87.01
352245	O-ring	12	2	1	14	9.58	91.10	97.13
352459	O-ring	12	2	1	14	1.57	56.73	78.63
352460	O-ring for flap	24	2	2	16	2.91	63.44	87.48
355002	Gasket	48	2	3	30	2.10	68.71	93.02
355011	Gasket	48	2	3	30	5.40	98.11	121.33
355025	O-Ring	24	2	2	16	2.10	59.70	84.01
357018	Gasket O-ring	24	2	2	16	1.57	57.25	81.74
						TOTAL:	**260,770.69**	**256,329.19**

It is observed that in previous year total incremental cost was $260,770.69 and by using scientific material management system total incremental cost becomes $256,329.19, which reduces 1.70% cost with covering extra 5% plant factor and more 19 schedule maintenance of which total incremental cost is USD 21,938.08. If this value is deducted from existing figure then it becomes 10.12% (USD 26,379.58) lower in comparison with previous year. If the Plant follows this system then it will save USD 263,795.80 in ten years.

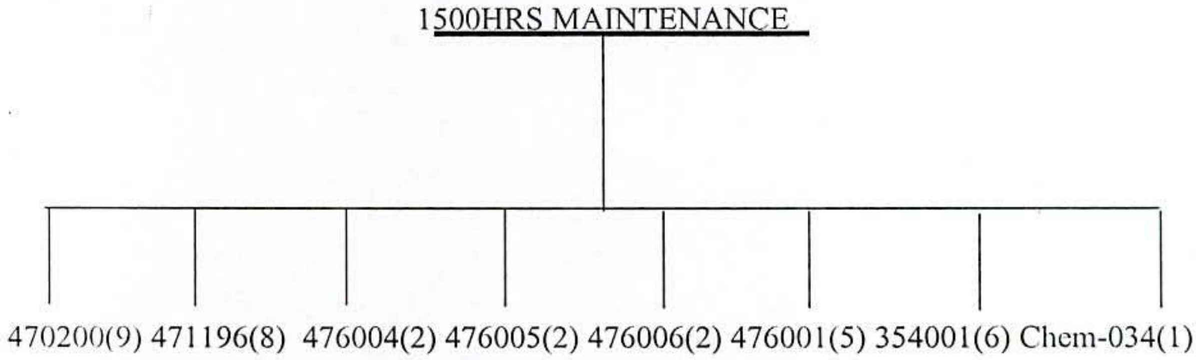
4.4 Material Requirement Planning of the Plant

1500 hrs. maintenance parts are taken as sample for materials requirement planning. Master schedule specifies how much maintenance shall be carried out monthly. Bill-of-materials specifies the "recipe" of 1500hrs. maintenance which shows how a maintenance is completed from different spare parts. From master schedule and bill-of-materials total requirements of different spare parts are calculated. MRP determines the net requirement of each part on a period-by-period basis. It acts as a bridge between inventory management and maintenance schedules.

Table 4.2
MRP SCHEDULE FOR 1500HRS MAINTENANCE

MASTER SCHEDULE FOR 1500HRS MAINTENANCE PARTS												
Month number	1	2	3	4	5	6	7	8	9	10	11	12
Requirements	8	7	4	12	6	9	6	8	5	7	6	3

BILL-OF-MATERALS



MRP Schedule for 1500hrs. Maintenance

Master Schedule for 1500hrs. Maintenance

Month number	1	2	3	4	5	6	7	8	9	10	11	12
Requirements	8	7	4	12	6	9	6	8	5	7	6	3

Component MRP Schedule

Fuel Filter L= 90days	Gross requirements	72	63	36	108	54	81	54	72	45	63	54	27
Order size=279, 261, 189	On hand	200	128	65	308	200	146	65	272	200	155	92	227
	Net requirements	-128	-65	-29	-200	-146	-65	-11	-200	-155	-92	-38	-200
	Schedule receipts			279				261				189	
	Planned order release	279			261				189				
Lube Filter L= 90days	Gross requirements	64	56	32	96	48	72	48	64	40	56	48	24
Order size=279, 261, 189	On hand	175	111	55	271	175	127	55	239	175	135	79	199
	Net requirements	-111	-55	-23	-175	-127	-55	-7	-175	-135	-79	-31	-175
	Schedule receipts			248				232				168	
	Planned order release	248			232				168				

Gasket L= 90days Order size=62, 58, 42	Gross requirements	16	14	8	24	12	18	12	16	10	14	12	6
	On hand	44	28	14	68	44	32	14	60	44	34	62	50
	Net requirements	-28	-14	-6	-44	-32	-14	-2	-44	-34	-20	-50	-44
	Schedule receipts			62				58				42	
	Planned order release	62			58				42				
Gasket L= 90days Order size=62, 58, 42	Gross requirements	16	14	8	24	12	18	12	16	10	14	12	6
	On hand	44	28	14	68	44	32	14	60	44	34	62	50
	Net requirements	-28	-14	-6	-44	-32	-14	-2	-44	-34	-20	-50	-44
	Schedule receipts			62				58				42	
	Planned order release	62			58				42				
Gasket L= 90days Order size=62, 58, 42	Gross requirements	16	14	8	24	12	18	12	16	10	14	12	6
	On hand	44	28	14	68	44	32	14	60	44	34	20	50
	Net requirements	-28	-14	-6	-44	-32	-14	-2	-44	-34	-20	-8	-44
	Schedule receipts			62				58				42	
	Planned order release	62			58				42				
Screw L= 90days Order size=155, 145, 105	Gross requirements	40	35	20	60	30	45	30	40	25	35	30	15
	On hand	110	70	35	170	110	80	35	150	110	85	50	125
	Net requirements	-70	-35	-15	-110	-80	-35	-5	-110	-85	-50	-20	-110
	Schedule receipts			155				145				105	
	Planned order release	155			145				105				
Gasket L= 90days Order size=186, 174, 126	Gross requirements	48	42	24	72	36	54	36	48	30	42	36	18
	On hand	130	82	40	202	130	94	40	178	130	100	58	148
	Net requirements	-82	-40	-16	-130	-94	-40	-4	-130	-100	-58	-22	-130
	Schedule receipts			186				174				126	
	Planned order release	186			174				126				

Cleaning Chemical L= 90days Order size=31, 29, 21	Gross requirements	8	7	4	12	6	9	6	8	5	7	6	3
	On hand	23	15	8	35	23	17	8	31	23	18	11	26
	Net requirements	-15	-8	-4	-23	-17	-8	-2	-23	-18	-11	-5	23
	Schedule receipts			31				29				21	
	Planned order release	31			29				21				

CHAPTETR 5

Discussion and Recommendation

5.1 Discussion

The Plant is passing through middle portion of its estimated life. So, its unscheduled maintenance is rare. The Plant management mainly maintains schedule maintenance. In general, the schedule maintenance is normally deterministic and the design of inventory systems is influenced by dependent demand. Our discussion so far pertains to the terms with dependent demand. The Plant gets an idea of annual power demand from BPDP. Based on BPDP's power demand, Operation department determines annual plant factor and Maintenance department makes annual maintenance schedule depending on plant factor. Logistics converts number of schedule maintenance into annual spare parts demand, review period spare parts demand and places orders accordingly. But, a power plant is a public-interest company and power acts as a vital energy in modern civilization. So, it is important to run the Plant continuously. As a result, the Plant always maintains a safety stock to avoid unexpected breakdown. Reasonable safety stocks of all items are suggested in this research, which will meet the extreme fluctuation in demand during lead time.

Theoretically, (R,s,S) system is appropriate when tight control is necessary, e.g. for class A items. Reorder point is the base-stock of the system. Relying on a reorder point replenishment actions are taken. But the Plant uses the (R,s,S) system for all type of spare parts to show a high degree of responsiveness to meet demand rate. Reorder point answers the question when to order in the system. It has been observed that existing reorder points in the Plant's system are not set analytically. So, the Plant has to face overstocking which in turn increases capital investment on spare parts management. Reorder points of schedule maintenance parts are shown in this research by analytical calculation.

Lead time is an important factor in placing an order. The ordered quantity depends on lead time. The Plant's calculated lead time is 90 days and review period 30 days. So, the Plant can place maximum three orders in a year. For lengthy lead time, it has to place order of large quantity. In the obtained data of previous year, it has been observed that the Plant's tendency is to bring yearly demand by placing two or a single order. In this research work, it has been shown that three orders can meet yearly variable demand easily. It reduces holding cost but increases ordering cost in the Plant. Ordering cost entirely depends on the salary of the employee of the purchase department. So, ordering cost is almost constant in the Plant. If for a given period actual demand is less than expected, extra inventory is left, which increases the holding cost. Therefore, there is no reason in decreasing ordering cost. The calculated holding cost in the Plant is 66% of unit value of an item and ordering cost is $25/order/item. Holding cost plays a vital role in increasing or decreasing of total incremental cost. The objective of this research was to reach a balance between the extra holding cost and the ordering cost.
During ABC classification out of 122 (one hundred twenty two) items those are required to perform the planned maintenance job, only 14(fourteen) items are graded as class A items. But all items are equally important from maintenance point of view. Without shortage of any item the maintenance task cannot be done successfully. So, from maintenance point of view all 122 (one hundred twenty two) items are regarded critical. Inventory fluctuation pattern for each maintenance job is same due to same lead time but difference in demand. For demand calculation, working days are considered 365 days in a year due to nonstop power producing organization. It is also observed that all the item's stock positions have dropped to reorder point or lower at first review period.

In comparing total incremental cost with the data of previous year, it is found that most of the low valued (class C) items are having lower holding cost than ordering cost. So, total incremental cost of these items becomes lower. Again, there is no benefit in decreasing ordering cost for C class items in the Plant. On the contrary, reducing holding cost, it is shown in this research that the total incremental cost of 2006 is 1.70% lower after covering extra 5% plant factor and 19 more schedule maintenance (in 2006 plant factor was 75% with 222 maintenance and in 2005 plant factor was 70% with 203 maintenance) of which total incremental cost is USD 21,938.08. If this value is deducted from existing figure then it becomes 10.12% lower in comparison with previous year. Total inventory cost is not compared because it is largely influenced by purchase cost.

The Materials Requirement Planning (MRP) may act as a bridge between Logistics and Maintenance department. But, the Plant does not maintain MRP. As a result, it has to face communication gap among the departments. MRP of 1500hrs. maintenance is shown in this research as a sample.

However, the developed Spare Parts management system will cover the followings if implemented in the plant-

- Shall reduce total incremental cost by reducing overstock. Overstocking is an extension of inventory holding cost. Excess materials that are held in the stock incur expenditure in the form of capital cost, storage cost, handling cost etc. Hence, return on investment shall be increased.

- Shall gear up warehousing activities by ensuring timely procurement and by reducing overstocking. Overstocking requires extra space and reduces shelf lives of items. The system will establish certain norms for storage- the levels of stock to be held within the financial and environmental constraints so that the best possible service can be provided to maintenance department.

- Shall protect against the stock-out of spares by stocking a reasonable safety stock. Stock out is an unusual phenomenon and is immediately reflected due to unexpected increase in consumption rate or breakdown during lead time.

- Shall answer the questions when and how much to order. Stock-out cost is always greater than inventory holding cost and hence, the tendency to order more. The policy will help to identify the reasons for high level of stocks and the executives to arrive at optimum levels of inventories.

In this research work, ABC classification, reorder point setting, safety stock, total incremental cost comparison and MRP are done. Moreover, following recommendations may be considered for further improvement.

1) For class C items, the Plant shall follow-up (s,Q) system for reducing ordering cost.

2) The Plant can reduce lead time by increasing communicative activities. Lead time is an important factor in placing replacement order. The Plant's lead time is lengthy. If lead time is decreased then the Plant can place more order in number. As a result, capital tight up in spare Parts will reduce.

3) The Plant can use MRP. It will reduce communication gap among the departments and enhance coordination between Maintenance, Logistics and Operation department.

4) To get discounts facilities and alternative source of spare parts supplier may be enlisted. It will reduce dependency of single supplier.

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APPENDIX

Table 3.1

Maintenance Projection for Year 2006: Based on 90% Plant factor of 6 (six) EGB (Exhaust gas boiler) engines and 67% plant factor of 13 (thirteen) non EGB engines.

Eng. No.	RH on 6/1/06	RH during the year	RH at the end of year	1500 hrs Maint.	2000 hrs Maint	3000 hrs Maint	4000 hrs Maint	6000 hrs Maint	9000 hrs Maint	12000 hrs Maint
1T1	39893	7884	47777	5	4	2	2	1	1	x
2T1	39657	7884	47541	5	4	2	2	1	1	x
3T1	29534	5869	35403	4	x	2	1	1	x	x
4T1	33631	5869	39500	4	x	2	1	1	1	1
5T1	31991	5869	37860	4	x	2	2	1	1	1
6T1	33735	5869	39604	4	x	2	1	1	1	1
7T1	34156	5869	40025	4	x	2	2	1	1	1
8T1	35483	5869	41352	4	x	2	2	1	1	1
9T1	42840	7884	50724	5	4	2	2	1	1	1
1T3	42233	7884	50117	5	4	2	2	1	1	1
2T3	42862	7884	50746	5	4	2	2	1	1	1
3T3	34485	5869	40354	4	x	2	2	1	1	1
4T3	30517	5869	36386	4	x	2	2	1	1	1
5T3	29957	5869	35826	4	x	2	1	1	x	x
6T3	35848	5869	41717	4	x	2	2	1	1	1
7T3	30011	5869	35880	4	x	1	1	x	x	x
8T3	36978	5869	42847	4	x	2	1	1	x	x
9T3	30928	5869	36797	4	x	2	2	1	1	1
10T3	41586	7884	49470	5	4	3	2	2	1	1
Total:				**81**	**24**	**38**	**32**	**19**	**15**	**13**

* 2000 hrs maintenance are carried out only in EGB engines. But same spares (2000 hrs maintenance parts) are required for 4000 hrs maintenance for non EGB engines.

* 1T1,2T1,9T,1T3,2T3 &10T3 are EGB Engines and rest are non EGB Engines

Table 3.2

Maintenance schedule during 1 st review period: Based on 90% plant factor of 6 (six) EGB engines and 58% plant factor of 13(thirteen) non EGB engines.

Eng. No.	RH on 6/1/06	RH in 31days interval	RH on 6/2/06 days	1500 hrs Maint.	2000 hrs Maint.	3000 hrs Maint	4000 hrs Maint.	6000 hrs Maint.	9000 hrs Maint.	12000 hrs Maint.
1T1	39893	669	40562	1	1		1			
2T1	39657	669	40326		1		1			
3T1	29534	431	29965							
4T1	33631	431	34062							
5T1	31991	431	32422				1			
6T1	33735	431	34166							
7T1	34156	431	34587	1						
8T1	35483	431	35914							
9T1	42840	669	43509	1						
1T3	42233	669	42902							
2T3	42862	669	43531	1						
3T3	34485	431	34916	1						
4T3	30517	431	30948							
5T3	29957	431	30388	1		1		1		
6T3	35848	431	36279	1		1	1	1	1	1
7T3	30011	431	30442							
8T3	36978	431	37409							
9T3	30928	431	31359							
10T3	41586	669	42255	1	1	1		1		
			Total:	**8**	**3**	**3**	**4**	**3**	**1**	**1**

Table 3.3

Maintenance schedule during 2nd review period: Based on 90% plant factor of 6 (six) EGB engines and 65% plant factor of 13(thirteen) non EGB engines.

Eng. No.	RH on 6/2/06	RH in 28 days interval	RH on 6/3/06 days	1500 hrs Maint	2000 hrs Maint	3000 hrs Maint	4000 hrs Maint	6000 hrs Maint	9000 hrs Maint	12000 hrs Maint
1T1	40562	604	41166							
2T1	40326	604	40930	1						
3T1	29965	437	30402	1		1		1		
4T1	34062	437	34499							
5T1	32422	437	32859							
6T1	34166	437	34603	1						
7T1	34587	437	35024							
8T1	35914	437	36351	1		1	1	1	1	1
9T1	43509	604	44113		1		1			
1T3	42902	604	43506	1						
2T3	43531	604	44135		1		1			
3T3	34916	437	35353							
4T3	30948	437	31385							
5T3	30388	437	30825							
6T3	36279	437	36716							
7T3	30442	437	30879							
8T3	37409	437	37846	1						
9T3	31359	437	31796	1						
10T3	42255	604	42859							
			Total:	**7**	**2**	**2**	**3**	**2**	**1**	**1**

Table 3.4

Maintenance schedule during 3rd review period: Based on 90% plant factor of 6 (six) EGB engines and 80% plant factor of 13(thirteen) non EGB engines.

Eng. No.	RH on 6/3/06	RH in 31 days interval	RH on 6/4/06 days	1500 hrs Maint	2000 hrs Maint	3000 hrs Maint	4000 hrs Maint	6000 hrs Maint	9000 hrs Maint	12000 hrs Maint
1T1	41166	669	41835							
2T1	40930	669	41599							
3T1	30402	595	30997							
4T1	34499	595	35094	1						
5T1	32859	595	33454	1		1				
6T1	34603	595	35198							
7T1	35024	595	35619							
8T1	36351	595	36946							
9T1	44113	669	44782							
1T3	43506	669	44175		1		1			
2T3	44135	669	44804							
3T3	35353	595	35948							
4T3	31385	595	31980	1						
5T3	30825	595	31420							
6T3	36716	595	37311							
7T3	30879	595	31474							
8T3	37846	595	38441							
9T3	31796	595	32391				1			
10T3	42859	669	43528							
			Total:	**4**	**1**	**1**	**2**	**0**	**0**	**0**

Table 3.5

Maintenance schedule during first 15days interval: Based on 90% plant factor of 6 (six) EGB engines and 80% plant factor of 13(thirteen) non EGB engines.

Eng. No.	RH on 6/4/06	RH in 15 days interval	RH on 21/4/06 days	1500 hrs Maint	2000 hrs Maint	3000 hrs Maint	4000 hrs Maint	6000 hrs Maint	9000 hrs Maint	12000 hrs Maint
1T1	41835	324	42159	1	1	1		1		
2T1	41599	324	41923							
3T1	30997	288	31285							
4T1	35094	288	35382							
5T1	33454	288	33742							
6T1	35198	288	35486							
7T1	35619	288	35907							
8T1	36946	288	37234							
9T1	44782	324	45106	1		1			1	
1T3	44175	324	44499							
2T3	44804	324	45128	1		1			1	
3T3	35948	288	36236	1		1	1	1	1	1
4T3	31980	288	32268				1			
5T3	31420	288	31708	1						
6T3	37311	288	37599	1						
7T3	31474	288	31762	1						
8T3	38441	288	38729							
9T3	32391	288	32679							
10T3	43528	324	43852							
			Total:	**7**	**1**	**4**	**2**	**2**	**3**	**1**

Table 3.6

Maintenance schedule during rest 15days interval: Based on 90% plant factor of 6 (six) EGB engines and 80% plant factor of 13(thirteen) non EGB engines.

Eng. No.	RH on 21/4/06	RH in 15 days interval	RH on 6/5/06 days	1500 hrs Maint	2000 hrs Maint	3000 hrs Maint	4000 hrs Maint	6000 hrs Maint	9000 hrs Maint	12000 hrs Maint
1T1	42159	324	42483							
2T1	41923	324	42247	1	1	1		1		
3T1	31285	288	31573	1						
4T1	35382	288	35670							
5T1	33742	288	34030							
6T1	35486	288	35774							
7T1	35907	288	36195	1		1	1	1	1	1
8T1	37234	288	37522	1						
9T1	45106	324	45430							
1T3	44499	324	44823							
2T3	45128	324	45452							
3T3	36236	288	36524							
4T3	32268	288	32556							
5T3	31708	288	31996							
6T3	37599	288	37887							
7T3	31762	288	32050				1			
8T3	38729	288	39017	1		1				
9T3	32679	288	32967							
10T3	43852	324	44176		1		1			
			Total:	**5**	**2**	**3**	**3**	**2**	**1**	**1**

Table 3.7

Maintenance schedule during 5th review period: Based on 90% plant factor of 6 (six) EGB engines and 80% plant factor of 13(thirteen) non EGB engines.

Eng. No.	RH on 6/5/06	RH in 31 days interval	RH on 6/6/06 days	1500 hrs Maint	2000 hrs Maint	3000 hrs Maint	4000 hrs Maint	6000 hrs Maint	9000 hrs Maint	12000 hrs Maint
1T1	42483	669	43152							
2T1	42247	669	42916							
3T1	31573	595	32168				1			
4T1	35670	595	36265	1		1	1	1	1	1
5T1	34030	595	34625	1						
6T1	35774	595	36369	1		1	1	1	1	1
7T1	36195	595	36790							
8T1	37522	595	38117							
9T1	45430	669	46099		1					
1T3	44823	669	45492	1		1			1	
2T3	45452	669	46121		1					
3T3	36524	595	37119							
4T3	32556	595	33151	1		1				
5T3	31996	595	32591				1			
6T3	37887	595	38482							
7T3	32050	595	32645							
8T3	39017	595	39612							
9T3	32967	595	33562	1		1				
10T3	44176	669	44845							
			Total:	**6**	**2**	**5**	**4**	**2**	**3**	**2**

Table 3.8

Maintenance schedule during 6th review period: Based on 90% plant factor of 6 (six) EGB engines and 80% plant factor of 13(thirteen) non EGB engines.

Eng. No.	RH on 6/6/06	RH in 30 days interval	RH on 6/7/06 days	1500 hrs Maint	2000 hrs Maint	3000 hrs Maint	4000 hrs Maint	6000 hrs Maint	9000 hrs Maint	12000 hrs Maint
1T1	43152	648	43800	1						
2T1	42916	648	43564	1						
3T1	32168	576	32744							
4T1	36265	576	36841							
5T1	34625	576	35201							
6T1	36369	576	36945							
7T1	36790	576	37366							
8T1	38117	576	38693							
9T1	46099	648	46747	1						
1T3	45492	648	46140		1					
2T3	46121	648	46769	1						
3T3	37119	576	37695	1						
4T3	33151	576	33727							
5T3	32591	576	33167	1		1				
6T3	38482	576	39058	1		1				
7T3	32645	576	33221	1		1				
8T3	39612	576	40188				1			
9T3	33562	576	34138							
10T3	44845	648	45493	1		1			1	
			Total:	**9**	**1**	**4**	**1**	**0**	**1**	**0**

Table 3.9

Maintenance schedule during 7th review period: Based on 90% plant factor of 6 (six) EGB engines and 70% plant factor of 13(thirteen) non EGB engines.

Eng. No.	RH on 6/7/06	RH in 31 days interval	RH on 6/8/06 days	1500 hrs Maint	2000 hrs Maint	3000 hrs Maint	4000 hrs Maint	6000 hrs Maint	9000 hrs Maint	12000 hrs Maint
1T1	43800	669	44469		1		1			
2T1	43564	669	44233		1		1			
3T1	32744	521	33265	1		1				
4T1	36841	521	37362							
5T1	35201	521	35722							
6T1	36945	521	37466							
7T1	37366	521	37887	1						
8T1	38693	521	39214	1		1				
9T1	46747	669	47416							
1T3	46140	669	46809	1						
2T3	46769	669	47438							
3T3	37695	521	38216							
4T3	33727	521	34248							
5T3	33167	521	33688							
6T3	39058	521	39579							
7T3	33221	521	33742							
8T3	40188	521	40709	1						
9T3	34138	521	34659	1						
10T3	45493	669	46162		1					
			Total:	**6**	**3**	**2**	**2**	**0**	**0**	**0**

Table 3.10

Maintenance schedule during 8th review period: Based on 90% plant factor of 6 (six) EGB engines and 65% plant factor of 13(thirteen) non EGB engines.

Eng. No.	RH on 6/8/06	RH in 31 days interval	RH on 6/9/06 days	1500 hrs Maint	2000 hrs Maint	3000 hrs Maint	4000 hrs Maint	6000 hrs Maint	9000 hrs Maint	12000 hrs Maint
1T1	44469	669	45138	1		1			1	
2T1	44233	669	44902							
3T1	33265	483	33748							
4T1	37362	483	37845	1						
5T1	35722	483	36205	1		1	1	1	1	1
6T1	37466	483	37949	1						
7T1	37887	483	38370							
8T1	39214	483	39697							
9T1	47416	669	48085	1	1	1	1	1		1
1T3	46809	669	47478							
2T3	47438	669	48107	1	1	1	1	1		1
3T3	38216	483	38699							
4T3	34248	483	34731	1						
5T3	33688	483	34171							
6T3	39579	483	40062				1			
7T3	33742	483	34225							
8T3	40709	483	41192							
9T3	34659	483	35142							
10T3	46162	669	46831	1						
			Total:	**8**	**2**	**4**	**4**	**3**	**2**	**3**

Table 3.11

Maintenance schedule during 9th review period: Based on 90% plant factor of 6 (six) EGB engines and 60% plant factor of 13(thirteen) non EGB engines.

Eng. No.	RH on 6/9/06	RH in 30 days interval	RH on 6/10/06 days	1500 hrs Maint	2000 hrs Maint	3000 hrs Maint	4000 hrs Maint	6000 hrs Maint	9000 hrs Maint	12000 hrs Maint
1T1	45138	648	45786							
2T1	44902	648	45550	1		1			1	
3T1	33748	432	34180							
4T1	37845	432	38277							
5T1	36205	432	36637							
6T1	37949	432	38381							
7T1	38370	432	38802							
8T1	39697	432	40129				1			
9T1	48085	648	48733							
1T3	47478	648	48126	1	1	1	1	1		1
2T3	48107	648	48755							
3T3	38699	432	39131	1		1				
4T3	34731	432	35163							
5T3	34171	432	34603	1						
6T3	40062	432	40494							
7T3	34225	432	34657	1						
8T3	41192	432	41624							
9T3	35142	432	35574							
10T3	46831	648	47479							
				5	**1**	**3**	**2**	**1**	**1**	**1**

Table 3.12

Maintenance schedule during 10th review period: Based on 90% plant factor of 6 (six) EGB engines and 58% plant factor of 13(thirteen) non EGB engines.

Eng. No.	RH on 6/10/06	RH in 30 days interval	RH on 6/11/06 days	1500 hrs Maint	2000 hrs Maint	3000 hrs Maint	4000 hrs Maint	6000 hrs Maint	9000 hrs Maint	12000 hrs Maint
1T1	45786	669	46455		1					
2T1	45550	669	46219		1					
3T1	34180	431	34611	1						
4T1	38277	431	38708							
5T1	36637	431	37068							
6T1	38381	431	38812							
7T1	38802	431	39233	1		1				
8T1	40129	431	40560	1						
9T1	48733	669	49402							
1T3	48126	669	48795							
2T3	48755	669	49424							
3T3	39131	431	39562							
4T3	35163	431	35594							
5T3	34603	431	35034							
6T3	40494	431	40925	1						
7T3	34657	431	35088							
8T3	41624	431	42055	1		1		1		
9T3	35574	431	36005	1		1	1	1	1	1
10T3	47479	669	48148	1	1	1	1	1		1
			Total:	**7**	**3**	**4**	**2**	**3**	**1**	**2**

Table 3.13

Maintenance schedule during 11th review first 15days interval: Based on 90% plant factor of 6 (six) EGB engines and 55% plant factor of 13(thirteen) non EGB engines.

Eng. No.	RH on 6/11/06	RH in 15 days interval	RH on 21/11/06 days	1500 hrs Maint	2000 hrs Maint	3000 hrs Maint	4000 hrs Maint	6000 hrs Maint	9000 hrs Maint	12000 hrs Maint
1T1	46455	324	46779	1						
2T1	46219	324	46543	1						
3T1	34611	198	34809							
4T1	38708	198	38906							
5T1	37068	198	37266							
6T1	38812	198	39010	1		1				
7T1	39233	198	39431							
8T1	40560	198	40758							
9T1	49402	324	49726	1						
1T3	48795	324	49119							
2T3	49424	324	49748	1						
3T3	39562	198	39760							
4T3	35594	198	35792							
5T3	35034	198	35232							
6T3	40925	198	41123							
7T3	35088	198	35286							
8T3	42055	198	42253							
9T3	36005	198	36203							
10T3	48148	324	48472							
			Total:	**5**	**0**	**1**	**0**	**0**	**0**	**0**

Table 3.14

Maintenance schedule during 11th review rest 15days interval: Based on 90% plant factor of 6 (six) EGB engines and 55% plant factor of 13(thirteen) non EGB engines.

Engine No.	RH on 21/11/06	RH in 15 days interval	RH on 6/12/06 days	1500 hrs Maint	2000 hrs Maint	3000 hrs Maint	4000 hrs Maint	6000 hrs Maint	9000 hrs Maint	12000 hrs Maint
1T1	46779	324	47103							
2T1	46543	324	46867							
3T1	34809	198	35007							
4T1	38906	198	39104	1		1				
5T1	37266	198	37464							
6T1	39010	198	39208							
7T1	39431	198	39629							
8T1	40758	198	40956							
9T1	49726	324	50050		1					
1T3	49119	324	49443							
2T3	49748	324	50072		1					
3T3	39760	198	39958							
4T3	35792	198	35990							
5T3	35232	198	35430							
6T3	41123	198	41321							
7T3	35286	198	35484							
8T3	42253	198	42451							
9T3	36203	198	36401							
10T3	48472	324	48796							
			Total:	**1**	**2**	**1**	**0**	**0**	**0**	**0**

Table 3.15

Maintenance schedule during 12th review period: Based on 90% plant factor of 6 (six) EGB engines and 53% plant factor of 13(thirteen) non EGB engines.

Eng. No.	RH on 6/12/06	RH in 15 days inter val	RH on 6/1/07 days	1500 hrs Mai nt	2000 hrs Mai nt	3000 hrs Mai nt	4000 hrs Mai nt	6000 hrs Mai nt	9000 hrs Mai nt	12000 hrs Maint
1T1	47103	669	47772							
2T1	46867	669	47536							
3T1	35007	394	35401							
4T1	39104	394	39498							
5T1	37464	394	37858	1						
6T1	39208	394	39602							
7T1	39629	394	40023				1			
8T1	40956	394	41350							
9T1	50050	669	50719							
1T3	49443	669	50112	1	1					
2T3	50072	669	50741							
3T3	39958	394	40352				1			
4T3	35990	394	36384	1		1	1	1	1	1
5T3	35430	394	35824							
6T3	41321	394	41715							
7T3	35484	394	35878							
8T3	42451	394	42845							
9T3	36401	394	36795							
10T3	48796	669	49465							
			Total:	**3**	**1**	**1**	**3**	**1**	**1**	**1**

Table 3.16

Annual Demands of spares for 1500 hrs Maintenance:

Item no.	Description	Required/ Maint.	No. of Maint.	Annual demand
470200	Fuel Filter	9	81	729
471196	Lube oil Filter	8	81	648
476004	Gasket	2	81	162
476005	Gasket	2	81	162
476006	Gasket	2	81	162
476001	Screw	5	81	405
354001	Gasket	6	81	486
Chem-034	Cleaning chemical	1	81	81

Table 3.17

Annual Demands of spares for 2000 hrs Maintenance:

Item no.	Description	Required/ Maint.	No. of Maint.	Annual demand
167011	Push rod	1	(24 + 20) = 44	44
167020	Nozzle	18	(24 + 20) = 44	792
167008	O-Ring	6	(24 + 20) = 44	264
167012	Cylindrical Pin	10	(24 + 20) = 44	440

* 2000 hrs maintenance are carried out only in EGB engines. But same spares (2000 hrs maintenance parts)
are required for 4000 hrs maintenance for non EGB engines.

Table 3.18

Annual Demands of spares for 3000 hrs Maintenance

Item no.	Description	Required/ Maint.	No. of Maint.	Annual demand
191052	O-Ring	1	38	38
354100	Gasket	2	38	76
354064	Gasket	1	38	38
354102	Gasket	1	38	38

Table 3.19

Annual Demands of spares for 4000 hrs Maintenance

Item no.	Description	Required/ Maint.	No. of Maint.	Annual demand
350421	Screw	24	32	768
131030	O-Ring	3	32	96
131031	O-Ring	3	32	96
167008	O-Ring	6	32	120
167012	Cylindrical Pin	10	32	200
167020	Nozzle	18	32	360
167011	Cylindrical Pin	1	32	20
167264	O-Ring	6	32	192
350184	O-Ring	4	32	128
357007	O-Ring	1	32	32
357012	O-Ring	1	32	32
350018	O-Ring	72	32	2304
378002	O-Ring	2	32	64
476012	Sleeve	2	32	64
156015	Gasket	2	32	64
156016	Gasket	1	32	32
350479	O-Ring	10	32	320
167265	O-Ring	12	32	384

Table 3.20

Annual Demands of spares for 6000 hrs Maintenance

Item no.	Description	Required/ Maint.	No. of Maint.	Annual demand
165003	O-Ring	18	18	324
165004	O-Ring	18	18	324
165014	O-Ring	18	18	324
165020	Sealing-ring	36	18	648
165031	O-Ring	6	18	108
165037	Sealing-ring	6	18	108
165105	O-Ring	18	18	324
165122	Retainer Ring	6	18	108
165173	Spring	18	18	324
165174	Shot	18	18	324
165175	Limiter	18	18	324
165200	Supporting Ring	36	18	648
165267	Sealing-ring	18	18	324
165280	Teflon-ring	18	18	324
167003	O-Ring	18	18	324

Table 3.21

Annual Demands of spares for 9000 hrs Maintenance

Item no.	Description	Required/ Maint.	No. of Maint.	Annual demand
191009	Bearing	2	15	30
191010	Bearing	2	15	30
191013	Radial Seal	2	15	30
191015	Shaft Seal	2	15	30
191043	Dry lock Screw	8	15	120
191044	Pair of friction ring	2	15	30
191045	Pair of friction ring	2	15	30
191054	Flinger	2	15	30

Table 3.22

Annual Demands of spares for 12000 hrs Maintenance

Item no.	Description	Required/ Maint.	No. of Maint.	Annual demand
32100	Bearing unit Compressor end	2	13	26
34100	Bearing unit Turbine end	2	13	26
51019	Hex, headed screw 51019/51015	12	13	156
51015	Hex, headed screw 51019/51015	12	13	156
51020	Locking plate 51020/51016	12	13	156
51049	Locking plate/ Gas inlet casing	12	13	156
52801	Gasket	8	13	104
76022	Locking washer for bearing bolt	2	13	26
76040	Gasket ring	2	13	26
AL-01E	Gasket	16	13	208
100088	O-ring	22	13	286
100096	Main bearing shell, upper	10	13	130
100097	Main Bearing shell, Lower	10	13	130
100111	D- Seal	36	13	468
100112	Thrust washer	4	13	52
100113	Flywheel thrust bearing shell	2	13	26
100156	Antipolishing ring	18	13	234
111004	Big end bearing shell upper	18	13	234
111005	Big end bearing shell lower	18	13	234
111019	Shim	18	13	234
113001	Piston Crown	4	13	52
113013	Piston Ring Set	18	13	234
120009	Seat Ring, Exhaust	8	13	104
120022	Valve Guide	8	13	104
120028	Allen Screw	4	13	52
120065	Sealing set for cylinder head	18	13	234
121006	Exhaust Valve	18	13	234
121010	Inlet valve	4	13	52
121033	Disk	20	13	260
121062	Ball	30	13	390
121063	Retainer ring	6	13	78
123001	O-ring	9	13	117
123025	Seal Ring	9	13	117
125447	Sealing Set	2	13	26
131007	Bush	2	13	26
131032	Allen Screw	12	13	156
131033	Allen Screw	24	13	312
131034	Allen Screw	24	13	312
145003	O-ring	4	13	52

Item no.	Description	Required/ Maint.	No. of Maint.	Annual demand
145008	O-ring	8	13	104
145010	O-ring	4	13	52
148011	Camshaft Bearing Bush	2	13	26
148013	Allen Screw	34	13	442
148014	Allen Screw	15	13	195
181160	Gasket	1	13	13
200011	Gasket	12	13	156
200014	Two-part ring	1	13	13
200015	Allen Screw	24	13	312
200016	Nut 10mm	24	13	312
200026	Allen Screw	12	13	156
200138	Stud	5	13	65
200139	Lock Nut	5	13	65
211016	O-ring	1	13	13
224040	Lock Nujt	4	13	52
228003	Hex. Screw	4	13	52
228032	Spring	1	13	13
228042	O-Ring	2	13	26
228043	O-Ring	1	13	13
228046	Gasket	1	13	13
228204	Male stud,	1	13	13
228279	Repair kit	1	13	13
352013	O-ring	1	13	13
352245	O-ring	1	13	13
352459	O-ring	1	13	13
352460	O-ring for flap	2	13	26
355002	Gasket	4	13	52
355011	Gasket	4	13	52
355025	O-Ring	2	13	26
357018	Gasket O-ring	2	13	26

Table 3.23

1500 hrs Maintenance parts

Variable demand during (L + R/2 = 90 + 30/2 =105) days interval

		Demand 1st 105 days Interval			Demand 2nd 105days Interval		Demand 3rd 105days Interval	
Item no.	Description	Qty./ Maint	No. of Maint	Dema nd	No. of Maint	Dema nd	No. of Maint	Dem and
470200	Fuel Filter	9	26	**234**	26	**234**	25	225
471196	Lube oil Filter	8	26	**208**	26	**208**	25	200
476004	Gasket	2	26	**52**	26	**52**	25	50
476005	Gasket	2	26	**52**	26	**52**	25	50
476006	Gasket	2	26	**52**	26	**52**	25	50
476001	Screw	5	26	**130**	26	**130**	25	125
354001	Gasket	6	26	**156**	26	**156**	25	150
Chem-034	Cleaning chemical	1	26	**26**	26	**26**	25	25

Maintenance Number during review interval

Review interval	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th
Maint. Number	8	7	4	12	6	9	6	8	5	7	6	3

Variable demand during review interval

Description	Qty./ Maint.	1 st	2 nd	3 rd	4 th	5 th	6 th	7 th	8 th	9 th	10 th	11 th	12 th
Fuel Filter	9	72	63	36	108	54	81	54	72	45	63	54	27
Lube oil Filter	8	64	56	32	96	48	72	48	64	40	56	48	24
Gasket	2	16	14	8	24	12	18	12	16	10	14	12	6
Gasket	2	16	14	8	24	12	18	12	16	10	14	12	6
Gasket	2	16	14	8	24	12	18	12	16	10	14	12	6
Screw	5	40	35	20	60	30	45	30	40	25	35	30	15
Gasket	6	48	42	24	72	36	54	36	48	30	42	36	18
Cleaning chemical	1	8	7	4	12	6	9	6	8	5	7	6	3

Table 3.24

2000 hrs Maintenance parts

Variable demand during (L + R/2 = 90 + 30/2 =105) days interval

		Demand 1st 105 days Interval			Demand 2nd 105days Interval		Demand 3rd 105days Interval	
Item no.	**Description**	**Qty./ Maint**	**No. of Maint**	**Demand**	**No. of Maint**	**Demand**	**No. of Maint**	**Demand**
167011	Push rod	1	13	13	15	**15**	10	10
167020	Nozzle	18	13	234	15	**270**	10	180
167008	O-Ring	6	13	78	15	**90**	10	60
167012	Cylindrical Pin	10	13	130	15	**150**	10	100

Maintenance Number during review interval

Review interval	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**	**7th**	**8th**	**9th**	**10th**	**11th**	**12th**
Maint. Number	5	3	2	7	6	2	3	4	2	4	2	4

Variable demand during review period

Description	**Qty./ Maint**	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**	**7th**	**8th**	**9th**	**10th**	**11th**	**12th**
Push rod	1	5	3	2	7	6	2	3	4	2	4	2	4
Nozzle	18	90	54	36	126	108	36	54	72	36	72	36	72
O-Ring	6	30	18	12	42	36	12	18	24	12	24	12	24
Cylindrical Pin	10	50	30	20	70	60	20	30	40	20	40	20	40

Table 3.25
3000 hrs Maintenance parts
Variable demand during (L + R/2 = 90 + 30/2 =105) days interval

		Demand 1st 105 days Interval			Demand 2nd 105days Interval		Demand 3rd 105days Interval	
Item no.	**Description**	**Qty./ Maint**	**No. of Maint**	**Demand**	**No. of Maint**	**Demand**	**No. of Maint**	**Demand**
191052	O-Ring	1	10	10	14	**14**	12	12
354100	Gasket	2	10	20	14	**28**	12	24
354064	Gasket	1	10	10	14	**14**	12	12
354102	Gasket	1	10	10	14	**14**	12	12

Maintenance Number during review interval

Review interval	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**	**7th**	**8th**	**9th**	**10th**	**11th**	**12th**
Maint. Number	3	2	1	7	5	4	2	4	3	4	2	1

Variable demand during review period

Description	**Qty./ Maint**	**1 st**	**2 nd**	**3 rd**	**4 th**	**5 th**	**6th**	**7th**	**8th**	**9th**	**10 th**	**11 th**	**12th**
O-Ring	1	3	2	1	7	5	4	2	4	3	4	2	1
Gasket	2	6	4	2	14	10	8	4	8	6	8	4	2
Gasket	1	3	2	1	7	5	4	2	4	3	4	2	1
Gasket	1	3	2	1	7	5	4	2	4	3	4	2	1

Table 3.26

4000 hrs Maintenance parts
Variable demand during (L + R/2 = 90 + 30/2 =105) days interval

		Demand 1st 105 days Interval			Demand 2nd 105days Interval		Demand 3rd 105days Interval	
Item no.	**Description**	**Qty./ Maint**	**No. of Maint**	**Demand**	**No. of Maint**	**Demand**	**No. of Maint**	**Demand**
350421	Screw	24	11	**264**	10	240	8	192
131030	O-Ring	3	11	**33**	10	30	8	24
131031	O-Ring	3	11	**33**	10	30	8	24
167264	O-Ring	6	11	**66**	10	60	8	48
350184	O-Ring	4	11	**44**	10	40	8	32
357007	O-Ring	1	11	**11**	10	10	8	8
357012	O-Ring	1	11	**11**	10	10	8	8
350018	O-Ring	72	11	**792**	10	720	8	576
378002	O-Ring	2	11	**22**	10	20	8	16
476012	Sleeve	2	11	**22**	10	20	8	16
156015	Gasket	2	11	**22**	10	20	8	16
156016	Gasket	1	11	**11**	10	1	8	8
350479	O-Ring	1	11	**11**	10	1	8	8
167265	O-Ring	12	11	**132**	10	120	8	96

Maintenance Number during review interval

Review interval	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**	**7th**	**8th**	**9th**	**10th**	**11th**	**12th**
Maint. Number	4	3	2	5	4	1	2	4	2	2	0	3

Variable demand during review period

Description	**Qty. / Maint**	**1 st**	**2 nd**	**3 rd**	**4 th**	**5 th**	**6 th**	**7 th**	**8 th**	**9 th**	**10 th**	**11 th**	**12 th**
Screw	24	96	72	48	120	96	24	48	96	48	48	0	72
O-Ring	3	12	9	6	15	12	3	6	12	6	6	0	9
O-Ring	3	12	9	6	15	12	3	6	12	6	6	0	9
O-Ring	6	24	18	12	30	24	6	12	24	12	12	0	18
O-Ring	4	16	12	8	20	16	4	8	16	8	8	0	12
O-Ring	1	4	3	2	5	4	1	2	4	2	2	0	3
O-Ring	1	4	3	2	5	4	1	2	4	2	2	0	3

Description	**Qty. / Maint**	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**	**7th**	**8th**	**9th**	**10th**	**11th**	**12th**
O-Ring	72	288	216	144	360	288	72	144	288	144	144	0	216
O-Ring	2	8	6	4	10	8	2	4	8	4	4	0	6
Sleeve	2	8	6	4	10	8	2	4	8	4	4	0	6
Gasket	2	8	6	4	10	8	2	4	8	4	4	0	6
Gasket	1	4	3	2	5	4	1	2	4	2	2	0	3
O-Ring	1	4	3	2	5	4	1	2	4	2	2	0	3
O-Ring	12	48	36	24	60	48	12	24	48	24	24	0	36

Table 3.27

6000 hrs Maintenance parts
Variable demand during (L + R/2 = 90 + 30/2 =105) days interval

		Demand 1st 105 days Interval			Demand 2nd 105days Interval		Demand 3rd 105days Interval	
Item no.	**Description**	**Qty. / Maint**	**No. of Maint**	**Demand**	**No. of Maint**	**Demand**	**No. of Maint**	**Demand**
165003	O-Ring	18	7	**126**	4	72	7	**126**
165004	O-Ring	18	7	**126**	4	72	7	**126**
165014	O-Ring	18	7	**126**	4	72	7	**126**
165020	Sealing-ring	36	7	**252**	4	144	7	**252**
165031	O-Ring	6	7	**42**	4	24	7	**42**
165037	Sealing-ring	6	7	**42**	4	24	7	**42**
165105	O-Ring	18	7	**126**	4	72	7	**126**
165122	Retainer Ring	6	7	**42**	4	24	7	**42**
165173	Spring	18	7	**126**	4	72	7	**126**
165174	Shot	18	7	**126**	4	72	7	**126**
165175	Limiter	18	7	**126**	4	72	7	**126**
165200	Supporting Ring	36	7	**252**	4	144	7	**252**
165267	Sealing-ring	18	7	**126**	4	72	7	**126**
165280	Teflon-ring	18	7	**126**	4	72	7	**126**
167003	O-Ring	18	7	**126**	4	72	7	**126**

Maintenance Number during review interval

Review interval	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**	**7th**	**8th**	**9th**	**10th**	**11th**	**12th**
Maint. Number	3	2	0	4	2	0	0	3	1	3	0	1

Variable demand during review period

Description	**Qty./Maint**	**1 st**	**2 nd**	**3 rd**	**4 th**	**5 th**	**6 th**	**7 th**	**8 th**	**9 th**	**10 th**	**11 th**	**12 th**
O-Ring	18	54	36	0	72	36	0	0	54	18	54	0	18
O-Ring	18	54	36	0	72	36	0	0	54	18	54	0	18
O-Ring	18	54	36	0	72	36	0	0	54	18	54	0	18
Sealing-ring	36	108	72	0	144	72	0	0	108	36	108	0	36
O-Ring	6	18	12	0	24	12	0	0	18	6	18	0	6
Sealing-ring	6	18	12	0	24	12	0	0	18	6	18	0	6

Description	Qty./Maint	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th
O-Ring	18	54	36	0	72	36	0	0	54	18	54	0	18
Retainer Ring	6	18	12	0	24	12	0	0	18	6	18	0	6
Spring	18	54	36	0	72	36	0	0	54	18	54	0	18
Shot	18	54	36	0	72	36	0	0	54	18	54	0	18
Limiter	18	54	36	0	72	36	0	0	54	18	54	0	18
Supporting	36	108	72	0	144	72	0	0	108	36	108	0	36
Sealing-ring	18	54	36	0	72	36	0	0	54	18	54	0	18
Teflon-ring	18	54	36	0	72	36	0	0	54	18	54	0	18
O-Ring	18	54	36	0	72	36	0	0	54	18	54	0	18

TABLE 3.28
9000 hrs Maintenance parts
Variable demand during (L + R/2 = 90 + 30/2 =105) days interval

		Demand 1st 105 days Interval			Demand 2nd 105days Interval		Demand 3rd 105days Interval	
Item no.	**Description**	**Qty. / Maint**	**No. of Maint**	**Demand**	**No. of Maint**	**Demand**	**No. of Maint**	**Demand**
191009	Bearing	2	5	**10**	5	**10**	4	8
191010	Bearing	2	5	**10**	5	**10**	4	8
191013	Radial Seal	2	5	**10**	5	**10**	4	8
191015	Shaft Seal	2	5	**10**	5	**10**	4	8
191043	Dry lock Screw	8	5	**40**	5	**40**	4	32
191044	Pair of friction ring	2	5	**10**	5	**10**	4	8
191045	Pair of friction ring	2	5	**10**	5	**10**	4	8
191054	Flinger	2	5	**10**	5	**10**	4	8

Maintenance Number during review interval

Review interval	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**	**7th**	**8th**	**9th**	**10th**	**11th**	**12th**
Maint. Number	1	1	0	4	3	1	0	2	1	1	0	1

Variable demand during review period

Description	**Qty./ Maint**	**1 st**	**2 nd**	**3 rd**	**4 th**	**5 th**	**6 th**	**7 th**	**8 th**	**9 th**	**10 th**	**11 th**	**12 th**
Bearing	2	2	2	0	8	6	2	0	4	2	2	0	2
Bearing	2	2	2	0	8	6	2	0	4	2	2	0	2
Radial Seal	2	2	2	0	8	6	2	0	4	2	2	0	2
Shaft Seal	2	2	2	0	8	6	2	0	4	2	2	0	2
Dry lock Screw	8	8	8	0	32	24	8	0	16	8	8	0	8
Pair of friction ring	2	2	2	0	8	6	2	0	4	2	2	0	2
Pair of friction ring	2	2	2	0	8	6	2	0	4	2	2	0	2
Flinger	2	2	2	0	8	6	2	0	4	2	2	0	2

Table 3.29

12000 hrs Maintenance parts
Variable demand during (L + R/2 = 90 + 30/2 =105) days interval

		Demand 1st 105 days Interval			Demand 2nd 105days Interval		Demand 3rd 105days Interval	
Item no.	**Description**	**Qty. / Maint**	**No. of Maint**	**Demand**	**No. of Maint**	**Demand**	**No. of Maint**	**Demand**
32100	Bearing unit	2	3	6	3	6	6	**12**
34100	Bearing unit	2	3	6	3	6	6	**12**
51019	Hex, headed screw	12	3	36	3	36	6	**72**
51015	Hex, headed screw	12	3	36	3	36	6	**72**
51020	Locking plate	12	3	36	3	36	6	**72**
51049	Locking plate	12	3	36	3	36	6	**72**
52801	Gasket	8	3	24	3	24	6	**48**
76022	Locking washer	2	3	6	3	6	6	**12**
76040	Gasket ring	2	3	6	3	6	6	**12**
AL-01E	Gasket	16	3	48	3	48	6	**96**
100088	O-ring	22	3	66	3	66	6	**132**
100096	Main bearing upper	10	3	30	3	30	6	**60**
100097	Main bearing lower	10	3	30	3	30	6	**60**
100111	D- Seal	36	3	108	3	108	6	**216**
100112	Thrust washer	4	3	12	3	12	6	**24**
100113	Flywheel thrust	2	3	6	3	6	6	**12**
100156	Antipolishing ring	18	3	54	3	54	6	**108**
111004	Big end bearing	18	3	54	3	54	6	**108**
111005	Big end bearing	18	3	54	3	54	6	**108**
111019	Shim	18	3	54	3	54	6	**108**
113001	Piston Crown	4	3	12	3	12	6	**24**
113013	Piston Ring Set	18	3	54	3	54	6	**108**
120009	Seat Ring, Exhaust	8	3	24	3	24	6	**48**
120022	Valve Guide	8	3	24	3	24	6	**48**
120028	Allen Screw	4	3	12	3	12	6	**24**
120065	Sealing set	18	3	54	3	54	6	**108**
121006	Exhaust Valve	18	3	54	3	54	6	**108**
121010	Inlet valve	4	3	12	3	12	6	**24**
121033	Disk	20	3	60	3	60	6	**120**
121062	Ball	30	3	90	3	90	6	**180**
121063	Retainer ring	6	3	18	3	18	6	**36**
123001	O-ring	9	3	27	3	27	6	**54**

		Demand 1st 105 days Interval			Demand 2nd 105days Interval		Demand 3rd 105days Interval	
Item no.	**Description**	**Qty. / Maint**	**No. of Maint**	**Demand**	**No. of Maint**	**Demand**	**No. of Maint**	**Demand**
125447	Sealing Set	2	3	6	3	6	6	**12**
131007	Bush	2	3	6	3	6	6	**12**
131032	Allen Screw	12	3	36	3	36	6	**72**
131033	Allen Screw	24	3	72	3	72	6	**144**
131034	Allen Screw	24	3	72	3	72	6	**144**
145003	O-ring	4	3	12	3	12	6	**24**
145008	O-ring	8	3	24	3	24	6	**48**
145010	O-ring	4	3	12	3	12	6	**24**
148011	Camshaft Bearing	2	3	6	3	6	6	**12**
148013	Allen Screw	34	3	102	3	102	6	**204**
148014	Allen Screw	15	3	45	3	45	6	**90**
181160	Gasket	1	3	3	3	3	6	**6**
200011	Gasket	12	3	36	3	36	6	**72**
200014	Two-part ring	1	3	3	3	3	6	**6**
200015	Allen Screw	24	3	72	3	72	6	**144**
200016	Nut 10mm	24	3	72	3	72	6	**144**
200026	Allen Screw	12	3	36	3	36	6	**72**
200138	Stud	5	3	15	3	15	6	**30**
200139	Lock Nut	5	3	15	3	15	6	**30**
211016	O-ring	1	3	3	3	3	6	**6**
224040	Lock Nujt	4	3	12	3	12	6	**24**
228003	Hex. Screw	4	3	12	3	12	6	**24**
228032	Spring	1	3	3	3	3	6	**6**
228042	O-Ring	2	3	6	3	6	6	**12**
228043	O-Ring	1	3	3	3	3	6	**6**
228046	Gasket	1	3	3	3	3	6	**6**
228204	Male stud,	1	3	3	3	3	6	**6**
228279	Repair kit	1	3	3	3	3	6	**6**
352013	O-ring	1	3	3	3	3	6	**6**
352245	O-ring	1	3	3	3	3	6	**6**
352459	O-ring	1	3	3	3	3	6	**6**
352460	O-ring for flap	2	3	6	3	6	6	**12**
355002	Gasket	4	3	12	3	12	6	**24**
355011	Gasket	4	3	12	3	12	6	**24**
355025	O-Ring	2	3	6	3	6	6	**12**
357018	Gasket O-ring	2	3	6	3	6	6	**12**

Table 3.30

12000 hrs Maintenance parts
Maintenance Number during review interval

Review interval	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th
Maint. Number	1	1	0	2	2	0	0	3	1	2	0	1

Variable demand during review period

Description	Qty./Maint	1 st	2 nd	3 rd	4 th	5 th	6 th	7 th	8 th	9 th	10 th	11 th	12 th
Bearing unit	2	2	2	0	4	4	0	0	6	2	4	0	2
Bearing unit	2	2	2	0	4	4	0	0	6	2	4	0	2
Hex, headed screw	12	12	12	0	24	24	0	0	36	12	24	0	12
Hex, headed screw	12	12	12	0	24	24	0	0	36	12	24	0	12
Locking plate	12	12	12	0	24	24	0	0	36	12	24	0	12
Locking plate	12	12	12	0	24	24	0	0	36	12	24	0	12
Gasket	8	8	8	0	16	16	0	0	24	8	16	0	8
Locking washer	2	2	2	0	4	4	0	0	6	2	4	0	2
Gasket ring	2	2	2	0	4	4	0	0	6	2	4	0	2
Gasket	16	16	16	0	32	32	0	0	48	16	32	0	16
O-ring	22	22	22	0	44	44	0	0	66	22	44	0	22
Main bearing upper	10	10	10	0	20	20	0	0	30	10	20	0	10
Main bearing lower	10	10	10	0	20	20	0	0	30	10	20	0	10
D- Seal	36	36	36	0	72	72	0	0	108	36	72	0	36
Thrust washer	4	4	4	0	8	8	0	0	12	4	8	0	4
Flywheel thrust	2	2	2	0	4	4	0	0	6	2	4	0	2
Antipolishing ring	18	18	18	0	36	36	0	0	54	18	36	0	18
Big end bearing	18	18	18	0	36	36	0	0	54	18	36	0	18
Big end bearing	18	18	18	0	36	36	0	0	54	18	36	0	18
Shim	18	18	18	0	36	36	0	0	54	18	36	0	18
Piston Crown	4	4	4	0	8	8	0	0	12	4	8	0	4
Piston Ring Set	18	18	18	0	36	36	0	0	54	18	36	0	18
Seat Ring, Exhaust	8	8	8	0	16	16	0	0	24	8	16	0	8
Valve Guide	8	8	8	0	16	16	0	0	24	8	16	0	8

Description	Qty./ Maint	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th
Allen Screw	4	4	4	0	8	8	0	0	12	4	8	0	4
Sealing set	18	18	18	0	36	36	0	0	54	18	36	0	18
Exhaust Valve	18	18	18	0	36	36	0	0	54	18	36	0	18
Inlet valve	4	4	4	0	8	8	0	0	12	4	8	0	4
Disk	20	20	20	0	40	40	0	0	60	20	40	0	20
Ball	30	30	30	0	60	60	0	0	90	30	60	0	30
Retainer ring	6	6	6	0	12	12	0	0	18	6	12	0	6
O-ring	9	9	9	0	18	18	0	0	27	9	18	0	9
Seal Ring	9	9	9	0	18	18	0	0	27	9	18	0	9
Sealing Set	2	2	2	0	4	4	0	0	6	2	4	0	2
Bush	2	2	2	0	4	4	0	0	6	2	4	0	2
Allen Screw	12	12	12	0	24	24	0	0	36	12	24	0	12
Allen Screw	24	24	24	0	48	48	0	0	72	24	48	0	24
Allen Screw	24	24	24	0	48	48	0	0	72	24	48	0	24
O-ring	4	4	4	0	8	8	0	0	12	4	8	0	4
O-ring	8	8	8	0	16	16	0	0	24	8	16	0	8
O-ring	4	4	4	0	8	8	0	0	12	4	8	0	4
Camshaft Bearing	2	2	2	0	4	4	0	0	6	2	4	0	2
Allen Screw	34	34	34	0	68	68	0	0	102	34	68	0	34
Allen Screw	15	15	15	0	30	30	0	0	45	15	30	0	15
Gasket	1	1	1	0	2	2	0	0	3	1	2	0	1
Gasket	12	12	12	0	24	24	0	0	36	12	24	0	12
Two-part ring	1	1	1	0	2	2	0	0	3	1	2	0	1
Allen Screw	24	24	24	0	48	48	0	0	72	24	48	0	24
Nut 10mm	24	24	24	0	48	48	0	0	72	24	48	0	24
Allen Screw	12	12	12	0	24	24	0	0	36	12	24	0	12
Stud	5	5	5	0	10	10	0	0	15	5	10	0	5
Lock Nut	5	5	5	0	10	10	0	0	15	5	10	0	5
O-ring	1	1	1	0	2	2	0	0	3	1	2	0	1
Lock Nujt	4	4	4	0	8	8	0	0	12	4	8	0	4
Hex. Screw	4	4	4	0	8	8	0	0	12	4	8	0	4
Spring	1	1	1	0	2	2	0	0	3	1	2	0	1
O-Ring	2	2	2	0	4	4	0	0	6	2	4	0	2
O-Ring	1	1	1	0	2	2	0	0	3	1	2	0	1
Gasket	1	1	1	0	2	2	0	0	3	1	2	0	1
Male stud,	1	1	1	0	2	2	0	0	3	1	2	0	1
Repair kit	1	1	1	0	2	2	0	0	3	1	2	0	1
O-ring	1	1	1	0	2	2	0	0	3	1	2	0	1
O-ring	1	1	1	0	2	2	0	0	3	1	2	0	1

Description	Qty./Maint	1 st	2 nd	3 rd	4 th	5 th	6 th	7 th	8 th	9 th	10 th	11 th	12 th
O-ring	1	1	1	0	2	2	0	0	3	1	2	0	1
O-ring for flap	2	2	2	0	4	4	0	0	6	2	4	0	2
Gasket	4	4	4	0	8	8	0	0	12	4	8	0	4
Gasket	4	4	4	0	8	8	0	0	12	4	8	0	4
O-Ring	2	2	2	0	4	4	0	0	6	2	4	0	2
Gasket O-ring	2	2	2	0	4	4	0	0	6	2	4	0	2