UNIT 7 SPARE PARTS INVENTORY MANAGEMENT

Objectives

After going through this unit the students shall be able to:

- understand the objective and types of spare parts management in Maintenance Management,
- understand the six stages of life cycle of spare parts management and importance of each stage,
- understand reorder level, safety stock etc. of inventory management relevant to Maintenance Management,
- understand ABC Analysis and VED analysis etc. w.r.t spare parts management,
- understand some aspects of Management Information System (MIS) for spare parts management,
- understand cost control and unique problem associated with spare parts management,
- discuss two case examples that discusses issues related to spare parts management.

Structure

7.1 AIM OF SPARE PARTS INVENTORY MANAGEMENT

The aim of spare parts inventory management is to make available to maintenance, the right spare part, at the right place, at the right time, in the right quantity, at the right price, and at the lowest total cost to the enterprise. Of these, the first four represent the 'service to the maintenance engineer' and must be given first priority. The next part means paying the least for a purchased item by locating and negotiating with the suppliers for a reasonable price-provided the item meets the technical needs of maintenance. The last part of the aim minimizes the total cost, consisting of the cost of administering the system and procedures, the price paid for the parts and the cost of machine downtime incurred if the needed part was not available when required.

7.2 TYPES OF SPARE PARTS

The three basic types of spares parts are: (a) PM spares: Those replaced during preventive or opportunity maintenance, (b) Repair Parts (Breakdown spares): those required to replace parts that fail during service, and (c) Overhaul (Shutdown) Parts: Those required during planned overhaul or shut down of the plant. The quantity and the time of requirement can not be predicted for the Repair parts. Only, the chance of their requirement can sometimes by predicted. Statistical methods are needed for their inventory control.

7.3 LIFE CYCLE OF SPARE PARTS

Spare parts go through the following six stages in their life cycle:

1) Design and specifications (The right spare)
2) Determination of initial requirements (The right quantity)
3) Procurement (The right Price)
4) Storage and preservation (Minimum custodial and inventory carrying cost)
5) Issue and replenishment (Minimum downtime cost through inventory control)
6) Disposal of damaged, surplus and obsolete spares (Minimum damage and maximum disposal value)

The details of each phase will be discussed below.

7.3.1 Stage 1: Design and Specifications

Stringent specifications, high quality of manufacture and careful operation/ maintenance of the machine reduce consumption and cost due to replacement of spares. Ideally, spare parts from the OEM (Original Equipment Manufacturer) should be used. spares have a huge range - each one having several specifications, which are not available to the user. Without actual fitting it is not possible to tell whether a part will fit or not. This is clearly not practicable as spares are stocked in advance of requirement. It will be worth paying for a certificate or warranty for the spare part from its supplier, at least for critical and expensive parts. Only large consumers such as railways, airlines, transport fleets, armed forces etc. can assess the life of parts by destructive or accelerated life-testing or from the quality records of the manufacturer. Warranties cannot compensate for the loss due to short life of a part. They only compensate for the cost of the part. Spurious, even reconditioned and defective parts or inferior quality parts are often sold at a lower price than that of the OEM. One should never buy from unauthorized dealers or unproved suppliers.

7.3.2 Stage 2: Determination of Initial Requirements

The machine supplier usually gives a 'Recommended List of Spares' to the user. This list should be scrutinized for additions that are basically profit-oriented. The supplier should be asked to give consumption rate for various spares. The maintenance engineer can than better assess the spares to be stocked for a chosen initial period –say, for one to two years based on his experience with similar items, number of machines installed, age of machines, operating conditions, engineering factors and the inventory control system in operation. Casual selection of spares at this stage will create a large inventory of nonmoving spares. In initial stages only a few will need replenishment.

Spare parts planning begin with the selection of the machine. At this stage, weight must be given to the following:

- Complete range of parts serviced by the manufacturer including those from his sub-suppliers to be available, along with illustrated catalogues for applicable models
- Assurance of supply for the lifetime of the machine
- Supply of manufacturing drawings as needed
- Availability of observed/estimated consumption rates (not sales data) of spare parts
- Technical data/specifications for assessing failure rate
- Warranty for quality and for life of supplied spares
- Guidance in identification, storage (for sensitive items) and preservation

Using this information and his own experience, the maintenance engineer assesses the initial requirement for a period that will cover one lead-time or one review period (and safety stocks) for spares for all types of maintenance, insurance items and repair pool. (these matters will be explained later in this paper). This is a painstaking and time consuming task but it will reduce considerable difficulties later. Prices of spares are usually negotiated at the time of buying the machine but a list of prices for further procurement should be agreed upon at this stage itself.

7.3.3 Stage 3: Procurement

For highly specialized equipment or for that likely to go out of production, the user should assess their availability. There is not much room for competitive procurement of spares except at the time of buying the machine. Machines using standard replacement parts (such as ball/roller bearings and hardware) should be preferred. Non-standard parts are always expensive, and often difficult to get. The contract for supply of spare parts should take care of the points made earlier.

7.3.4 Stage 4: Receipt, storage and Preservation

On receipt, the spare parts are checked for correctness of quantity and quality before storing them. The principles here is 'a place for everything in its place' Spares are stocked machine-wise. Items common to more than one machine are stocked together. The location of each spare is marked on the bin card for the spare. These bin-cards are also the account cards, which indicate the receipt and issue (and stock balance) and particulars (part number etc) of the spare. Mentioning details of interchangeable or substitute spares is a great help in an emergency.

Security of spares in custody is the responsibility of the storekeeper. Small and expensive spares can be easily pilfered. They are kept in a locker. Spares are issued only to authorized maintenance personnel who need them for their work. Physical stock of all items should be checked with ledger balance annually and differences reconciled. Errors are investigated to avoid recurrence.

Different preservatives and methods are needed for different spares. Corrosion is the greatest enemy of all spares. Ball and roller bearings are easily damaged by dust/humidity and should be kept in original packing till needed. Heat sensitive electronic items like transistors should be kept in cool places. Rubber and textile items should not be exposed to direct sunlight or to come in contact with mineral oils. Rubber belts and tubing should not have twists or sharp bends when stored. The condition of all spares including the surplus or obsolete ones should be checked regularly such as at the time of annual stocktaking.

7.3.5 Stage 5: Issue and Replenishment : The Reorder Level system of inventory control

The replenishment of parts withdrawn from stock involves two basic questions, namely, 'How much to order?' and 'When to order?' The quantity (and especially) the time of replenishment has to be determined scientifically as they profoundly affect the cost effectiveness of inventory management. Figure 1 shows the stock position of a typical item being used up at a steady rate of 30 pieces per week. The value of an initial stock of, say 300 pieces, each costing Rs.10 will be Rs.3000 (point A). It will linearly fall to zero (point B) after 10 weeks. If the item can be ordered and received instantly, we may order it only at this point. Then the stock will rise to the original value of Rs.3000 (Point C), assuming that we ordered 300 pieces. This is called 'Order quantity' or OQ, or just Q. It is expressed either in rupees or in numbers. The average inventory during this repeating cycle of steady consumption is obviously half the OQ i.e. 150 pieces or Rs.1500.

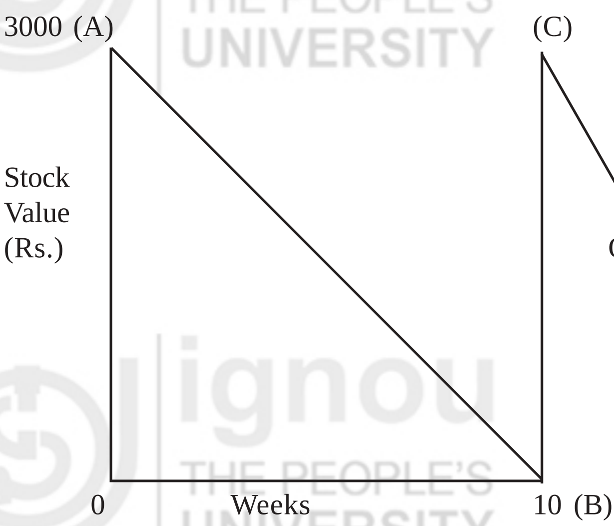

Figure 1

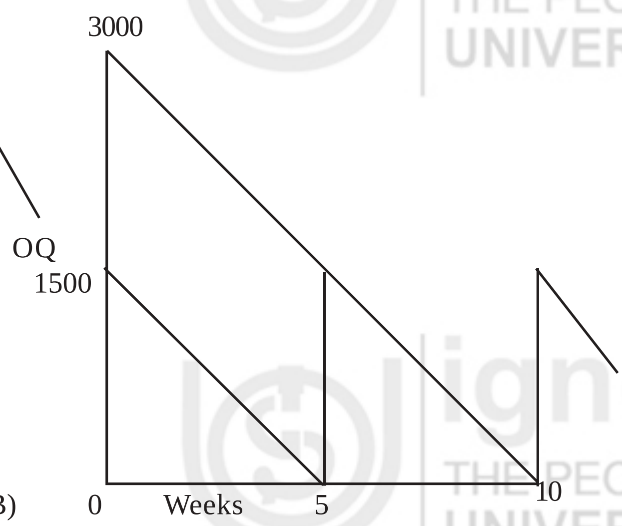

Figure 2

The inventory carrying cost consists of borrowing (or the interest lost) on the capital tied up in inventory and that of handling damage, aging, storage, preservation and obsolescence. These depend upon the nature of the part but can be approximated to an annual 20% of the cost of the spare part i.e., Rs.300 per year. We can reduce this cost by ordering less-say only 150 numbers (Rs.1500) at a time. The stock graph will now be as shown by the lower line in Figure 7.2. The average inventory carrying cost per year will be Rs.750, but we will have to order twice as frequently as before. The ordering cost is for advertisement for supply, contacting and selecting the supplier, paper work and postage involved in correspondence, receiving, inspecting, and putting in bins. Local purchase from dealer's stock may be less expensive.

In the present case, if 'S' is the cost of placing an order, say, Rs,100 per order, then we will spend Rs.100 on ordering 300 pieces once annually, or Rs.200 if we order 150 pieces twice annually. If the annual cost of carrying inventory 'I' is 20%. It will be (Q) (I) /2 for an order size of Q. If the value of annual usage of the item is Rs. N, we will place N/Q order per year, and the annual ordering cost will be (S)(N/Q). The annual total cost is the sum of these two opposite costs will be [(Q)(I)/2+(S)(N/Q)]. It can be shown that this cost will be

minimum when Q = . This minimum is called Economic Ordering Quantity (EOQ).

In the above case, EOQ= =Rs.173/300 = 0.57 piece. Since fractional spares have no existence this will be rounded off to 1. Even with large values of Q, the EOQ is hardly more than 2 or 3, because the high cost items usually have very law consumption (failure) rate and the product (Unit Cost Annual consumption) will be small. That is why EOQ is meaningful only for the high usage (fast moving) spare parts, which are very few in range, and the monetary advantage of EOQ is insignificant. On the other hand, the risk of obsolescence and uncertainly of long-term availability outweighs the EOQ advantage. Finally, OQ powerfully affects safety stock and the risk of stock-out. This consideration is far more important than the above.

Safety Stock

The second question in an inventory system is ‘When to order?’ Spares have to be ordered ahead of the possible need as there is an ‘internal’ lead-time of several weeks to months to process an indent, obtain quotations, select supplier and place the supply order after arranging for funds (in case of imports). There is also an external lead-time of several weeks to months, for the supplier to organise dispatches, transportation, customs clearance etc. the total lead-time (abbreviated as LT) must be allowed for while ordering any kind of replenishment.

In Figures 3, a replenishment time of three weeks has been set off (Point D) backwards from the day when stock is expected to fall to Zero. On this day (D) the stock would have fallen to 30 i.e., the expected consumption during LT.A little safety stock, of say 5 pieces, to cater for any unexpected increase in this consumption after the order is placed, is added. The order should be initiated when the stock falls to 30+5=35(point E). This stock level is called the Re Order Level (ROL).

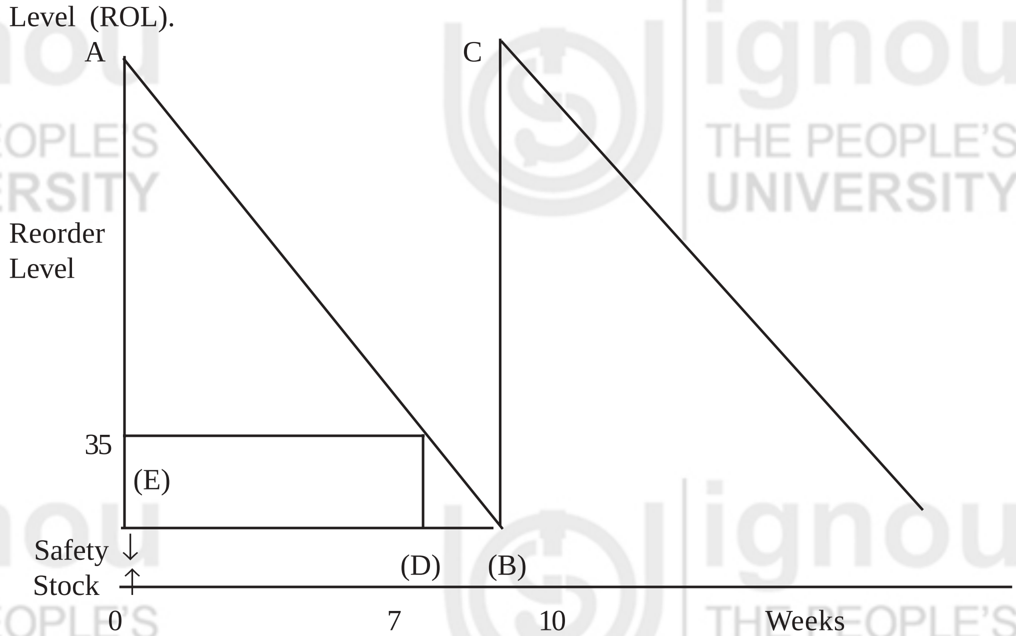

Figure 3

The general inventory expression is, ROL = Average Consumption during LT + Safety stock

Notice that in a typical operation of this ROL System (*Figure 3*) the safety stock remains at full value, whereas the cycle stock i.e. the OQ, gets consumed and replenished resulting in an average inventory of half the OQ. Hence, it can be said that one unit of safety stock is twice as expensive to carry as one unit of cycle stock. Minimizing safety stock, subject to some acceptable risk of stock out during the LT, is much more important than the economic of order quantity.

Studies have established that the consumption of repair parts during any period (such as LT) varies randomly and asymmetrically, following the Poisson probability distribution. From this, we can calculate Safety Stock (SS) as under:

SS=(k).× ($\sqrt{M}$), where M is the average consumption during lead-time, and K is the safety factor, which takes the following values for different levels of assurance of availability:

Assurance of availability: =	50%	70%	80%	85%	90%	95%	98%
Safety factor : =	0.0	0.7	0.8	1.0	1.3	1.7	2.1

Note that the safety factor 'k' increases rapidly with the demand for higher assurance so that for every additional item in SS we get relatively less and less additional assurance. At some point it may not be worth spending so much on SS inventory. This is used in a decision matrix shown later in Figure 5. This matrix has to be approved by the top management as it reflects their policy of delivering different levels of service for investment in this non-moving inventory (safety stock). Incidentally, an assurance level of 90% does not mean that 90% of the quantity ordered will be delivered ex-stock. It means that 90% of the orders will arrive on time, on time, or that the risk of non-availability ex-stock was 10%.

7.3.6 ABC Analysis – Pareto's Law

In 1948, the Chief Materials Manager of General Electric Co. in USA listed the annual consumption value of each and every material that the company used in decreasing order of magnitude. He noticed that the top 15 to 20 percent of the whole range of items contributed to almost 80% of the total cost contributed by all items. He designated them as A items (*Figure 4*). The next 30 to35% of the range of items contributed to 15 to 20% of the total cost (B items). Finally, the last 50%of the range of items contributed to barely 5 to 10% of the total cost (C items). ABC analysis suggests that we should control 'A' items tightly, 'B' items carefully and "c" items loosely i.e. concentrate on preventive and corrective action only for a few, worthwhile items. For spare parts we should give generous safely stock for C items (we can afford it), adequate for B items and minimum for A items – in short, allot high, medium and low value of 'k', respectively.

The Italian economist wilfredo Pareto, after whom it is named, first discovered this pattern eighty year ago. He had shown that that every natural phenomenon seems to concentrate in a few points or stages. Typical examples are city traffic on a few roads, failures concentrating in a few components of a machine; most cost of spare parts contributed by only a few spares.

Annual Consumption Value

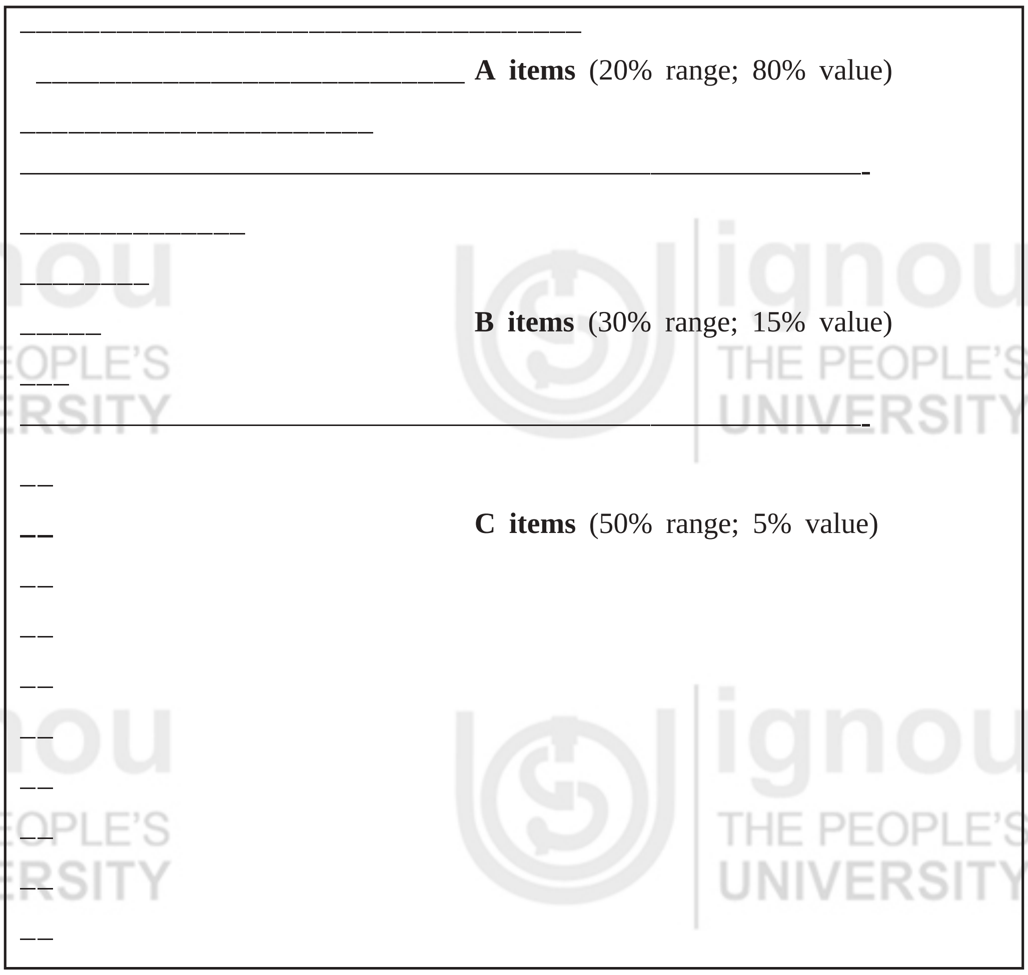

Figure 7.4 : A B C Analysis

Activity A

List out the spare parts inventory consumption of an organisation and carry out ABC analysis.

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The Materials Manager listened to all this new fangled talk with growing impatience. Finally when the presentation was over, he asked Anil just one question, “Where is the inventory reduction?” Anil was ready with the answer. He said, “Well Sir, don’t you see that very high cost contribution of copper-the top item in the Pareto analysis? Our Management must give it the closest attention- by exerting the tightest control over its consumption, purchase price, ordering on the basis of EOQ, and sharpening other inventory parameters”

This was too much for Onkar. He thundered, “Look son, this fancy ABC analysis or whatever you call it has told me precisely what I have known by my old fashioned instinct. As regards control on cost of copper etc, why, I spend more time on this one item than all others put together.

I even dream of it at night. The boss himself decides when to buy copper and how much. Nobody has taught him anything about your EOQ and what have you – and we are still the best in this business. Now go back and do something more useful - like stock taking for all the raw materials as of today"

Activity B

Comment on the manner in which Anil had done the ABC analysis, keeping in view the extent of the study, its aim and objective, and the logic of costing adopted by him.

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Suggested response:

The suggested response is contained in the follow up action in this case study

Follow up after the discussion with the Materials Manager:

Initially, Anil was downcast by this outburst. He had evidently made a wrong impression on his boll. Nevertheless, he decided to study his books on inventory control once again and see whether and where he had gone wrong. After consulting his professor, he realized his errors. He understood the following points better:

1) ABC analysis is an analysis that refines control. In the present case, the very high cost of copper was very well known. It did not need ABC analysis to point it out.

2) An equally important aspect of ABC analysis is 'decontrol'. The paperwork for a large range of 'C' items was as complicated as that for high usage value items. There was room for simplifying it. That would give the stores personnel more time to control the worthwhile items.

3) The cost contribution from items also has a pattern according to the class of items. Thus, raw materials should be treated as one class and ABC analysis for items within this class should be done. In that cast, the contribution of copper would probably be closer to about 60% or so amongst all items of raw materials only- and not as 0.04% of all materials. There would be a similar pattern for the class of General Stores.

4) Within the class, the base period should be the same. Raw material is consumed constantly and in large quantities. A base period of six to twelve months is adequate. For General Stores one to two years would be satisfactory. If a few items were not consumed in that period they need not be included in the calculation.

5) Spare parts are a unique class. Unlike other materials, the consumption value of spare parts is very little in comparison to their stock value. This is due to the unique relationship of safety stock-this may be as high as 0.5to5or times the annual consumption value, or even more. For the many nonmoving items (in particular, the insurance items) the consumption in several years may be nil. In these cases, one refers to their inventory in terms of years of stock, whereas the Stock of raw

materials is in terms of days or weeks of consumption. Therefore in case of spare parts, ABC analysis of consumption value is less useful than ABC analysis of stock value (except as explained below). For the 'A' items from the latter analysis, steps could be taken to examine why the stocks were so high , whether they could be sold off, whether the inventory parameters were incorrect, whether they could be shared by other units etc.

6) ABC/VED analysis of consumption value of repair items only is used for deciding on the safety stock of such items. This is not meant for other items e.g., items needed for overhaul/shutdown maintenance. In these cases there is no need for safety stock for variation of consumption. The time and quantity needed for overhaul is generally well known. In any case, it does not follow a statistical pattern. All items for overhaul are really equally critical because a single item can hold up the refitting of an assembly that had been stripped for overhaul.

7) ABC analysis of consumption value of all spares together can and should be made to identify those that contribute most. Maintenance should be asked to find ways and means to reduce their consumption of A items. Purchasing can locate alternative (cheaper) supplier or renegotiate price of such items. However, generally this potential is small.

This time Anil was on surer ground. He had understood the purpose of theoretical analysis and its relationship with practical utility. He had been so struck by the complexity and challenges in spare parts management that he volunteered and was sent for a special training program on spare parts management.

7.3.7 Criticality Analysis (V-E-D Analysis)

While ABC analysis controls the cost of having the inventory when not immediately required, VED analysis controls the huge cost of not having a part in stock (safety stock) when it is needed. SS reduces the risk of non-availability. For repair parts, the maintenance engineer must define items whose non-availability will cost heavily to the organisation (such as due to machine downtime, risk of accidents and loss of opportunity of sale) as very critical or vital (V) items. The moderately critical items are defined as essential (E) items, and the rest are desirable (D) items. *Figure 7.5* shows a typical decision matrix for the joint ABC/VED classifications for repair parts along with values of K.

	'A' ITEMS	**'B' ITEMS**	**'C' ITEMS**
VITAL 'V'	90%(k=1.30)	95%(k=1.70)	99%(k=2.30)
ESSENTIAL 'E'	80%(k=1.00)	90%(k=1.30)	95%(k=1.70)
DESIRABLE 'D'	75%(k=0.70)	80%(k=1.00)	90%(k=1.30)

Figure 7.5: A Typical Decision Matrix for ABC/VED

Example: A gate valve is used at a rate of (m=0.56) per month. The LT is 3 months, so that M, the consumption during LT is(θ.56 × 3) = 1.68. the B/V item for which k= 1.7 (from Figure 7.5). Hence, ROL= 168+(1.7) (Sqrt of 1.68) = 1.68 +2.20=3.88,rounded off to 4. if this was a 'E' item the SS would be 1.68 and the ROL would be 3.36 rounded off to 3.

We can define the service level in terms of 'period to stock out' or ' number of stock outs in a given period, such as one year'. The former is a more meaningful measure to a maintenance engineer. Note that the assurance of availability is for one inventory cycle. If the demand for replenishment is once a year we will be exposed to the risk of stock out only once annually. If order is once in six months the exposure will be doubled. Thus, suppose that the tolerable 'period to stock out'= T years. (i.e., 1 stock out in T years). With an order Quantity Q, and annual consumption rate A, we will have A/Q replenishment orders per year and (A) (T)/(Q) in T years. Of these, (A) (T) (r)/Q will be at risk, where r is the risk of stock out per order cycle. Since one stock out in T years is acceptable, we can put (A)(T) (r)/Q=1, from which we get the assurance level of (1-r) i.e. 1- [(Q)/(A) (T)]. This figure is to be used to calculate SS. A decision matrix can now be drawn for various periods to stock out and related levels of assurance (with corresponding values of k. A and Q can be expressed in numbers or in Rupees).

The following example will show the calculations using different value of A and T:

Let	A=Rs.2,000			Rs.20,000			Rs.50,000		
	Q=Rs.4,000 (Common for all cases for illustrative purposes)								
	T= 1 yr	5 yrs	10 yrs	1 yr	5yrs	10 yrs	1yr	5yrs	10yrs
1-[(Q)/(A) (T)]=	0.00*	0.60	0.80	0.80	0.96	0.98	0.92	0.98	0.99

*In this case, the assurance level becomes negative. Negative or Zero assurance means that no safety stock is needed (k = 0). The high OQ itself gives the protection against stock out.

The appropriate values of k, the safety factor to be used to calculate safety stock can now be read off from a table of Poisson probabilities. Typically, if A=Rs.20,000 and Q = Rs.4,000 then for T=1 year, the assurance level works out to 80% for which the value of k (from Poisson tables) is 0.80. For T = 10 years, k will be 2.1. As will be seen, the value of k (and the safety stock associated with it) rises as the 'stock out-free' period increases from1 year to 10 years

In the Reorder Level (ROL) system, the ROL and Q are fixed but the time for replenishment varies inversely with consumption. The ROL is like the 'reserve' in the fuel tank of a motorcycle. Replenishment quantity is always the same i.e. full tank, but the time for replenishment will vary.

7.3.8 Periodic Review System

In the periodic review system, replenishment is at fixed intervals but the OQ changes. Figures 6 shows an ordering cycle with a Review Period (RP) of six month i.e., interval between points A,B, and C. on the day of review (Point A) the physical stock in hand plus 'dues in' i.e. order placed earlier but not received yet, are noted as 'Assets'. Forecast consumption during (LT+RP) plus (SS) is calculated as 'Liability'. Excess of Liability over Assets is the order quantity.

Order is placed at A,B,C etc; stock is received at D,E,F, etc after Lead Time (LT), and Quantity on order = Liability – Assets

= [Consumption during (AB+BE)+SS}]-[Stock on hand and on order]

= [Consumption during AE] + [AH+0], (assuming that no order was pending)

= HG

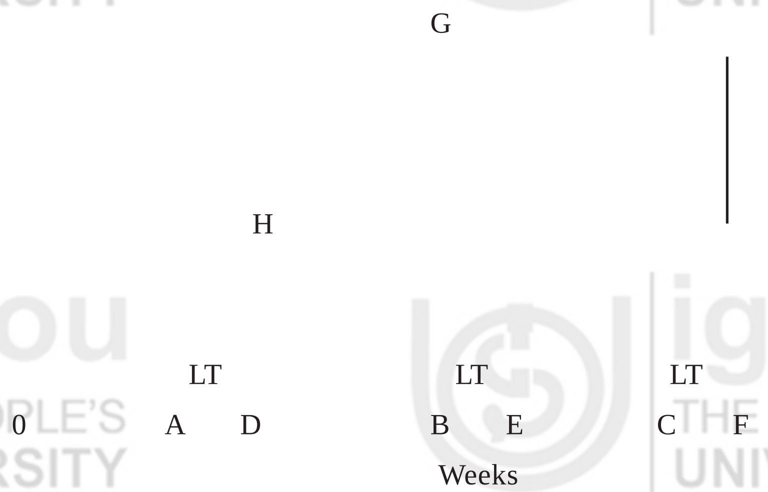

Figure 7.6 : An ordering cycle with a review period of six months

In the above example, stock On Order = 0 because the LT is small compared to the Review Period. If the LT exceeds the Review Period, some earlier orders would still be pending and will have to be included in the 'assets'. In this system, the forecast has to cover both the LT and the Review Period. Safety stock caters for both LT and review period. Typically, if the consumption rate (M) of an item is 5 per month, the LT is 4 months, and the review period is 6 months, then, Liability= (5)(4+6) +SS for (4+6) months.

SS is calculated as for the ROL system using the appropriate safety factor, k. Thus, if the consumption during Review Period Plus LT was 50, the SS was 10, the stock in hand was 20 and the stock on order (also called 'dues in') was 12, the OQ can be calculated as under:

OQ = Liability – Assets = (50+10) – (20 +12) = 60 – 32 = 28

Theoretically, this system requires higher safety stock than the ROL system but in both systems, for most spare parts the error caused by rounding off fractional order quantity overshadows the precision of other calculations and this disadvantage can be ignored. The review cycle can be matched to the supplier's production cycle so as to get stable, predictable lead times for supply- especially for the parts that are not normally sold off the shelf through a dealer network. All spares from the same suppliers can be packed and transported together cheaply, unlike the piecemeal – and hence expensive- deliveries for the ROL system. Therefore, large transport companies who deal directly with their suppliers prefer this system. Those having distributed stocks of spares (users or dealers), obviously have to use this system. It does not need the excessive amount of documentation of the ROL system. An 'Economic Review Period' can also be calculated for this system. However, for the same reasons mentioned earlier for the ROL system, other factors (such as matching with supplier's production cycle etc) neutralize the economic advantage.

7.3.9 Slow Moving Items

The consumption rates for fast moving items can be assessed fairly accurately even without any consumption data. Later, data accumulates quickly and the rates can be updated fast. The relative period-to-period variation in consumption increases as the mean value of a Poisson distribution goes down. For items having low consumption rates, consumption data over moderate period does not give a reliable average; an average based on short periods is extremely unreliable. Most spares fall into this category.

The variation of consumption from period to period is so great that any moving average that we may use will have large error. Basing the SS on the 'higher-than-true-average' will further inflate safety stock. Hence, we have to apply the statistical approach of 'Prediction Intervals' in which the ROL is calculated from the following formula:

$$ROL = C(T2/T1) + z\sqrt{C(T2/T1)(T1+T2)}$$

Here, T1 is the base period during which the consumption was C. The lead-time is T2, and Z (Similar to the safety factor 'k') takes the value of 0.65 and 1.65 for 75% and 90% levels of assurance respectively, fractions are to be rounded off as in case of the fast moving spare parts. For the periodic Review System, T2 includes Review Period, besides Lead Time.

Example: C=3; T1 = 2 years. For an assurance level of 90% (z=1.65), and

forecast base of T2 = 0.5yr, ROL =3(0.50)/2+1.65 = 3.12, i.e. 3 numbers of spares. Ordinarily, we would have calculated the ROL as

3(0.50/2)+1.3 = = 1.87,i.e. 2. It is conceivable that in the particular two years of our observation, the consumption happened to be on the low side and our estimate of the average was understated. It could also have been over stated, as the variation from period to period is quite high in the Poisson distribution. The method of prediction intervals is a via media. It gives safety against underestimates but without increasing safety stock too much.

Activity C

In a University library, randomly select 1000 books. Verify the frequency of issue of these books to readers. Categorize the books as fast, slow and non-moving types (a typical FSN analysis). What management decisions you are taking for slow and non-moving items?

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$\sqrt{3(0.50/2)}$ $(2+0.5)$

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Insurance Spares

When M, the consumption during LT is only a small fraction, the rounding off error is large, as can be seen from the following examples. (k is kept at 2.1 for all values of M, for easy comparison).

M	1	0.5	0.1	0.01
SS	2.1	1.47	0.7	0.21
ROL=M+SS	3.1	1.97	0.8	0.22
Rounded off to	3	1 or 2	0 or 1	0 or 1

The rounding off error in the last two cases is (-100% to + 40%) and (-100% to + 350%). This will increase further for still lower consumption rates (i.e. for very long life items). The safety stock given is already large, since k=2.1 (98% assurance). Rounding off adds still more to safety stock. If these spares are extremely critical (and expensive) both the options i.e., of stocking zero or 1 are wrong, have a large margin of error, and extremely expensive. Such spares are called 'insurance spares'. They are indeed in the nature of insurance as both the options have a large order of error.

The maintenance engineer naturally prefers to stock these items (which eventually become the non-moving items) whereas the high cost of stocking makes the management question the wisdom of stocking them. This decision has to be made on the basis of risk/cost relationship. Thus, if C1 = Cost of the spare (as quoted by the supplier at the time of buying the machine), say Rs.1 lakh, C2 is the expected loss due to non-functioning of the machine during later period of its life, say Rs.20 lakh, then the ratio (C1/C2) = 1/20=5% can be used as a 'break even point' for making this decision. The maintenance engineer makes his best judgment as to whether the probability of requiring the spare part during the lifetime of the machine would exceed this figure, if it is likely to, then the spare is to be stocked; otherwise the decision is postponed till more experience on the machine is available. At that point the same question is again asked.

Rotables/Floats/Repair Pool

A repairable item or assembly is called a rotable, float, or repair pool. It goes through a repair cycle. That can be treated as the LT, the other calculations being the same as for other repair parts. They, amongst the installed costly electric motors ('A' item) of a particular model which is also very critical to production ('V' item) there are on an average 3 failures per year. The Repair cycle time (treated as LT) is two months. A-V items are given 85% assurance in this organisation (k=1.0).

Hence, ROL =(3) (2)/12+1.0 [= 1.2, rounded off to 1.0. This is held in stock as a rotable, float or a repair pool. In a large airline or transport fleet, several engines may be kept in the repair pool on this basis. A very critical, expensive and long life repairable item can also become an insurance item for which the decision will be to stock 1or none.

7.3.10 Stage 6: Disposal of Damaged, Surplus and Obsolete Spare Parts

An organisation expecting good resale value for its surplus spare parts should ask itself whether it would buy 'second hand' spares from another unit at any price other than scrap value. One can never be sure as to how long the parts had been in stock and what deterioration had set in during storage. Such spares get some value only when they are sold along with the used machine itself. Further, it is not wise to dispose off spare parts applicable to existing machines simply because they had not been used. Only stock of insurance spares exceeding 1 could be sold off-but not at scrap value. It is safer to carry the inventory. Possibilities should be explored for alternative uses or as substitutes (Even with modifications) for the surplus/ obsolete spare parts.

Activity D

Carry out a detail study of spare parts management in an organisation. Examine each one of the six stages of spare parts life cycle and give suggestion for improvement.

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7.4 MANAGEMENT INFORMATION SYSTEM (MIS)

The MIS for spare parts is similar to that for other materials and has the same aims. Typical reports generated by the MIS are:

- Stock and Consumption Status Report
- Pending Indents Report
- Pending Purchase Orders Report
- Stock-out Report (also dangerously low stock position report)
- Over-stock/Under-stock Report
- ABC analysis- separately for repair items and overhaul items

In addition, the computer should automatically adjust the inventory parameters, such as ROL, SS, LT for routine indenting. Special' 'alerts' may be build into the system to identify deviations from expectations e.g. sudden rise/fall of consumption rates of spares. Typically, a sudden increase in the usage rate of a component may be due to related increase in failure rate, which in turn could be due to poor quality for latest supplier. If the drop in consumption of a part is accompanied by sudden rise in the consumption of the assembly into which is goes, evidently for some reason maintenance had started replacing assemblies instead of parts.

The range of spare parts is so vast that computers have to be sued for getting replies to the numerous queries that will arise in managing spare parts.

Activity E

Design a MIS for spare parts inventory management in your organisation or in an assembly unit. Which type of reports you are likely to get from your spare parts MIS?

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7.5 COST CONTROL FOR SPARE PARTS: ROLE OF MAINTENANCE

Cost due to and of spare parts occurs as (a) Cost due to non-availability when required for the machine, (b) Consumption value (c) Inventory carrying cost, and (d) capital cost of non-moving items. To minimize the need for troublesome repair parts, operations must prevent failures, and maintenance must ensure that maintenance is done on time and is of high quality. Maintenance must give top priority to eliminate failures requiring the high cost items that are also critical. Worn parts can often be rebuilt at a fraction of the price of new parts. Standard parts, low LT, purchase from OEM/reliable suppliers will reduce cost. Simple procedures, using computer for scientific analysis and updating of inventory parameters will reduce the operating cost of the spare parts system. Maintenance must assist in identification, preservation, and inspection of spare parts.

7.6 ORGANIZING FOR EFFECTIVE SPARE PARTS MANAGEMENT

In large organizations there should be a 'spare parts cell' consisting of a representative each of maintenance, purchasing, and stores. Apart from initiating the indents, this cell should operate the MIS and continuously look for improvement in inventory control and cost control, introduce computers for MIS, carry out various analyses, and in general, act as 'internal consultants' in the complex area of spare parts management. They should report to a senior level in the Technical Services Department. The members of the cell should develop expertise in this area. In a medium size organisation the spare parts cell may have part-time members. They should report to the Chief of materials. This places the responsibility of planning and providing spare parts squarely where it belongs. In small organizations, only those maintenance engineers who are trained in scientific inventory control of spare parts should be allow ed to indent spares parts. Their services should be utilized during a period (say, every two or three years) updating of the system as a whole.

7.7 UNIQUE PROBLEMS OF SPARE PARTS MANAGEMENT

Raw materials and consumables are primary materials, which are related to continuous functioning of the machines. Spare parts are 'secondary' items and are related non-functioning of the machines. These characteristics create most of the problems of managing spare parts inventory. These are summarized below:

1) Requirements are unpredictable in time and quantity
2) In relation to consumption rate the safety stock is very high, resulting in idle inventory.
3) Separate inventory control system needed for different types of spare parts
4) Detailed inspection of purchased parts is not possible. This gives rise to spurious spares market.
5) Data is not available for estimating consumption rates for most spares. Engineering assessment can go wrong for new type of machines.
6) Prices of spare parts are not related to cost of their production, but to other commercial interests.
7) Changes in models, modifications create difficulties in procurement of older parts.
8) The range of spare parts needed is too large for effective control by manual methods
9) The large variety makes identification and preservation difficult and error prone.
10) Obsolescence is common. Even serviceable parts have practically no resale value

7.8 SUMMARY

Managing spare parts is the biggest challenge in materials and maintenance management. With the scientific tools available now, much improvement can be achieved, provided those tools are used. The spare parts go through six stages in their life cycle: Design and specifications; Determination of initial requirements;

Procurement; Storage and preservation; Issue and replenishment; Disposal and damaged, surplus and obsolete spares. Like inventory management, ABC and VED analysis play important role in spare parts management. For low consumption and slow moving spares, the re-order level has been computed. MIS of spare parts management can be effectively used for preparation of reports for stock and consumption, pending indents, purchase orders, stock-out etc.

7.9 SELF-ASSESSMENT QUESTIONS

1) What is the aim of spare parts inventory management? In what way does it influence the different stages of the life cycle of spare parts?
2) What are the different types of spare parts, and when are they used?
3) What is EOQ? Why is the EOQ formula not useful for spare parts?
4) What is Pareto's Law? In what ways is it used for spare parts?
5) What is VED analysis and how is it used?
6) Using the following decision matrix calculate the ROL for the following spares:
7) Which problems are unique to spare parts that other materials do not exhibit? Why do these problems occur?

7.10 BIBLIOGRAPHY AND SUGGESTED READINGS

1) "Spare Parts Management" by Lt Gen. S.S. Apte (PVSM), Vanity Books
2) "Maintenance and Spare Parts Management " by P. Gopalkrishnan and A.K. Banerji, Prentice-Hall of India Pvt. Ltd., 1991.
3) "Materials Management an Integrated Approach" by P. Gopalkrishnan and M. Sunderesan, Prentice-Hall of India Pvt. Ltd., 1996.

7.11 CASE STUDY IN SPARE PARTS MANAGEMENT-I

Ajay Engineering Works (AEW) started as a small jobbing company for the engineering industry during World War II as a family concern. Soon after the war, they expanded their range of machines in the machine shop and also added a non-ferrous foundry. An ambitious family, they also took up manufacture of brass and copper tubes for the electrical and refrigeration industry. When the neighboring company that used to supply them the brass/copper ingots was in serious financial trouble AEW bought this company too and became self sufficient for basic raw material. Later, expending their product line they began to produce copper plates in various sizes and grades.

The Directors of the AEW were shrewd businessmen and stayed in business mainly because of their astute forecasts of the fluctuating world prices of copper- the most expensive imported raw material for their major product. They were also alert to new business opportunities and continued to diversify into virgin fields, or those where the competition was less. A few years back they added manufacture of copper conductors for State Electricity Boards on the condition that the latter supplied them the raw material in the form of scrap copper (with generous allowance being allowed to the Company for metal losses in melting).

The Company Directors soon realized that due to diversification their production control and inventory control systems were becoming inadequate. In fact, till then these functions were largely 'played by the ear' by their own experienced production planners and stores manager, who had literally grown with the Company. The tight money position also dictated that the inventory had to be tightly controlled by scientific methods the spare parts were also giving a lot of headaches to them. Their range and value had shot up thanks to the increase in the general purpose as well as specialized plant and machinery over the years.

Not being familiar with the modern techniques, they decided to hire a qualified young man as inventory controller. Anil Verma, a distant relative of the Managing Director had just acquired a Diploma in Business Management and was immediately employed as 'Inventory Controller'.

Shri. Onkar, the old stores manager who had now taken on the impressive title of Materials Manager, was clod to the idea. He even felt that it showed lack of confidence of the management in him. As he was not consulted before employing the new manager he had no option but to keep him. Still, he was an old timer, loyal to the Company and decided to test out the young man before giving him a major responsibility.

He decided to give Anil the task of looking into the problems of general stores, and oh yes, the spare parts also. That was huge in range but did not contribute as much to the inventory as the few raw materials, mainly copper, which he handled personally. Inventory control of copper occupied much of his time. He kept track of its consumption (against norms), Physical stocks, wastage, and the perennial risk of thefts. The MD, with the assistance of an old purchase manager, himself handled the procurement of this most expensive raw material. Onkar felt that the huge range of general stores like lubricating oils, fasteners, cotton waste, hand tools etc and of course, the never ending list of spare parts would keep Anil occupied long enough for the former to decide on how best to utilize his services.

Anil took on his first assignment seriously. He analyzed each and every item of the inventory as under:

- 3 grades of copper
- 27 other items of raw material (such as fluxes and alloying metals, that were directly influenced by the production rate of copper-the dependent demand items)
- 1858 items of general stores, which included cleaning materials, lubricants, hand tools, fasteners, adhesives, and other repair material. They included some non-stock items i.e. items which were not used often. These were purchased only when required but not for stocking
- 5497 items of spare parts which included complete electric motors and other assemblies, subassemblies, spare parts for mechanical, hydraulic, electrical and instrument items.

It took him four weeks to get the data on unit costs and consumption of each item during the past one year, based on which he carried out his first ABC analysis. This is what he found:

1. Out of the range of 7382 items only 74 i.e. I% items contributed as high as 96% of the total consumption value. He showed these as the 'A' items.
2. Of these 74 items, the highest contribution came from the 3 grades of copper, followed by 24 other raw materials (dependent demand items) and just 47 items of general stores. Further, copper alone represented 0.40% of the total range of all items but contributed a whopping 36% of the total annual usage value.

3. Approximately 20% i.e. 40 items of general stores had no consumption during the past one-your (database). Similarly, as many as 4502 i.e., 82% of the entire range of spare parts showed no consumption at all during the base year. In fact, many of the spare parts had not been issued even once in the past few years. Yet, maintenance engineers had often complained that work was often held up due to insufficient spares in stock.

Anil found this analysis intriguing. At the business school he was told that usually about 15% to 20% of the range of the items in an inventory contributed to some 70% to 80% of the total annual consumption value. Books on inventory control also quoted these figures while referring to the lopsided behavior of inventory costs with respect to range. The present analysis showed a far more lopsided pattern. He had not overlooked a single item in the inventory. He had even included the sweeper's brooms.

While doing the analysis he had been a little undecided about how the annual' usage value' of nonmoving items was to be included-since the consumption was zero. Should he remove them from the analysis? But then, some of them had been issued only a few weeks or months before the year under consideration. How was he to allow for their cost contribution? would it be better to take a two-year data? If yes, why not a five-year data base?

Not having any answer to this question for the non-moving items, he just decided to ignore the consumption value but used the stock value in stead. He made an appointment with Onkar to show him what he had done. With much enthusiasm he explained to the older man, the great advantages of ABC analysis for the management of inventory, he also explained the steps that could be taken to control the top few high cost-contributing items as explained in various textbooks on materials management, which he had avidly studied in the business course.

7.12 CASE STUDY IN SPARE PARTS MANAGEMENT-II

Anil Verma took his job seriously. He tried to learn from every experience in his department. He had several job offers from large organizations. Seeing the limited possibility of a career in this family owned company, he changed his job. Over the next few years he had an opportunity to serve in all aspects of materials management-procurement, storage and distribution, receipt and issue accounting, inventory control, and disposal of surplus and scrap. But nothing provided as many challenges and as many frustrations as spare parts management. In due course he was promoted to the position of materials manager in a large mining complex, where he looked after all aspects of all materials.

His big problem was that the maintenance engineers were never happy about supply of parts. He had to accept their indents, even when he felt that the quantity indented was inflated. His function did not permit him to question the maintenance engineer's judgement. All too often, the indents from maintenance were delayed too much and left no time for him to procure. Rush purchases had become the rule.

In the weekly management meetings of the General Manager he often argued that forecasting of spare parts should not be left to maintenance, as they had done a bad job of it. Yet, he was not too sure whether his own staff could do any better. As far as the raw materials were concerned, norms of consumption of material (such as explosives) per tonne of overburden/ore were well established and the production plan was known in advance. It did not change very much either. As a result, it was a matter of simple arithmetic to convert the production plan into raw materials procurement plan. Since many departments used the general stores, the average consumption rate was fairly steady and established from past consumption data. Here too, he did not have any problem of inventory control except for a few sporadically required items.

Forecasting of requirement in a future period is the starting point for inventory control. He used to argue with maintenance that if they did the forecasting correctly his inventory controller would be able to take the decision of how much to stock and when. The maintenance engineers, in stead of forecasting consumption rates (for fast moving items) and quantities (for the slow movers), only told him how much to stock (through their indents). Due to delay in indenting, he had to rush to get the needed spares. He had often discovered that such spares were not used at all or much later. In short, his firm belief was that maintenance were just' crying wolf' all the time. As a result, his staff had also taken it easy when attending to maintenance requests. Unfortunately, whenever such points came up in the weekly conferences the GM simply asked the materials and maintenance people to sort the matter out amongst them. Yet, he sternly warned that he was not going to tolerate any delay in getting spares. They had to be available at any cost.

The GM's weekly coordination conference was going on. Today's discussion was for the delay in repair of equipment. As usual, the maintenance manager has vehemently complained about delay in getting spares. Today, Anil Verma was on the defensive. He knew that the examples quoted by maintenance were genuine. He thought that at this time, attack was the best form of defence. He said' "These chaps are never satisfied with the spare parts service rendered by us. They are always asking for more. Consumption rates of most spares are shooting up and I need additional funds" He felt he had now neatly transferred the problem to the top management. Providing funds was their problem.

The GM would not buy it. He asked," why do we need so many spares? In fact, why do we need any spares?" "Because the machines fail" was the answer from maintenance. The plant manager was not going to give up. Looking at the operations manager he asked, "Why do the machines fail? Can we not do some analysis of all this rather than simply ask for more funds? I want operations maintenance, and spare parts managers to sit and analyze the problem and suggest something more useful in their findings – two weeks from now" The meeting was over.

During the next week, Anil did separate ABC analyses of annual consumption value and stock value of all the spares for the main machines. He also listed out the frequency of consumption of these spares in decreasing order of values. He presented the analyses in the next meeting with the GM. The analysis brought out the following facts:

- The frequency of failures of all the 138 dump trucks for the past year had a pattern. Only 7 out of 72 types of all failures contributed to 378 i.e. 45% of all incidences of failures. Thus,

	Types of Faults	No. of Incidences	Percentage
	7	378	46.0
	7	137	17.0
	8	128	15.3
	8	73	9.5
	42	128	12.2
Total =	**72**	**844**	**100**

The GM wanted to know if maintenance and operations had any comments.

Requirement I: What is your comment on this data? Please remember the context in which the analysis was made. Can you recall the exact concern of the GM?

Suggested Response: The GM was concerned with avoiding the need for spare parts in the first instance

Follow up on the Above Discussion:

Operations manager had nothing to say but the maintenance manager had realized that this was the same ABC pattern he had heard about somewhere in connection with materials but did not know enough about it. The same pattern was obviously applicable to the frequency of failures too. In answer to the GM's query, he said that the top few faults, which caused the most interruptions to machine operation, had to be attended to first. The GM then went a stage beyond. He stated that more than attending quickly to the repair of the top few faults it was necessary to see that they did not occur at all. He discussed this further with the other managers and gave the following decisions:

1. Maintenance and operations should jointly study the causes of the top 14 faults in the frequency table above and go all out to reduce their occurrence. They should be given higher priority to those faults, which took longer time to rectify, and/or needed expensive spares.
2. At the same time, the spare parts manager should show the ABC analysis of annual consumption value of spare parts and give a list of the 'A' items to maintenance to see that the faults that needed these spares were also included in the list for reduction of failures.
3. Spare parts manager should look into the reasons for accumulation of the 'A' items from the ABC analysis of stock value and jointly with the maintenance manager take steps to avoid this in future. Maintenance should also find alternative uses for these items. If any of them were truly in excess of foreseen needs, they should be disposed off.
4. Progress should be reported in the next two conferences.

Further follow up (six months later)

For the first time, operations, maintenance, and materials managers were jointly involved in an exercise in improving rather than complaining. They undertook the task with enthusiasm. Six months later, they discussed the benefits obtained. These were:

1. Failures of machines had reduced significantly;
2. quantity and cost of related spare parts had reduced significantly;
3. Machine downtime was much less;
4. Quite unexpectedly the frequency of other faults, which were not directly attempted for reduction, also diminished. It was observed that many of them were caused by the faults which were deliberately reduced;
5. Materials Manager had more time to attend to other spare parts problems;
6. there was an all round feeling of ownership of the problem and of achievement in solving it.

Requirement II: What is the most important lesson you can draw from this Cost Study?

Suggested Response: Spare parts management begins with minimizing their need in the first instance.