Optimal planning of store allocation and assignment of spare parts in a warehouse

by

MOSAMMAT FERDAUSHI SULTANA

A thesis submitted in partial fulfillment of the requirements for the award of the degree of Master of Science in Industrial Engineering & Management.

Khulna University of Engineering & Technology
Khulna 9203, Bangladesh

September, 2008

Declaration

This is to certify that the thesis work entitled "Optimal planning of store allocation and assignment of spare parts in a warehouse" has been carried out by Mosammat Ferdaushi Sultana in the Department of Industrial Engineering & 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.

06/09/08

Professor Dr.Md. Kutub Uddin
Head
Department of Industrial Engineering and Management

Ferdaushi 06/09/08

Mosammat Ferdaushi Sultana
Roll No. 0411506

Approval

This is to certify that the project work submitted by Mosammat Ferdaushi Sultana entitled "Optimal planning of store allocation and assignment of spare parts in a warehouse" has been approved by the Board of Examiners for the partial fulfillment of the requirements for the award of the degree of Master of Science in Engineering in the Department of Industrial Engineering & Management, Khulna University of Engineering & Technology, Khulna, Bangladesh in September 2008.

BOARD OF EXAMINERS

1. 06/09/08

Prof. Dr.Md. Kutub Uddin — Chairman
Department of Mechanical Engineering — (Supervisor)
Khulna University of Engineering & Technology

2. 06/09/08

Head of the Department — Ext. Officio
Department of Industrial Engineering and Management
Khulna University of Engineering & Technology

3. 06/9/08

Prof. Dr. Naseem Ahmed — Member
Department of Mechanical Engineering
Khulna University of Engineering & Technology

4. 6/9/08

Prof. Dr.Tarapada Bhowmick — Member
Department of Mechanical Engineering
Khulna University of Engineering & Technology

5. 6/9/08

Prof. Dr. Shyamal Kanti Biswas — Member(External)
Department of Mechanical Engineering
Chittagong University of Engineering & Technology

ACKNOWLEDGEMENTS

The author expresses her indebtedness and deep sense of gratitude to Dr. Md. Kutub Uddin, Professor and Head of the department of Industrial Engineering & Management, Faculty of Mechanical Engineering, Khulna University of Engineering & Technology, Khulna-9203, Bangladesh for his continuous encouragement, constant guidance and keen supervision throughout the course of this study.

The author had the privilege of intensive and in depth interaction with many senior executives engaged in Store allocation and assignment of spare parts in the warehouse of the Barge Mounted Power Plant, Wartsila Bangladesh Ltd, Khulna. The author wishes to acknowledge the help rendered by those senior executives of the Plant for collecting data, by answering the research survey questionnaires, which form the basis of this thesis.

The author would like to acknowledge her gratitude to Contact Manager, Operation & Management, Wartsila Bangladesh Ltd. and Plant Manager, Wartsila Bangladesh Ltd., Barge Mounted Power Plant, Kashipur, Daulatpur, Khulna for providing her facilities and assistance to make possible to complete the M.Sc. Engineering thesis.

Finally, the author would like to extend her gratitude and heartfelt thanks to all the teachers of the department of IEM, KUET for encouragement and support in doing this research work.

6th September, 2008 Author

ABSTRACT

Unscientific method of store allocation and assignment of spare parts in warehouse has been one of the major factors that have been causing loss in many companies. To keep pace with the competitors the modern managers are very much aggressive to attain a standard product or service in a minimum cost. The modern managers are very conscious to reduce cost by keeping standard in respect of all aspects which involve better management of workmen, raw materials, spare parts and production output etc. Organizing these functions will require proper guidance, regulation and control so that materials are arranged in such a manner as to enable easy storage, minimized pilferage, proper identification and quick retrievals with minimum waste of time and effort. For this purpose stores location and layout must be considered and the job analysis must be done for the personnel involved to discharge their duties in an effective manner. Management and allocation of spare-parts is a vital problem for sound operation of store. Miss-allocation of spare-parts takes huge time to find parts out. This problem causes extra time consumption and money expenditure for the involvement of labor for long time and also creates risk of unavailability which lead to improper maintenance or repair of machines. So, a standard model for allocation of spare parts in the store is developed in this research.

This thesis is an outcome of scientific planning of store allocation and assignment policy for spare parts of the Barge Mounted Power Plant in Bangladesh. The existing policy of spare parts is taken into account for preparing the basis of this thesis. In the existing system scientific policy is not followed. As a result, the plant faces problems in arranging the spare parts in the shelf and also in quick issues/retrievals with minimum waste of time and effort. Materials enter into the Plant as spare parts or as consumable items and are kept in Plant Warehouse which is under Logistics Department. Finally, these are used to produce electricity for national grid. Spare parts and components are utilized for the smooth functioning of production machineries. Total spare parts stock on hand in the Plant is 4,000 approximately in number. Theoretically, the Plant uses the sequence system in arranging all the spare parts in the warehouse shelves i.e. the system calls for the location of items in alphabetical order and numerical order without regard to issue frequency, size, weight or volume (chapter 2).

From the past demand, it is seen that the spare parts are required for a scheduled or unscheduled maintenance of a particular part of engine. To repair, to replace or to overhaul always contains a list of spare parts which is mostly similar each time (chapter 3). All these similar parts as required for a particular maintenance, is called family of spare parts (SPF). We have classified all the 4,000 approximately items in 56 SPF. So, if we keep a spare parts family(SPF) which is required as per work order in the same shelf in the warehouse then the issue/retrieve of spare parts will be more easy and less time consuming. In existing system spare parts are not arranged as per family of spare parts. So, the existing system takes much time to issue and retrieve the list of items as per work order (chapter 3)

The weight is used to identify each SPF as slow or fast moving. The weight of a SPF is the summation of all item's frequency of usages in a year. By considering weight, higher weight SPF(fast moving) should be kept near to issue counter and less weight (slow moving) SPF is to be placed far from counter (chapter 2).

By comparing total transport work and travel distance with the data of year 2007, it is found that for the existing system of 56 engine parts SPF total transport work is 704,097.77 pcs-ft and travel distance is 9,746.43 feet in the year 2007 but if we could arrange the warehouse according to the proposed allocation system total transport work would have been only 168,951.16 pcs-ft and travel distance 4,015.70 feet in year 2007. The net outcome would be the reduction of transport work by 535,146.61 pcs-ft and travel distance by half. So, we can say that if we would implement this new system 76% less work per year with respect to present system (chapter 4) could be achieved.

Scientific storage allocation system ensures the right material in the right place and serves the user in the most effective manner through the shortest possible distance in the least amount of time. It will increase efficiency and accuracy in receiving process, will increase storage capacity, reduce the level of safety stock by analyzing FSN method.

All the data available in the Plant are deterministic. It may change due to the change of any planned and unplanned maintenance.

Contents

List of Tables

List of Figures

Nomenclature

Maint.	Maintenance
CAC	Charge Air Cooler
Int.	Intermediate
Reqn.	Requisition
Reqd.	Required
Qty.	Quantity
WMS	Warehouse Management System
LO	Lube oil
FO	Fuel oil
FSN	Fast, slow and non moving
SPF	Spare parts family
L_d	Traveled distance
R_f	Number of deliveries per year
TTW	Total transport work

CHAPTER-1

Introduction

1.1 General

Spare parts are valuable goods for a company in terms of money and necessity. Without this a company can not run smoothly. So an efficient and effective storage system is very much essential. For this purpose manufacturing as well as service industries hold inventories. For smooth functioning of any organization various department perform their duties and responsibilities meticulously. A store manager is a custodian of the spare parts. He receives the spare parts, stores it in a convenient way, follows the storing procedure so that the parts are kept safe and functional and the rapid issue of the spare parts by demand becomes easier. The store manager must have adequate knowledge for proper storage and handling of spare parts. Time to time he must inform the authority about the stock status of spare parts and their condition. Expansion of trade and commerce has enhanced the need for proper storage of materials. Warehousing or storage of spare parts is a critical but neglected sector in the field of spare parts management. Good storage system can greatly assist the warehouse personnel in quick retrievals with minimum time to collect the items, in producing accurate stock status report, timely detection of discrepancies, prompt clearance of goods to expedite bill payment, reduction in demurrage and better claims management. Storage location plan decides where the spare parts are to be stored. The company must ensure a proper place for stoking. Literature reports that most of the industries spend more than 60% of all operation cost for order picking [12].

Any storage system is a compromise between the use of space and the use of time to retrieve materials. There are three basic ways of storing:

- Fixed location: While stocks can be found immediately without a complex system of recording.
- Random location: Goods and elaborate records have to be kept about the location of materials.
- Zoned location: Goods of a particular product group are stored in a given area.

In highly automated warehouse, sometimes slow moving and non-moving items are grouped together. The purpose is to assign most suitable types of storage and material handling equipment to different kinds of stock movement. Fast moving lines are

positioned near the input and output end of a store with the object of reducing the travel time and thus speeding up throughput [6].

If the spare parts are located in a random order the store keeper will face difficulty to issue the goods. He will lose valuable time; increase material handling cost and keeps the machine idle. If the spare parts are kept in fixed location again it will be difficult for store keeper to find out the desired items quickly. In a large industry or organization the difficulties will be more. To avoid these difficulties at first spare parts should be arranged in such a way that both the time to retrieve/store and the handling cost would be minimum. Different store or warehouse requires different strategy for spare parts arrangement. Sometimes spare parts can be arranged in ascending order of Stock keeping unit or it can be arranged by considering slow moving and fast moving items. If these steps can be taken simultaneously, the warehouse will be able to manage the spare parts quickly and effectively. When the spare parts are in a large number then it is very important to find out the location of spare parts very quickly that saves both time to retrieve/issue and as well as cost of material handling.

1.2 Introduction of the Barge Mounted Power Plant

The Barge Mounted Power Plant of Khulna Power Company Ltd. is located at Goalpara, Khalishpur in the city of Khulna. It is situated on the bank of the Vairab River and is near to Goalpara Power station, Khalishpur, Khulna.

The Plant utilizes Wartsila model 18V32 LN (Low nitrogen oxides, NO_X) Diesel engines each of 6.5 MW capacities which are installed on two Power Barges Tiger-I and Tiger- III. The power barge Tiger-I consists of 9 engines and Tiger-III consists of 10 engines. Installed Capacity of the Plant is 114 MW of electricity operating with heavy fuel oil (HFO). The barges are permanently moored in man made lagoon specially created for this purpose. Once the gas is made available, the conversion of the Plant to gas operation will be carried out. The plant is in continuous operation since September 1998 and the plant is currently dispatching at about 82% of the capacity. The Plant sells it's generated power to Bangladesh Power Development Board (BPDB) under power purchase agreements. The Plant is operated by Wartsila Bangladesh Ltd., the manufacturer of the Power Plant under Operation and Management (O & M) agreement with the owner, Khulna Power Company Ltd.

The plant has achieved accreditation and Certification of ISO 9001 on quality,14001 on environment and 18001 on occupational health and safety by LRQA (Lioy'd Resister Quality Assurance), UK.

1.3 Existing system of store allocation and assignment of spare parts

The storage allocation system in the plant warehouse for spare parts is looked after by Logistics personnel and controlled by MAMA (Maintenance Management) software. Spares are purchased from Wartsila Finland under Operation & Management (O& M) agreement with the owner and stocked in the plant warehouse for future use. The plant warehouse contain 23 shelves, numbering from A shelf to W shelf, stand in column wise to store about four thousand items. Shelves A to J are in ground floor and K to W are in 1st floor. Warehouse ground floor area is1,806 square feet and 1st floor area is 560 sq feet. Each shelf structure is made of MS angle, MS bar and wood. Each shelf is divided into four columns such as A shelf into A1, A2, A3 and A4 and so on. Each column is divided in four sections such as A1 into A1a,A1b,A1c,A1d and so on. Again A1a shelf is arranged into A1a1, A1a2, A1a3, A1a4 and so on. Every sub shelf contains 10 to 15 steel (size 18*8*6 inch) boxes which are divided in three or four sections so that items can be kept separately. The Plant Logistics department keeps about four thousand items in 56 (fifty six) engine parts subgroups for smooth running of nineteen engines. Spare parts are stored in the shelf according to the stock keeping unit number. Different stock locations in Plant warehouse are given for different stock keeping unit. The plant warehouse always puts things by giving stock location for each item in MP2 during receiving.

Plant Logistics are storing the spare parts as follows:

- Engine parts and auxiliary parts are stored separately.
- Spare parts are arranged in the warehouse shelf as per engine parts subgroup in ascending order but some items such as gasket, o-rings, screws, nuts, bearings, unions etc are kept in different shelves.
- Gaskets in one shelf, o-rings in one shelf, screws in one shelf, nuts in one shelf, bearings in one shelf and unions are arranged in one shelf and so on.
- Electrical items normally are kept in 1st floor due to low weight and heavy items normally are kept in lower shelf of ground floor. Chemicals and lube oils are

stored in a designated place out site the warehouse. The existing layout system is shown in figure 3.1

1.4 Drawbacks of present store allocation system

In a preliminary study of the existing warehouse system of the Barge Mounted Power Plant, it is seen that all the spare parts for a particular maintenance work are not located in the same zone or shelf. So, when requisition comes, we have to find out the spare parts from different zones or shelves. As a result, it takes more time to retrieve/store the spare parts and increase cost of material handling. So, if it is possible to develop appropriate storing/retrieving method (s) the above mentioned problems can be over come.

An effective stock location arrangement can lower storing cost i.e. the reduction of travel time for storage / retrieval or picking. The scientific storage assignment which is conceived as a comprehensive supply system can substantially contribute to company's profit through its systematic influence on store management.

1.5 Objective

In the earlier section, it is mentioned that management and allocation of spare-parts is a vital problem for sound operation of store. Miss-allocation of spare-parts takes huge time to find and retrieve parts. This problem causes extra time consumption, money expenditure for involvement of labor for long time and also creates risk of unavailability which lead to improper maintenance or repair of machine. The problems mentioned above attracted me and I wanted to concentrate my research view to establish a standard model for allocation of spare parts in the store. Keeping this in mind the specific objectives of the research are as follows:

- Analyze the existing store management system of Wartsila Power station Bangladesh Ltd. to find out any limitation in spare parts allocations.
- Develop a standard model for allocation of spare parts in the store.
- Comparing the performance of existing system with the proposed system.
- And at last but not least to make some recommendations to the management of Wartsila Power Station Bangladesh Ltd. regarding the implementation of the proposed system.

CHAPTER –2

Back ground of research

In this chapter some necessary definitions and concepts for warehouse layout planning and methodology are provided.

2.1 Existing classification of spare parts

Instruction manuals supplied by the manufacturers along with their equipments contain description of the equipments and their spare parts, guide line for installation and operation, types of lubricants and frequency of lubricating various parts and the estimated life span of different components. These manuals therefore need to be referred to at the time of installation of the equipment during initial period of its operation for determining production capacity and for planning of maintenance work of the equipment in question [14]. Spare parts catalogue [15] for Wartsila model Engine type VASA 18V32 duel –fuel engines as supplied by manufacturer Wartsila contain 15 chapters which are further divided into sections to offer a clear and more detailed view of parts needed. There are 56 sub groups under these 15 chapters. A sub group is identified by a three digit in section number and a two digit individual number i.e. 100-01. The chapters are as follows: Chapter-100 is for Engine Block, bearings, oil sump and covers, Chapter-110 is for Crankshaft, flywheel Connecting rod, Piston, chapter-120 is for cylinder head with valves etc. These are grouped according to the main division of the engine. Such as in chapter 100 all spare parts are included which are needed for Engine block connected, in chapter 110 all spare parts are included which are connected in Crankshaft and connecting rod and in chapter 120 all spare parts are included which are needed for cylinder head with valves and so on. To ensure fast and efficient spare parts ordering, delivery and issuing all spare parts in the warehouse which is required for engine is divided in 56 sections in engine parts subgroup under these 15 chapters in the spare parts Catalogue. Each subgroup contains many stock keeping units such as different types of gaskets, O-rings, screws, nuts, bearings, bush etc. The listing of all items includes the number of pieces (pcs) that are normally needed to assembly the main parts. The existing classification of spare parts system is given in below table 2.1.

Table 2.1: Main Group and subgroup of Spare Parts

Chapter No.	Table of contents	Main group	Subgroup	Description	Sl No.
1	Engine Block, Bearings, Oil sump,	100	100	Engine Blocks, Cylinder Liner, Oil sump	1
			107	Casings & covers	2
2	Crankshaft, Flywheel, connecting Rod, Piston	110	110	Crankshaft	3
			111	Connecting Rod	4
			113	Piston	5
			114	Flywheel	6
3	Cylinder head with valves	120	120	Cylinder head	7
			121	Exhaust & Inlet valve	8
			123	Starting valve	9
			125	Cylinder head safety valve	10
4	Intermediate Gears	130	131	Intermidiate gear	11
	Valve Mechanism, camshaft	140	143	Rocker arms	12
			145	Valve tappet	13
			148	Chamshaft	14
5	Charge Air System	150	156	Air Band	15
6	Injection Equipment	160	165	Injection Pump	16
			167	Injection valves	17
	Fuel Feed Pumps	170	174	Fuel feed pump	18
7	LO pumps, Thermostatic Valves, dipstic	180	181	LO pump spare	19
			182	Prelube pump spare	20
			183	Thermostatic valves for LO	21
			184	Oil Dipstic	22
8	Cooling water pumps,thermostatic	190	191	Water Pumps	23
			196	HT/HTthermostatic valve	24
9	Exhaust Manifold	200	200	Exhaust Manifold	25
			205	Insulation Box	26
	Starting Equipment	210	211	Starting air distributor	27
			213	stop lever	28
			214	Starting fuel limiter	29
			217	Main starting valve	30
10	Regulating Mechanism	220	223	Booster Survometer	31
			224	Regulating Mechanism	32
			228	Overspeed trip device	33
	Speed Measuring	230	231	Speed pick up	34
11	Maniold(fuel, lube oil,cooling water, starting)	350	350	Fuel lines	35
			352	LO pipes	36
			354	Cooling water pipes	37
			355	HT & TC pipe connections	38
			357	Control air system	39
			358	Leak Oil pipes	40
12	Cleaning device	370	372	Turbocharger spare	41
			377	Crankase cover	42
			378	Crankcase breather	43
13	Filters, coolers	470	470	Fuel filter	44
			471	Lube Oil filter	45
			473	Centrifugal filter	46
			476	Air cooler	47
			483	Spare for turning device	48
14	Tranducers, instrument panel, thermometers	500	501	Connection Box	49
			506	Exhaust temperature sensor	50
			507	Temperature transmitter	51
			508	LO alarm tranducer	52
			511	Thermometers	53
			516	Instrument pannel	54
15	Connecting pcs, extension shaft,	600	600	Connectio piece for TC	55
			604	Accessories for engine	56

2.2 Store Location and Layout Considerations

The most important factor, when establishing a warehouse, is locating it in the most appropriate place. The general principle is to minimize the total kg-km of transportation of materials within the constraints. To have the warehouse nearest to the point of usage is a great advantage. The guiding factor in locating the warehouse is minimizing the material handling efforts while serving the user. This implifies the location of spare parts near the user side and location of spare or goods near the assembly point. The stock should be nearest to the user in the form of a decentralized warehouse. However, the slow moving and /or costly common items can be kept in a central place. For fast moving and routine items serves the consumer better, should be nearest to the issue counter. The layout of a warehouse should be suited to the commodities that are being received, stored and issued. If the movements of commodities stored and analyzed thoroughly, it is seen that a fairly small percentage around 10% of the item contributes to around 60% of movements. This suggests that items which are handled frequently should be so located as to minimize the distance traveled. Normally, the available floor space in a warehouse is splited as receiving bay, inspection area, bulk storage area, activity area, gangway, outsides, smoking area and issue area. This is done in order to avoid confusion and overcrowding of bays. The layout should be such that entry of unauthorized persons must be prohibited. The premises should be kept clean by regular sweeping, use of disinfectants, and provision of adequate drainage facilities. There should be proper ventilation, and undue overcrowding of employees must be avoided. There should be sufficient lighting. Thus the warehousing layout ensuring the right material in the right place and serving the user in the most effective manner through the shortest possible distance in the least amount of time must be developed [6].

Effect of plant layout

Plant layout is an important factor influencing the design of a material handling system. The layout should provide the following information for use in the design of the handling system:

- Locations where materials must be picked up (load stations)
- Locations where materials must be delivered (unload stations)
- Possible routes between these locations

- Distance that must be traveled to move materials
- Flow patterns, opportunities to combine deliveries, possible places where conjunction might occur
- Total area of the facility and areas of the specific departments in the layout
- Arrangement of equipment in the plant [13]

2.3 Material Handling and Storage Systems

Material handling is defined as the movement of materials (raw materials, scrap, semi finished and finished products) to, through and from productive processes, in warehouse and storage, receiving and shipping areas. Warehouse concerns those material handling activities that take place within the warehouse areas, i.e. receiving of goods, storage, order picking, accumulation and sorting and shipping. It covers an activity that goes on in a storage place, warehouse or at the place where materials and equipments are picked up and moved. Every operation requiring raising, lowering or moving an item may be termed as material Handling. According to the British Institute of material handling, it can be sub divided into two separate but closely interlinked disciplines. Material handling management and material handling technology and engineering. The former is applied to systems covering such matters as production manning and control, buying, storage and distribution and the second applies to technological aspects, for example, technical & mechanical means of handling and movement of a commodity, be it either solid, liquid or gaseous. Management strategy is concerned with coordination of the movement and storage of materials and supplies from the acquisition to the distribution of finished products.

Material handling, movement and storage operations are inefficient in the utilization of resources and a further improvement in efficiency in these operations offers the most profitable way of achieving economy. In identifying the material handling cost, research have further shown that (i) many companies do not know what their material handling (MH) costs are and (ii) a very wide disparity exists between the worst and the best practices [6].

2.4 Spare Parts

Spare parts are those parts of the machines which because of wear and tear, use or breakage, need replacement. Spare part is defined as a part identical to the part of a

machine which needs replacement due to wear and tear during the operating life of the equipment.

2.4.1 Classification of spare parts

Organizations classify spares in a variety of ways like regular, fast moving, emergency, consumables, major, minor, moving, non-moving, electrical, obsolete, mechanical, instruments, proprietary, permissible and project spares. But spare parts must be classified as maintenance, overhauling, commissioning, and rotable, insurance and capital spares for introducing scientific controls.

- **Maintenance spares** are those which are generally fast moving like bearings, belts, ands hardware items. Normally these are available in plenty and the spare parts can be stocked after building a database depending on the consumption pattern.
- **Overhauling spares** are those which are specially needed during regular overhaul in order to give a new lease of life to the equipment. Hence these need not to be stocked and ordered just in time before overhauling.
- **Commissioning spares** are needed to start a project or commission equipment and these parts are declared as project surplus after the machines starts its operation.
- **Rotable Spare:** Costly assemblies like motors, engines, and pumps are repaired and stored for use.
- **Insurance spares** are those vital parts of a machine which have life nearly equal to that of a machine itself and are held as a standby against any breakdowns.
- **Capital spare:** These standby units have a high reliability of performance and can be capitalized [7].
- **ABC classification:** About 20% of people account for about 80% of activities and the remaining 80% of the people are engaged in the balance 20% of the activities. This is the 20/80 rule. This is based on the principle-"few are vital" and "many are trivial" and aims to direct efforts where results are important.[4]. This 20/80 rule in materials management is known as ABC (Always Better Control) analysis [4]. 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 [3]. The specific unit of stock to be controlled will be called a Stock-Keeping Unit (SKU). An SKU is defined by an item of stock that is completely specified as to function, size, coding and usually location. For example, the same O-ring in two sizes would constitute two different SKUs. All SKUs of the Plant should not be controlled to the same extent.

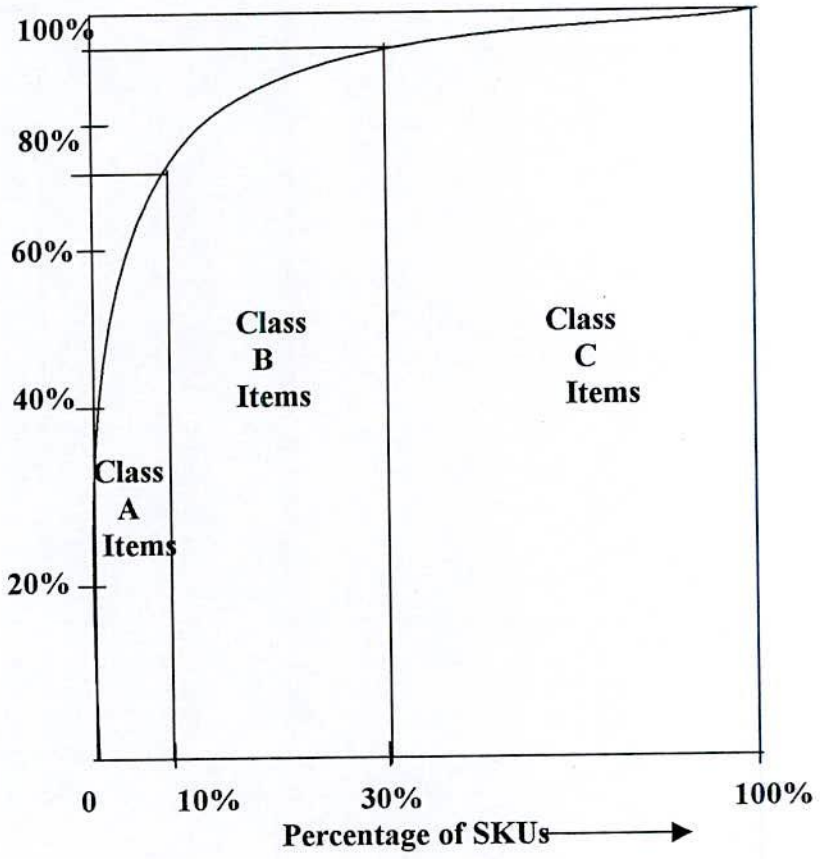

Figure 2.1: Graph for ABC classification

These SKUs are assigned a higher priority in allocation of management and rated A (most important), B (moderate in importance) and C (least important).

- **Class A items:** The first 10% percent of the SKUs that account for 70% percent of the dollar usage.

- **Class B items:** These are of secondary importance in relation to class A because of their values or considerations, rated moderate but significant amount of attention needed. The 20% percent of the SKUs that account for 20% percent of the annual dollar usage fall in this group.
- **Class C items:** The largest groups 70% of the SKUs that account for 10% percent of the annual dollar usage fall in this group [4].

If the percentage is plotted graphically-with the number on the x-axis and the cumulative annual value on the y-axis, it will be noticed that the curve appreciably changes at two places giving the A, B, C categories. Typically, the plant shall try to keep relatively large number of low-valued items 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 more attention on mostly dollar usage to reduce cost of the unit power generation. So ABC classification is done on the basis on dollar usage. 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 items under loose or normal control [3].

- **HML classification:** This method is similar to the ABC classification. But in this case, only the unit value of the item is considered, instead of taking the annual consumption value. Items are classified according to the unit value as high value, medium value and low value and this is used to control the purchase value of the items. Here also the cut off points vary from unit to unit. Some organizations use both HML and ABC classification for control of unit value of items and the overall consumption pattern. Both ABC and HML analysis are used for controlling the average inventory as well as purchase value [4].
- **Movement/FSN classification:** F stands fast, S stands slow moving and N stands for non moving materials and parts. The FSN –Fast-moving, Slow-moving and Non-moving analysis- checks stock rotation and identifies the obsolescence of items. This analysis is particularly useful for spare parts. The combination of the movement analysis and unit price/HML analysis results in the conventional ABC analysis. The cut –off periods for fast moving, slow – moving and non-moving may be varied according to the class of items and organizations' culture. The pattern is different for selling organizations. For instance, raw materials and components move faster than spare parts. Many

organizations consider items with at least one withdrawal in a quarter as fast moving, one issue in a year as slow moving and no issue in a year as non-moving. The duration can be changed to suit the individual organization's needs. For instance, in a sales organization, many may consider at least one sale in a week as fast moving and no sale in a year as non- moving [4]. FSN study may be made to weed out unwanted materials and parts. This will automatically reduce inventory costs. If a part or material has not been issued within a period of three years this can be completely weeded out. If a part moves to sparingly within this period, its stock can be substantially reduced. Fast moving materials, however, pose no such problem [6].

- **Criticality Criteria (VEIN/VED) classification:** Technical considerations form the basis for the above criteria. VEIN is the accepted classification for equipments as Vital, Essential, Important and Normal. Vital equipment is one which feeds a battery of equipments downstream. A vital part getting into vital equipment is more critical than the same part getting into a normal machine. Essential spares are those in which stock out would result in moderate losses while the non-availability of desirable spares will cause only minor disruptions for a short duration. A desirable item is one without which the system can effectively function, usually an extra fitting, like the seat cover in a car [7]. VED is the art of classifying parts into vital part, Essential part and Desirable part. It should be looked at the criticality of the spare part from the technological/production/design/safety/pollution point of view and hence the decision is based on technological considerations to ensure smooth functioning of the production system. Vital items are those items without which the plant system will come to a grinding halt, a typical example being the spark plug in a car. Vital spare parts include all items which if not in stock, would result in huge losses and complete closure of the plant, for a considerable period of time. In a spare parts selling organization, non-availability will result in loss of image of the firm. Hence a very heavy cost has to be incurred to procure the items on an emergency basis [7]. The classification is based on performance, guarantee, warranty, reliability, safety, maintainability, functional utility, criticality, etc., taking the operational point of view into account. This is particularly useful for spare parts control and has to be done by the maintenance and design staff. The

tendency to classify every item as vital should be discouraged. For instance, in summer months, when there is power cut the diesel generator providing electricity for high tension industrial consumers is the most vital equipment and major parts of this are critical parts. Non-availability of the critical spare parts can cause havoc in the industry. The VED and VEIN analysis can be combined to give the highly critical and non-critical items [4].

2.5 Development of Storing system

Assuming the need for an order assembly area the methods of stock positioning which will provide the most effective service is to be selected. Choosing the most suitable storage system means dealing with a number of interacting and often conflicting factors. The degree of mechanization affects layout, while scarcity of space affects height. The need for rapid over picking means an easy accessibility to stock but it weights against space economy. Any storage system is therefore a compromise between the use of space and the use of time. There are many ways of storing which are appended below:

I. **Fixed location:** While stocks can be found immediately without a complex system of recording, there can be a considerable waste of space.

II. **Random location:** Space is better utilized. But elaborate records of goods have to be kept about the location of materials.

III. **Zoned location:** Goods of a particular product group are stored in a given area. They may be randomly stored in a zoned location or stored according to fixed location [6].

IV. **Spot location system:** In the spot location system stocks are positioned in any space that is available that suits the volume to be carried. In this system the store keeper memorizes the location and is thereby made the indispensable man. The chief advantage of this system is effective use of space; the disadvantage is ineffective positioning of fast and slow movers, thereby creating high order assembly costs.

V. **Sequence system:** The sequence system calls for the location of items in alphabetical order and numerical order without regard to issue frequency, size, weight or volume. In an order assembly area of say 40,000 items, considerable ground will be covered to collect, say, six items which may be spread over this range. In general 90% of the activity in a store comes from approximately 20%

of the items or put another way about 90% of the work can be carried out in about 25% of the area if materials are located by frequency. Therefore careful analysis of all phases of the order assembly operation is essential for a sequence location system to be effectively applied.

VI. **Size system**: The techniques with the size system are to place the smallest items at the front and the largest items at the back. The advantage is that the greatest number of items is near the front area. However, it is also advisable to provide space at the front for the popular large items in order to reduce walking while processing orders. Size location systems should therefore be coupled with additional planning to provide for stock positioning by demand.

VII. **Order pad system:** In the order pad system items are located following the sequence set down on a pre-printed order pad. If a small percentage of the items are in big demand, excessive walking will greatly increase the assembly time. It may be advantageous, therefore, to develop two or more order pads. This will results in better utilization of manpower and should also result in improved customer service. The order pad system can be satisfactory but again it can be made more efficient by considering stock positioning demand.

VIII. **Popularity location system:** In this system, emphasis is placed on item demand and materials are so placed that the most popular items are located in the most advantageous position. In addition, where conventional shelving is used, the central position of the unit is used for small popular items, the upper shelves for light weight and least popular items and the lower shelves for heavy items. A variety of bin sizes are useful to accommodate both large and small materials. By dispersing stock in this way congestion is relieved in the order assembly area. Popularity location, in other words, combines all the best features of other systems and properly applies to produce the most satisfactory results [14].

Particularly in a large, highly mechanized or automated warehouse fast moving or high turnover goods and some times medium and slow moving items are also grouped together. The purpose is to assign most suitable types of storage and material handling equipment to different kinds of stock movement. Fast moving lines are positioned near the input and output end of a store with the object of reducing the travel time and thus speeding up throughput [6].

2.6 Warehouse management system (WMS)

A warehouse generally consists of a number of parallel aisles with products stored along sides. A large variety of storage equipment and methods are in use. A warehousing system refers to the combination of equipment and operating policies used in an item picking or storage and retrieval. Typical planning issues in warehouses are inventory management and storage location assignment. Intelligent inventory management may result in a reduction of the warehousing costs. Reduced inventory levels not only reduce inventory costs but also improve the efficiency of the order picking operation within the warehouse. Clearly in a small warehouse, the travel times for order picking are smaller. Further more an effective storage location assignment policy may reduce the mean travel times for storage/retrieval and order picking. The Planning policies define a framework for the control of the warehouse process. Inventory management and storage location assignment policies determine products arrival and where these should be stored. Control problems typically deal with the sequencing of order picking and storage/retrieval operations and hence with the routing of manual order pickers, with the allocation of products to storage positions in a zone wise location as per engine part main group, with the internal movement of items to more attractive retrieval positions. Warehousing function is important as a service function in which the parts executive acts as a custodian of spare parts carried to the store. This has resulted in the emergence of various types of warehouse to facilitate receipt, storage, issue and disposal of all types of items in a systematic manner. Products from different suppliers are collected for delivery to customer. Goods are delivered by trucks which are unloaded at the receiving area. Here quantities are verified and random quality checks are performed on the delivered loads. Warehousing or storage of spare parts is a critical but neglected activity in the field of spares management.

2.6.1 Inventory Management System

Inventory refers to idle scarce resources waiting to be used to satisfy demand. The Inventory problem consists of deciding when and in what amounts to replenish inventory so that demand can continue to be satisfied at minimum cost or maximum profit. The importance of inventories to achieve a smooth and economical operation of the production distribution system and to find more economical methods for its management.

2.6.2 Codify and Identify

Codify refers to the assignment of an alphanumeric reference number to each warehouse items. The codes for the spare parts and equipment manufactured by Wartsila as follows: The first two digits correspond to the letters WD that identify the spare parts of Wartsila. The next six digits identify the part number. Example: WD167020 for Injection Nozzle. Codes for spare parts and equipment manufactured by the supplier other than Wartsila are as follows: The first letters of each word identify the name of the manufacturer when the name has two or more words. Example: AL = Alfa level, AM = Aura Marine. If the name of the manufacture has only one word then the first three letters are used. Example: TAM = Tamrotor, SPI = Spirax. The marking of all parts, material and equipment of the warehouse in MP2 with the following information: Item name, Item code, Vendor item number, Specification, Type, cost centre, Account code, present stock, stock location and stock site.

2.7 Work orders

The purpose of work order is to authorize and direct a company to do a certain job. It enables maintenance of records of cost incurred on that job. Work orders can also be used for communicating to workers the method and facilities required for execution of the work and the dates and times. Design of a work order form for maintenance work should therefore allow for the incorporation of the following information:

- Work order number
- Cost centre
- Description of the job
- Location of the job
- Craftsmen allocated for the job
- Job priority
- Reasons for undertaking the job
- Scheduled and actual time/date of commencement and completion of the job and machine shut-down
- Estimated and actual labour and material cost
- Job steps in their proper sequence, also indicating the special tools, materials, skills and estimated time for each job.

- Remarks of the operating department personnel with respect to quality of work [14].

2.8 Material handling analysis and techniques

There are several approaches that can be used to represent the material handling problem for visualization and analysis purposes. Tabular and graphical techniques are quite helpful for visualizing the moves and quantitative approaches can be useful for determining material flow rates, operation times and other aspects of performance in material handling. One of the techniques for displaying information about the material flow is the from- to chart. The from –to chart is similar to a mileage chart on a road map.

Table 2.2: From –To chart showing number of deliveries required per year from different shelf

From	To
Shelf location	# of deliveries per year, R_f

Table 2.3: From –To chart showing distance from different shelf in a layout

From	To
Shelf location	traveled distance, L_d

2.9 Material flow diagram showing materials flow from different shelf to different loading and unloading stations.

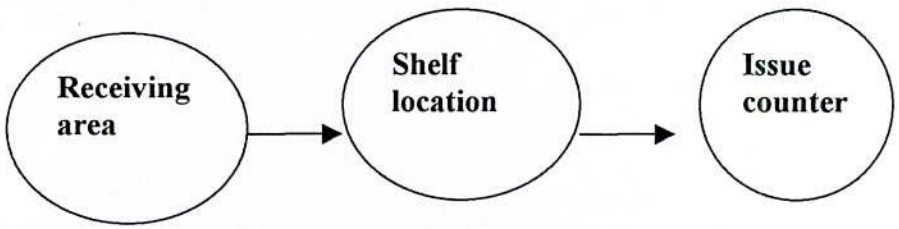

Figure 2.2: Material flow layout

Let us use the symbol R_f to represent this flow rates. This flow rate applies to the movement over a certain distance and L_d is the length of a delivery in the warehouse.

The product of these two parameters gives a measure of what Muther and Hagans call the transport work, TW, where $TW = R_f L_d$ Pcs-ft/year [13]

The transport work might be different due to different location. We can aggregate these various deliveries to determine the total transport work, $TTW = \sum R_f L_d$ Pcs-ft/year [13].

2.10 Mama Pro Software (MP2)

Successful and cost effective operation of a power Plant is closely related to the high quality of maintenance. MAMA Pro handles all areas of maintenance management and warehouse management for the entire installation and meets the demand for full control of all activities, a systematic way of working and good follow up procedures. It is a computerized maintenance management system software application invented by Datastream System Inc., 50 Datastream Plaza, Greenville, SC 29605. Mama software stores all WMS information in a database, a collection of related information stored in tables. 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 work order data in a third table. Mama software tracks Inventory items including usage, quantities in multiple location and sites, substitute items, vendors, and reorder points. One who has access in the database at any time, can add, change or delete information in any record in the table.

2.11 Group technology

Group technology is an approach that seeks to identify those attributes of a population that permit its members to be collected into groups, sometimes called families. The members of each particular group possess attributes that are similar. There are usually efficiencies and advantages to be gained from dealing with the population when it is divided into groups. Group technology can be applied to many different areas including design, manufacturing, warehousing etc. Another definition is "Group technology is a manufacturing philosophy in which similar parts are identified and grouped to take advantage of their similarities in manufacturing and design". Similar parts are arranged into parts families. For example, a plant producing 10,000 different parts number may be able to group the vast majority of these parts into 50 or 60 distinct families. A part family is a collection of parts which are similar either because of geometric shape and

size or because similar processing steps are required in their manufacture. The parts with in a family are different, but their similarities are close enough to merit their identification as members of the part family. Each family would possess similar design and manufacturing characteristics. Hence, the processing of each member of a given family would be similar and this results in manufacturing efficiencies. These efficiencies are achieved by arranging the production equipment into machine groups or cells, to facilitate work flow. In product design, there are also advantages obtained by grouping parts into families. These advantage lie in the classification and coding of parts. Parts classification and coding is concerned with identifying the similarities among parts and relating these similarities to a coding system. Parts similarities are of three types:

- Design attributes (such as geometric shape and size).
- Manufacturing attributes (the sequence of processing steps required to make the part).
- Similarity of uses.

While the processing steps required to manufacture a part are usually closely correlated with the part's design attributes, this is not always the case. Accordingly, classification and coding system are often devised to allow for differences between a part's design and its manufacture [11]. Spare parts which are required for a particular maintenance are similar each time, so if we would arrange all the spare parts in shelf as per similarity of uses then the issue /retrieve of spare parts will be easier and less time consuming.

Benefits of group technology

The problems that have prevented the widespread application of group technology include the following:

- The problems of identifying parts families among the many components produced by a plant.
- The expense of parts classification and coding.
- Rearranging the machines in the plant into the appropriate machine cells.
- The general resistance that is commonly encountered when changeover to a new system is contemplated.
- Rearranging the spares in the plant as per similarity of uses.

When these problems are solved and group technology is applied, benefits are typically realized in the following areas:

- Design
- Tooling and setups
- Material handling
- Production and inventory control
- Process planning
- Employee satisfaction
- Warehousing

CHAPTER –3

Theoretical consideration

In this chapter some concepts used in this research and the proposed algorithm for warehouse layout planning have been provided.

3.1 Family of Spare parts

From the past demand (requisition) of spare parts, it is evident that the spare parts are required for a scheduled or unscheduled maintenance of a particular part of engine to repair, to replace or to overhaul by new spare parts. To do this maintenance, every assigned person related to the work order has to collect the required spare parts from warehouse by filling a material requisition form. It is seen that the work order contains a list of spare parts which is required for that particular portion of engine is similar each time. All these similar parts required for a particular maintenance, is called family of spare parts (SPF). So, if we keep a spare parts family(SPF) which is required as per work order in the same shelf in the warehouse then the issue/retrieve of spare parts will be more easy and less time consuming. In existing system spare parts are not arranged as per family of spare parts. So, the existing system takes much time to issue and retrieve the list of items as per work order. An example of spare parts family which is given below is for a work order of cam shaft maintenance.

Table 3.1: Spare for camshaft maintenance

Issued date	Code #	Description	Present Location	Qty required
23-Jan-07	WD148011-005	Camshaft Bearing Bush	A4b	√
	WD148013-001	Allen Screw M12x35mm	A4b	√
	WD148014-001	Allen Screw M12x80mm	A4b	√
	WD148071-002	Bearing Bushing	A4b	√
	WD148072-001	O-ring	E1a2	√
	WD148073-001	O-ring	E1a2	√
	WD148075-003	Hex. Screw 10x25mm	J3c1	√
	WD148077-001	Gasket	E3b2	√

1.(√) Quantity required

3.2 Weight calculation of a spare parts family(SPF)

This weight is used to identify each SPF as slow or fast moving. It is equal to the total number of all items issued/used in each SPF per year or the total frequency of times all items of a particular SPF is used. The higher the frequency of usages the more is the weight. Each SPF contains number of items. Therefore, the weight of a SPF is the summation of all item's frequency of usages in a year. An example is given below for weight calculation for SPF 471 which contains two spare parts, namely lube oil (LO) insert and sealing set only.

Table 3.2: Weight calculation for LO filter maintenance

SPF	Req.#	Issued date	Code No. & Description	
			WD471196 LO filter insert	WD471235 Sealing set
471	1	1-Feb-07	√	X
	2	24-Feb-07	√	√
	3	17-Mar-07	√	X
	4	19-Mar-07	√	√
	5	12-May-07	√	X
	6	6-Jun-07	√	X
	7	19-Jun-07	√	X
	8	22-Jun-07	√	X
	9	23-Jun-07	√	X
	10	1-Jul-07	√	X
	11	30-Jul-07	√	√
	12	8-Aug-07	√	X
	13	30-Aug-07	√	√
	14	10-Sep-07	√	X
	15	15-Oct-07	√	X
	16	20-Oct-07	√	X
	17	30-Oct-07	√	X
	18	10-Nov-07	√	X
	Total Frequency:		**18**	**4**
			Grand Total frequency:	**22**

1. (√) Spare required
2. (X) Spare not required

3.3 Distance calculation

It stands the distance from where the store keeper has to travel to collect the items to the issue counter. The warehouse floor space is 43x 42 square feet and size of each shelf is equal to 2.04x 6.4 square feet (approximately). Column height is equal to 16 feet. Each column is divided in shelves a, b, c, and d. Each shelf height is equal to 4 feet. Each shelf is again divided into sub shelves as a1,a2,a3, and a4. Distance from a1 to a2 is equal to 1 feet. Let us consider the issue counter (X, Y, Z) as (0, 0, and 0) as shown in figure 3.1. To illustrate the calculation of distance a sample requisition for engine parts SPF WD148 as shown in Table 3.3 is taken. To collect the items from different shelves for this requisition the total distance traveled shall be the summation of the followings:

a) Distance from counter to Shelf E1a2 = 13.8+11+1=25.8 feet

b) Distance from Shelf E1a2 toE3b1 = 6.4*2+4=16.8 feet

c) Distance from Shelf E3b1 to J3c1 = 6.4*3+4+4=27.2 feet

d) Distance from Shelf J3c1 toA4b = 32+23.58+32+4=91.58 feet

e) Distance from A4b to counter =32+11+23.58+13.8 = 80.38 feet

I.e. to collect all the items of SPF-148 the store keeper has to travel a distance equal to (25.8+16.8+27.2+91.58+80.38) = 241.76 feet/requisition.

Table 3.3: A sample requisition for camshaft maintenance

SPF	SKU #	Code #	Description	Shelf number
148	SKU 1	WD148011	Camshaft Bearing Bush	A4b
	SKU 2	WD148013	Allen Screw M12x35mm	A4b
	SKU 3	WD148014	Allen Screw M12x80mm	A4b
	SKU 4	WD148071	Bearing Bushing	A4b
	SKU 5	WD148072	O-ring	E1a2
	SKU 6	WD148073	O-ring	E1a2
	SKU 7	WD148075	Hex. Screw 10x25mm	J3c1
	SKU 8	WD148077	Gasket	E3b2

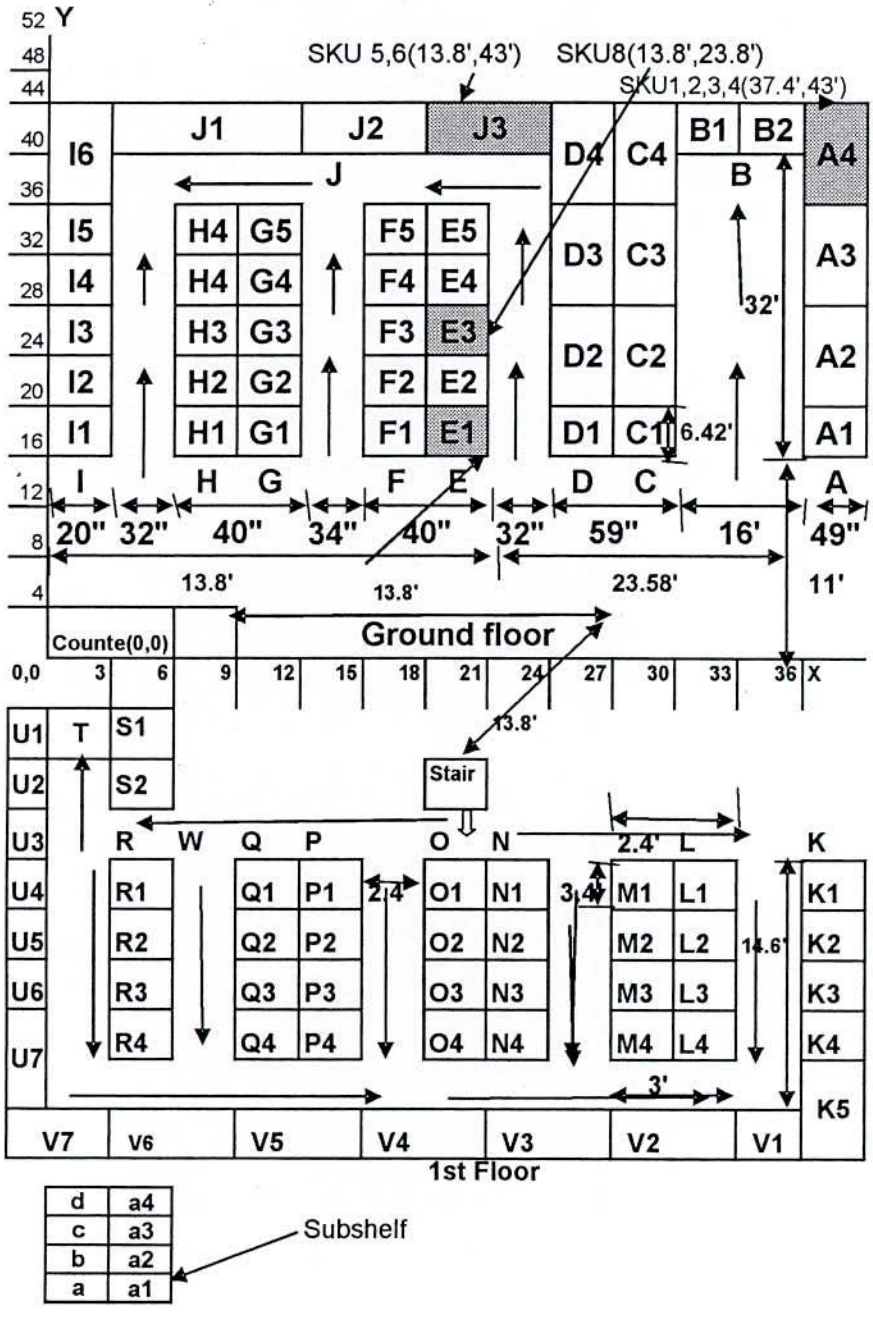

Figure 3.1: Existing Shelf Layout

3.4 Proposed algorithm:

Following are the steps which were considered in this research are appended below:

Step-I: Identifying the spare parts family (SPF): Each requisition contains a set of items. These items are called demand sets. These demand sets are used to identify the SPF. Following are the steps to identify the SPF:

10 Arrange the spare parts demand (requisition) sets in descending order of number of elements in the set.

20 Take a set from the top of the list. Form a SPF with this set.

30 Take another set from the list. Check whether this set is subset of any SPF already formed. If yes, merge these two sets, otherwise form a new SPF with this set.

40 Continue step-20 and 30 until the list formed in step 10 is empty.

Step -II: Calculation of weight for each spare parts family as described in Art. # 3.2

Step –III: Distance calculation for each shelf as described in Article # 3.3

Step-IV: Assignment of each spare parts family to shelves according to the following steps:

10 Arrange the shelf number in ascending order of distance. Name this list as A.

20 Arrange the spare parts family (SPF) in descending order of weight. Name this list as B.

30 Take a spare parts family (SPF) from the top of the list B

40 Assign this family to the shelves from the top of the list A.

50 Continue 30 and 40 until the list in B is empty.

CHAPTER-4

Analysis

The Plant's strategy is to keep all spare parts in the warehouse shelves as per ascending order of stock keeping unit during receiving of any consignment of spare parts except LO and FO filter. These are stored in plant container which is outside the warehouse. All types of gaskets, o-rings, bearings, nuts, screws, unions and pipes are kept in different shelves. It is observed that the plant more or less follows "Random location and sequence system". But practically from the past demand of spare parts, it is evident that the spare parts are required for a scheduled or unscheduled maintenance are similar each time. So, all similar items which we called family of spare (SPF) are not located in the same zone or shelf. For that reason when requisition comes we have to find out the spare parts from different zones or shelves. As a result, it takes more time to retrieve/store the spare parts and increase cost of material handling. Therefore, if it is possible to develop appropriate storing/retrieving method (s) the above mentioned problems can be overcome. So, our objective is to identify the spare parts family (SPF) and to calculate weight of each spare parts family (SPF) on the basis of past demand. Thus, if we keep a spare parts family (SPF) which is required as per work order in the same shelf in the warehouse then the issue/retrieve of spare parts will be more easy and less time consuming and by considering weight, higher weight SPF (fast moving) should be kept near to issue counter and less weight (slow moving) SPF to be placed far from counter. The algorithm proposed in the previous section (3.4) is applied to the warehouse management system of the Plant. The results and related discussions are provided in the subsequent sections of this chapter.

4.1 Identifying family of spare parts(SPF)

The step-I of the proposed algorithm (3.4) is applied to identify the family of spare parts (SPF) for 4,000 ((approx.) spare parts used by the maintenance department. The algorithm identified 56 spare parts family (SPF). The results are presented in Table 4.1.

Table 4.1: Identification table for spare parts family

(Ref. Table # 3.4 to 3.59 in appendix)

Sl No. of SPF	Code # of SPF	Description	SKU number of Spare parts family
1	100	Engine Blocks, Cylinder Liner, Oil sump	100003,100004,100010,100025,100026,100064, 100085,100088,100090,100091,100093,100095, 100096,100097,100098,10099,100100,100103,1 00109,100110,100153,100154,100156
2	107	Casings & covers	107003,107004,107007,107009,107010,107011, 107013,107015,107017,107028,107035,107040, 107041,107044,107080,107081,107082,107134, 107191,107272,107273
3	110	Crankshaft	110017,110024
4	111	Connecting Rod	111002,111004,111005,111008,111012,111013, 111015,111016,111017,111019
5	113	Piston	113001,113008,113010,113013,113014,113021, 113025
6	114	Flywheel	114001
7	120	Cylinder head	120003,120006,120009,120010,120011,120012, 120018,120022,120024,120027,120028,120031, 120032,120041,120049,120061,120062,120065
8	121	Exhaust & Inlet valve	121004,121006,121010,121033,121061,121062, 121063,121065
9	123	Starting valve	123001,123010,123035
10	125	Cylinder head safety valve	125010,125025,125445,125447
11	131	Intermediate gear	131007,131020,131021,131023,131030,131031, 131032,131033,131036
12	143	Rocker arms	143003,143004
13	145	Valve tappet	145003,145005,145008
14	148	Cam shaft	148011,148013,148014,148071,148072,148073, 148075,148077
15	156	Air Band	156003,156009,156012,156015,156016,156081, 156088,156111,156201,156202
16	165	Injection Pump	165003,165004,165014,165018,165020,165031, 165037,165042,165084,165102,165105,165106, 165107,165108,165109,165122,165129,165130, 165159,165173,165174,165175,165190,165191, 165200,165267,165280
17	167	Injection valves	167004,167008,167012,167020
18	174	Fuel feed pump	174003,174004,174005,174006,174008,174011, 174017
19	181	LO pump spare	181153,181157,181160,181162,181163,181166, 181171,181174,181175,181176,181177,181178, 181192,181193

Sl No. of SPF	Code # of SPF	Description	SKU number of Spare parts family
20	182	Prelube pump spare	182055,182058,182063,182064,182087,182092
21	183	Thermostatic valves for LO	183024,183025
22	184	Oil Dipstic	WD184001-002
23	191	Water Pumps	191009,191010,191013,191015,191042,191043, 191044,191045,191048,191050,191051,191052, 191054,191068
24	196	HT/LT thermostatic valve	196251,196258,196264,196266,196271,196273
25	200	Exhaust Manifold	200011,200014,200015,200016,200026,200028, 200137,200138,200139,200163,200357,200358
26	205	Insulation Box	205014,205115
27	211	Starting air distributor	211009,211011,211016
28	213	stop lever	213006,213007,213008
29	214	Starting fuel limiter	WD214021-002
30	217	Main starting valve	217003,217008,217012,217021,217025,217029, 217030,217031,217032,217033,217034,217038, 217046
31	223	Booster Survometer	223003,223007,223022,223035,223036,223041, 223044,223054,223079
32	224	Regulating Mechanism	224006,224007,224015,224017,224034,224040, 224052,224055,224073,224076,224089,224090, 224092,224095,224096,224103,224104,224111, 224157
33	228	Overspeed trip device	228003,228018,228019,228024,228025,228032, 228041,228042,228043,228046,228101,228105, 228106,228120,228160,228162,228163,228164, 228171,228174,228176,228186,228190,228196, 228201,228203,228204,228215,228237,228239, 228240,228241,228249,228262,228279,228280
34	231	Speed pick up	231035,231037
35	350	Fuel lines	350016,350018,350019,350021,350024,350025, 350027,350039,350060,350132,350133,350134, 350137,350167,350175,350184,350199,350419, 350421,350424,350428,350431,350432,350555, 350556,350559

Sl No. of SPF	Code # of SPF	Description	SKU number of Spare parts family
36	352	LO pipes	352013,352027,352075,352087,352107,352114, 352115,352116,352117,352123,352125,352152, 352163,352165,352176,352180,352182,352183, 352188,352237,352238,352239,352245,352267, 352269,352295,352458,352459,352460,352476, 352478,352676,687,688,704,705,708,776,35277 7
37	354	Cooling water pipes	354001,354024,354040,354064,354095,354099, 354100,354102,354173,354229,354238
38	355	HT & TC pipe connections	355002,355011,355020,355025,355031,355107, 355109,355112,355113,355117,355155,355165, 355188,355252,355347,355356,355479,355519
39	357	Control air system	357007,357012,357018,357021,357076,357077, 357078,357081,357118,357163,357208
40	358	Leak Oil pipes	358004,358010,358014,358154,358156,358169, 358213,358401,358403,358404,358514,358515, 358520,358530,358531
41	372	Turbocharger spare	372002,372038,372136,372149,372153,372185, 372206,372208,372209,372225,372242
42	377	Crankase cover	377002,377003
43	378	Crankcase breather	WD378002-002
44	470	Fuel filter	470200,470241,470255
45	471	Lube Oil filter	471196,471235
46	473	Centrifugal filter	WD473003-001
47	476	Air cooler	476001,476003,476005
48	483	Spare for turning device	483040,483081,483082,483082,483084,483085, 483115
49	501	Connection Box	501100
50	506	Exhaust temperature sensor	506068,506069,506213
51	507	Temperature transmitter	507755,507810,507811
52	508	LO alarm tranducer	508022,508027
53	511	Thermometers	511132,511136
54	516	Instrument pannel	516007,516009,516019,516023,516025,516028
55	600	Connectio piece for TC	600002,600007
56	604	Accessories for engine	604068,604069,604070,604076,604084,604088, 604093,604095,604103,604104

4.2 Calculation of weight for spare parts family(SPF) in 2007

In the step-II of the proposed algorithm (3.4) weight calculation is done according to the procedure described in Article # 3.2 of the 56 family of spare parts (SPF) for 4,000 ((approx.) spare parts used by the maintenance department. The results are presented in Table 4.2.

Table 4.2: Weight table for spare parts family

Sl No. of SPF	Code # of SPF	SKU number of Spare parts family	Weight in 2007
1	100	100003,100004,100010,100025,100026,100064,100085,100088,100090,100091,100093,100095,100096,100097,100098,10099,100100,100103,100109,100110,100153,100154,100156	293
2	107	107003,107004,107007,107009,107010,107011,107013,107015,107017,107028,107035,107040,107041,107044,107080,107081,107082,107134,107191,107272,107273	68
3	110	110017,110024	4
4	111	111002,111004,111005,111008,111012,111013,111015,111016,111017,111019	62
5	113	113001,113008,113010,113013,113014,113021,113025	56
6	114	114001	0
7	120	120003,120006,120009,120010,120011,120012,120018,120022,120024,120027,120028,120031,120032,120041,120049,120061,120062,120065	228
8	121	121004,121006,121010,121033,121061,121062,121063,121065	158
9	123	123001,123010,123035	51
10	125	125010,125025,125445,125447	51
11	131	131007,131020,131021,131023,131030,131031,131032,131033,131036	62
12	143	143003,143004	6
13	145	145003,145005,145008	12

Sl No. of SPF	Code # of SPF	SKU number of Spare parts family	Weight in 2007
14	148	148011,148013,148014,148071,148072,148073,148075,148077	79
15	156	156003,156009,156012,156015,156016,156081,156088,156111,156201,156202	39
16	165	165003,165004,165014,165018,165020,165031,165037,165042,165084,165102,165105,165106,165107,165108,165109,165122,165129,165130,165159,165173,165174,165175,165190,165191,165200,165267,165280	711
17	167	167004,167008,167012,167020	21
18	174	174003,174004,174005,174006,174008,174011,174017	55
19	181	181153,181157,181160,181162,181163,181166,181171,181174,181175,181176,181177,181178,181192,181193	110
20	182	182055,182058,182063,182064,182087,182092	24
21	183	183024,183025	19
22	184	WD184001-002	2
23	191	191009,191010,191013,191015,191042,191043,191044,191045,191048,191050,191051,191052,191054,191068	98
24	196	196251,196258,196264,196266,196271,196273	77
25	200	200011,200014,200015,200016,200026,200028,200137,200138,200139,200163,200357,200358	109
26	205	205014,205115	3
27	211	211009,211011,211016	14
28	213	213006,213007,213008	6
29	214	WD214021-002	1
30	217	217003,217008,217012,217021,217025,217029,217030,217031,217032,217033,217034,217038,217046	45
31	223	223003,223007,223022,223035,223036,223041,223044,223054,223079	38
32	224	224006,224007,224015,224017,224034,224040,224052,224055,224073,224076,224089,224090,224092,224095,224096,224103,224104,224111,224157	57
33	228	228003,228018,228019,228024,228025,228032,228041,228042,228043,228046,228101,228105,228106,228120,228160,228162,228163,228164,228171,228174,228176,228186,228190,228196,228201,228203,228204,228215,228237,228239,228240,228241,228249,228262,228279,228280	176
34	231	231035,231037	10

Sl No. of SPF	Code # of SPF	SKU number of Spare parts family	Weight in 2007
35	350	350016,350018,350019,350021,350024,350025,350027,350039,350060,350132,350133,350134,350137,350167,350175,350184,350199,350419,350421,350424,350428,350431,350432,350555,350556,350559	183
36	352	352013,352027,352075,352087,352107,352114,352115,352116,352117,352123,352125,352152,352163,352165,352176,352180,352182,352183,352188,352237,352238,352239,352245,352267,352269,352295,352458,352459,352460,352476,352478,352676,687,688,704,705,708,776,352777	165
37	354	354001,354024,354040,354064,354095,354099,354100,354102,354173,354229,354238	131
38	355	355002,355011,355020,355025,355031,355107,355109,355112,355113,355117,355155,355165,355188,355252,355347,355356,355479,355519	273
39	357	357007,357012,357018,357021,357076,357077,357078,357081,357118,357163,357208	47
40	358	358004,358010,358014,358154,358156,358169,358213,358401,358403,358404,358514,358515,358520,358530,358531	58
41	372	372002,372038,372136,372149,372153,372185,372206,372208,372209,372225,372242	48
42	377	377002,377003	8
43	378	WD378002-002	20
44	470	470200,470241,470255	36
45	471	471196,471235	22
46	473	WD473003-001	1
47	476	476001,476003,476005	8
48	483	483040,483081,483082,483082,483084,483085,483115	14
49	501	501100	0
50	506	506068,506069,506213	18
51	507	507755,507810,507811	8
52	508	508022,508027	3
53	511	511132,511136	9
54	516	516007,516009,516019,516023,516025,516028	20
55	600	600002,600007	16
56	604	604068,604069,604070,604076,604084,604088,604093,604095,604103,604104	30

Note: (*) Ref. Table # 3.4 to 3.59 in appendix

4.3 Calculation of distance

The step-III of the proposed algorithm (3.4) for distance calculation of the different shelves is done according to the procedure described in (Article # 3.3). The results are presented in Table 4.3.

Table 4.3: Distance table for Spare Parts family

(Ref. Table # 3.4 to 3.59 in appendix)

Sl No. of SPF	Code # of SPF	Description	Shelf number	Distance travel, ft
1	100	Engine Blocks, Cylinder Liner, Oil sump	E3a3,A1b1,J3c1,E1a2,J3b2,J2b1,E1a1,G1d,E2a2,A1a2,A1b3,A1b2,E2a4,C3a,E1c2,E3a3,A1b3,C2d	204.48
2	107	Casings & covers	J3c1,A3d,A1a1,A1a3,E1a4,J3b2,J3c2,J2b1,E3b2,E3c1	217.78
3	110	Crankshaft	J3b2,C2a	141.40
4	111	Connecting Rod	C4c,A2a,C2a,C2c1,A3a,A3b1,A1b3	156.58
5	113	Piston	A2a,A3b3,C3d,A3a,A2a	123.96
6	114	Flywheel		0.00
7	120	Cylinder head	A3b2,E2a4,A3b1,E1a3,C3d,A3b3,E2a3,E2a1,A3b2,J2c1,E3a2,J3c1,E1b2,D1d	205.10
8	121	Exhaust & Inlet valve	E2a2,A2b,A3c1	148.16
9	123	Starting valve	E2b2,E1b1	71.40
10	125	Cylinder head safety valve	A3b2,E2a3,E2b1	145.16
11	131	Intermediate gear	A4a	135.16
12	143	Rocker arms	B2c2,J2b1	250.76
13	145	Valve tappet	E2a4,J3c2,E2a2	122.80
14	148	Camshaft	A4b,E1a2,J3c1,E3b2	241.76
15	156	Air Band	E3c1,J2c2,E2b2,E3c2,C1c2,J3c2,J2b1	146.10
16	165	Injection Pump	B2b1,B2b2,B2d,B2b3,B2c2	172.76
17	167	Injection valves	B2b3,B2b1	168.76
18	174	Fuel feed pump	H2a3,H2b2,G1a2,	36.79

Sl No. of SPF	Code # of SPF	Description	Shelf number	Distance travel, ft
19	181	LO pump spare	A2c1,A2c2,E2b2,	128.78
20	182	Prelube pump spare	I1a2,F1a1,I2b1	36.50
21	183	Thermostatic valves for LO	E4c2,V1d	154.40
22	184	Oil Dipstic	A2c3	129.56
23	191	Water Pumps	D1b1,D1b2,B1a	112.50
24	196	HT/LT thermostatic valve	D1b1,E4c2,V2d,V3d,E2a4	184.00
25	200	Exhaust Manifold	A1b3,A1c1,J3b2,A1c3,A1c1,A1c2,	179.08
26	205	Insulation Box	J3c1	121.60
27	211	Starting air distributor	J2c2,E1a2	125.60
28	213	stop lever	C3b1	93.00
29	214	Starting fuel limiter	C3b1	93.00
30	217	Main starting valve	E3b1,E3a4	83.20
31	223	Booster Survometer	C4b1,C3b3,D2c3	136.70
32	224	Regulating Mechanism	J2c2,C1b2,C1b3,C1c1,J2b2,	139.50
33	228	Overspeed trip device	J2b2,C1c3,C1c2,C1b1,C2c3,E1a3,E3a2,J3b2,D2c3,E4a1,D3b3,E4a1,E3a3,D4b1,E5a4,E5b1,E3a4,E5b1,C1c3,V3c,D4b3,E4c1	200.90
34	231	Speed pick up	V3c	90.40
35	350	Fuel lines	D4b2,E2a2,C2b2,J2b1,V4d,J3c2,H2a3,J2c1,V5c,J2b2,E1a2,C2b3	248.50
36	352	LO pipes	E2a2,E5a3,E3a2,E3a3,D4c1,D4b1,E5a1,E4a2,J2b1,D4b2,C3b3,E5a3,E2a4,E1a1,E1a3,E2a2,E1a2,C1b1,E2a3,E5a2,D4c1,E4a4,D4b3,C2b3,J2b2,E2a2	137.80
37	354	Cooling water pipes	E2b1,C2c2,C3a,E2b2,C2c1,E3d,E4c1,J2b2,E4a3,E4a2	118.50

Sl No. of SPF	Code # of SPF	Description	Shelf number	Distance travel, ft
38	355	HT & TC pipe connections	E2b1,E4a3,E1a1,J2b1,J2b2,E4d,C2 c1,E2a4,E3d,E2b2	167.30
39	357	Control air system	E1a2,E1a3,E2c1,C2c1,E4a1,E2a3,E 4a4,E5a2,E2a1	157.30
40	358	Leak Oil pipes	E1a1,E2c1,E5a3,E2a1,C2c2,V3c,E3 a2,D4b1,E5a4,E4b1,E4a3,D3c3	228.80
41	372	Turbocharger spare	B1b3,B1b2,E4c1,D2c3,E3a3,E4c1,E 3a4,E4b2	205.80
42	377	Crankase cover	E2a1,E4b2	105.80
43	378	Crankcase breather	E1a1	49.60
44	470	Fuel filter	Cont.,E1d,E3a3	1,090.20
45	471	Lube Oil filter	Cont.,E1e	1,051.80
46	473	Centrifugal filter	E2b1	66.40
47	476	Air cooler	E3a1,E2c2	84.20
48	483	Spare for turning device	V3c,C3b2	140.00
49	501	Connection Box	–	-
50	506	Exhaust temperature sensor	V3a,V2c	90.40
51	507	Temperature transmitter	J2c1,V1c	188.60
52	508	LO alarm tranducer	E4a4,J2b2	121.60
53	511	Thermometers	V1c,V1b	87.40
54	516	Instrument panel	V2b,V3b,E5c1,D4c1,A3c2	284.00
55	600	Connection piece for TC	M4e,B1b2	148.00
56	604	Accessories for engine	V3b,A3c2,E3c1,E2a4,E1a3,E2b1,J2 c1,E5b2	276.80

4.4 Assignment of each spare parts family to shelves

The step-IV f the proposed algorithm (3.4) is applied for assignment of spare parts (SPF) to shelves. The results are presented in Table 4.4

Table 4.4: Assignment table for spare parts family to shelves

(Ref. Table # 3.4 to 3.59 in appendix)

Sl No. of SPF	Code # of SPF	Description	R_f, Weight in 2007	Proposed shelf location	L_d, average proposed distance ,ft
1	165	Injection Pump	711	H1	22.00
2	100	Engine Blocks, Cylinder Liner, Oil sump	293	I1	27.40
3	355	HT & TC pipe connections	273	G1	28.66
4	120	Cylinder head	228	F1	34.40
5	350	Fuel lines	183	H2	34.80
6	228	Overspeed trip device	176	I2	40.14
7	352	LO pipes	165	G2	41.00
8	121	Exhaust & Inlet valve	158	D1	41.46
9	354	Cooling water pipes	131	E1	46.40
10	181	LO pump spare	110	F2	47.20
11	200	Exhaust Manifold	109	H3	47.60
12	191	Water Pumps	98	I3	52.94
13	148	Camshaft	79	G3	53.80
14	196	Thermostatic valve	77	O1	54.26
15	107	Casings & covers	68	F3	55.20
16	111	Connecting Rod	62	N1	58.40
17	131	Intermediate gear	62	D2	60.00
18	358	Leak Oil pipes	58	E2	60.00
19	224	Regulating Mechanism	57	H4	61.40

Sl No. of SPF	Code # of SPF	Description	R_f, Weight in 2007	Proposed shelf location	L_d, average proposed distance ,ft
20	113	Piston	56	O2	61.20
21	174	Fuel feed pump	55	C1	64.80
22	123	Starting valve	51	I4	65.74
23	125	Cylinder head safety valve	51	N2	66.00
24	372	Turbocharger spare	48	G4	66.60
25	357	Control air system	47	O3	67.06
26	217	Main starting valve	45	M1	67.20
27	156	Air Band	39	L1	69.60
28	223	Booster Survometer	38	N3	69.60
29	470	Fuel filter	36	F4	71.20
30	604	Accessories for engine	30	D3	72.00
31	182	Prelude pump spare	24	E3	72.80
32	471	Lube Oil filter	22	J3	73.60
33	167	Injection valves	21	K1	74.40
34	378	Crankcase breather	20	L2	75.60
35	516	Instrument pannel	20	M2	75.60
36	183	Thermostatic valves for LO	19	C2	77.60
37	506	Exhaust temperature sensor	18	N4	78.00
38	600	Connection piece for TC	16	K2	79.40
39	211	Starting air distributor	14	L3	80.40
40	483	Spare for turning device	14	M3	81.60
41	145	Valve tappet	12	J1	81.60
42	231	Speed pick up	10	J2	84.00
43	511	Thermometers	9	K3	86.00
44	377	Crankase cover	8	L4	86.00
45	476	Air cooler	8	M4	86.40
46	507	Temperature transmitter	8	D4	87.60

Sl No. of SPF	Code # of SPF	Description	R_f,Weight in 2007	Proposed shelf location	L_d, average proposed distance ,ft
47	143	Rocker arms	6	E4	87.60
48	213	stop lever	6	C3	90.40
49	110	Crankshaft	4	K4	92.40
50	205	Insulation Box	3	A1	96.76
51	508	LO alarm tranducer	3	C4	103.20
52	184	Oil Dipstic	2	A2	109.56
53	214	Starting fuel limiter	1	A3	122.36
54	473	Centrifugal filter	1	B1	128.80
55	114	Flywheel	0	A4	135.16
56	501	Connection Box	0	B2	160.80

4.5 Comparison of existing layout system with the proposed.

Sample calculation of total transport work for SPF Code number 148

To collect the items from shelf for this SPF, the total transport work, TTW = $\sum R_f L_d$ deliveries-ft/year [13]

Where R_f= number of deliveries per year

L_d = traveled distance per delivery

For existing system the total transport work TTW = $\sum R_f L_d$ =79*241.76=19,099.04 feet/ year.

For proposed system the total transport work TTW = $\sum R_f L_d$ == $R_f * L_d$ = 79*53.80 = 4,250.20 feet/year

Table 4.5: Comparison table for total transport work

Sl No. of SPF	Code # of SPF	Description	R_f,Weight in 2007	L_d, Existing average distance, feet/delivery	TTW for existing system, feet/year	Proposed shelf location	L_d, average proposed distance, feet/delivery	TTW for proposed system, feet/year
1	165	Injection Pump	711	172.76	122,832.36	H1	22.00	15,642.00

Sl No. of SPF	Code # of SPF	Description	R_f, Weight in 2007	L_d, Existing average distance, feet/delivery	TTW for existing system, feet/year	Proposed shelf location	L_d, average proposed distance, feet/delivery	TTW for proposed system, feet/year
2	100	Engine Blocks, Cylinder Liner, Oil sump	293	204.48	59,912.64	I1	27.40	8,028.20
3	355	HT & TC pipe connections	273	167.30	45,672.90	G1	28.66	7,824.18
4	120	Cylinder head	228	205.10	46,762.80	F1	34.40	7,843.20
5	350	Fuel lines	183	248.50	45,475.50	H2	34.80	6,368.40
6	228	Overspeed trip device	176	200.90	35,358.40	I2	40.14	7,064.64
7	352	LO pipes	165	137.80	22,737.00	G2	41.00	6,765.00
8	121	Exhaust & Inlet valve	158	148.16	23,409.28	D1	41.46	6,550.68
9	354	Cooling water pipes	131	118.50	15,523.50	E1	46.40	6,078.40
10	181	LO pump spare	110	128.78	14,165.80	F2	47.20	5,192.00
11	200	Exhaust Manifold	109	179.08	19,519.72	H3	47.60	5,188.40
12	191	Water Pumps	98	112.50	11,025.00	I3	52.94	5,188.12
13	148	Camshaft	79	241.76	19,099.04	G3	53.80	4,250.20
14	196	Thermostatic valve	77	184.00	14,168.00	O1	54.26	4,178.02
15	107	Casings & covers	68	217.78	14,809.04	F3	55.20	3,753.60
16	111	Connecting Rod	62	156.58	9,707.96	N1	58.40	3,620.80
17	131	Intermediate gear	62	135.16	8,379.92	D2	60.00	3,720.00
18	358	Leak Oil pipes	58	228.80	13,270.40	E2	60.00	3,480.00
19	224	Regulating Mechanism	57	139.50	7,951.50	H4	61.40	3,499.80
20	113	Piston	56	123.96	6,941.76	O2	61.20	3,427.20
21	174	Fuel feed pump	55	36.79	2,023.45	C1	64.80	3,564.00
22	123	Starting valve	51	71.40	3,641.40	I4	65.74	3,352.74

Sl No. of SPF	Code # of SPF	Description	R_f,Weight in 2007	L_d, Existing average distance, feet/delivery	TTW for existing system, feet/year	Proposed shelf location	L_d, average proposed distance, feet/delivery	TTW for proposed system, feet/year
23	125	Cylinder head safety valve	51	145.16	7,403.16	N2	66.00	3,366.00
24	372	Turbocharger spare	48	205.80	9,878.40	G4	66.60	3,196.80
25	357	Control air system	47	157.30	7,393.10	O3	67.06	3,151.82
26	217	Main starting valve	45	83.20	3,744.00	M1	67.20	3,024.00
27	156	Air Band	39	146.10	5,697.90	L1	69.60	2,714.40
28	223	Booster Survometer	38	136.70	5,194.60	N3	69.60	2,644.80
29	470	Fuel filter	36	1,090.20	39,247.20	F4	71.20	2,563.20
30	604	Accessories for engine	30	276.80	8,304.00	D3	72.00	2,160.00
31	182	Prelude pump spare	24	36.50	876.00	E3	72.80	1,747.20
32	471	Lube Oil filter	22	1,051.80	23,139.60	J3	73.60	1,619.20
33	167	Injection valves	21	168.76	3,543.96	K1	74.40	1,562.40
34	378	Crankcase breather	20	49.60	992.00	L2	75.60	1,512.00
35	516	Instrument panel	20	284.00	5,680.00	M2	75.60	1,512.00
36	183	Thermostatic valves for LO	19	154.40	2,933.60	C2	77.60	1,474.40
37	506	Exhaust temperature sensor	18	90.40	1,627.20	N4	78.00	1,404.00
38	600	Connection piece for TC	16	148.00	2,368.00	K2	79.40	1,270.40
39	211	Starting air distributor	14	125.60	1,758.40	L3	80.40	1,125.60
40	483	Spare for turning device	14	140.00	1,960.00	M3	81.60	1,142.40
41	145	Valve tappet	12	122.80	1,473.60	J1	81.60	979.20
42	231	Speed pick up	10	90.40	904.00	J2	84.00	840.00

Sl No. of SPF	Code # of SPF	Description	R_f,Weight in 2007	L_d, Existing average distance, feet/delivery	TTW for existing system, feet/year	Proposed shelf location	L_d, average proposed distance, feet/delivery	TTW for proposed system, feet/year
43	511	Thermometers	9	87.40	786.60	K3	86.00	774.00
44	377	Crankcases cover	8	105.80	846.40	L4	86.00	688.00
45	476	Air cooler	8	84.20	673.60	M4	86.40	691.20
46	507	Temperature transmitter	8	188.60	1,508.80	D4	87.60	700.80
47	143	Rocker arms	6	250.76	1,504.56	E4	87.60	525.60
48	213	stop lever	6	93.00	558.00	C3	90.40	542.40
49	110	Crankshaft	4	141.40	565.60	K4	92.40	369.60
50	205	Insulation Box	3	121.60	364.80	A1	96.76	290.28
51	508	LO alarm tranducer	3	121.60	364.80	C4	103.20	309.60
52	184	Oil Dipstic	2	129.56	259.12	A2	109.56	219.12
53	214	Starting fuel limiter	1	93.00	93.00	A3	122.36	122.36
54	473	Centrifugal filter	1	66.40	66.40	B1	128.80	128.80
55	114	Flywheel	0	0.00	-	A4	135.16	-
56	501	Connection Box	0	0.00	-	B2	160.80	-
Grand total:				**9,746.43**	**704,097.77**		**4015.70**	**168,951.16**

It is observed that for existing system for 56 engine parts SPF total transport work is 704,097.77 feet and total traveled distance is 9,746.43 feet in year 2007 but for the proposed allocation system total transport work is only 168,951.16 feet and total traveled travel distance is 4,015.70 feet in year 2007, which reduce transport work to 535,146.61 feet and travel distance to half. So, we can say that if we implement this new system which will be reduced by 76% less work per year with respect to present system. If the Plant follows this allocation system then it will save 5,351,466.10 feet less transport work in ten years.

4.6 Proposed layout

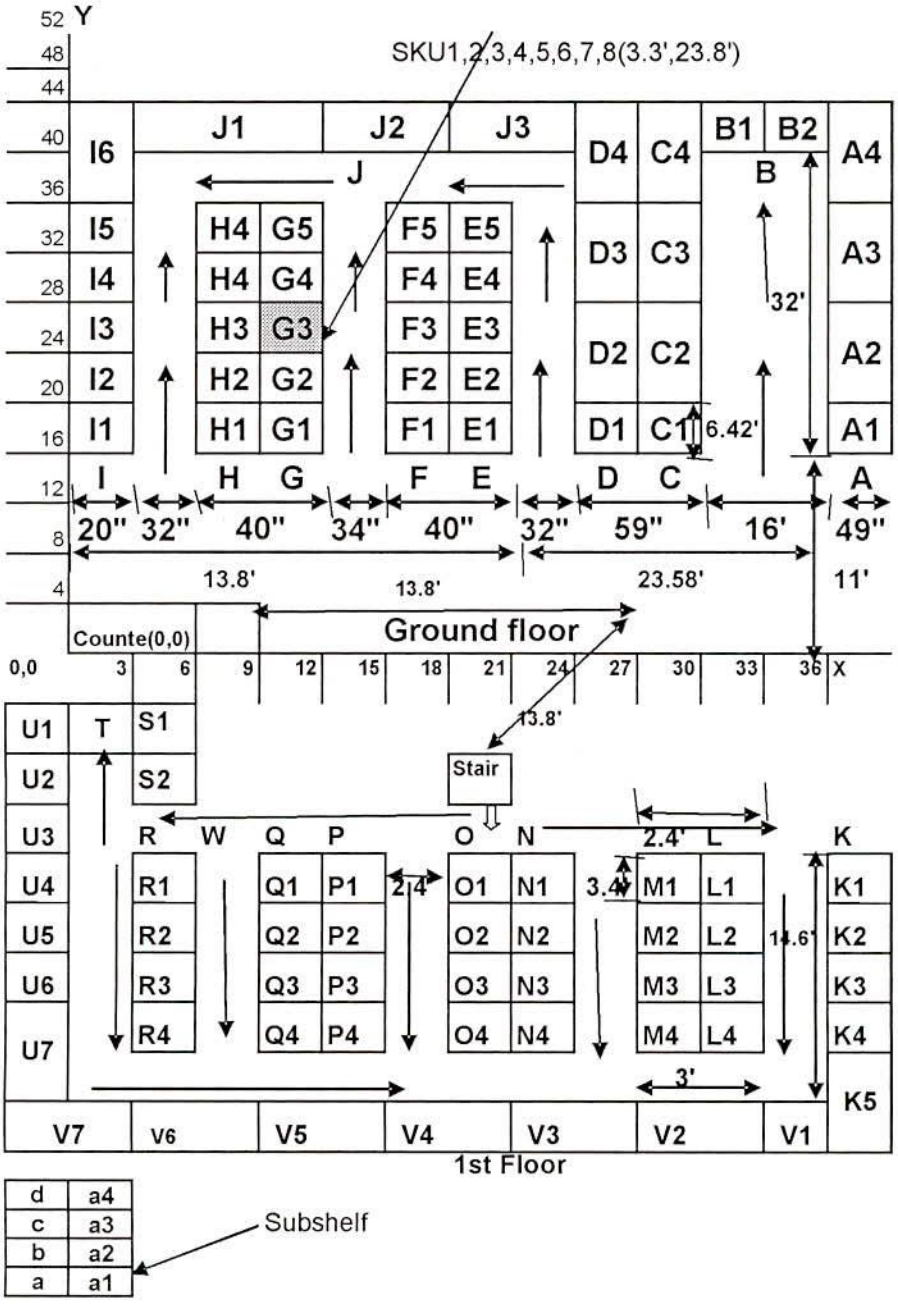

Figure 4.1: Shelf Layout proposed for spare part family

CHAPTER -5

Discussion and Recommendations

5.1 Discussion

A power plant is a public interest industry and modern civilization entirely depends on electricity. So it's continuity of running is important. To keep 19 engines of the power plant under study in running condition, right quantity spares should be provided in right time. To keep pace with the competitors the modern managers are very much aggressive to attain a standard product or service at a minimum cost. The modern managers are very conscious to reduce the cost by keeping standard with respect to all aspects which involve better management of workmen, raw materials, spare parts and production output etc. Organizing the function will require proper guidance, regulation and control so that materials are arranged in such a manner as to enable easy storage, minimized pilferage, proper identification and quick retrievals with minimum waste of time and effort. For this purpose stores location and layout must be considered and the job analysis must be done for the personnel involved to discharge their duties in an effective manner. In the earlier section it is mentioned that management and allocation of spare-parts is a vital problem for sound operation of store. Miss-allocation of spare-parts takes huge time to find parts out. This problem causes extra time consumption, money expenditure for involvement of labor for long time and also creates risk of unavailability which lead to improper maintenance or repair of machine.

Theoretically, the Plant uses the sequence system in arranging all the spare parts in the warehouse shelves i.e. the systems calls for the location of items in alphabetical order and numerical order without regard to issue frequency, size, weight or volume.

During spare parts family classification, it is seen that the spare parts are required for a scheduled or unscheduled maintenance of a particular part of engine to repair, to replace or to overhaul always contains a list of spare parts which is similar each time. All these similar parts required for a particular maintenance, is called family of spare parts (SPF). We have classified all the 4,000 approximately items are in 56 SPF. So, if we keep a spare parts family(SPF) which is required as per work order in the same shelf in the warehouse then the issue/retrieve of spare parts will be more easy and less time

consuming. In existing system spare parts are not arranged as per family of spare parts. So, the existing system takes much time to issue and retrieve the list of items as per work order.

The weight is used to identify each SPF as slow or fast moving. The weight of a SPF is the summation of all item's frequency of usages in a year. By considering weight, higher weight SPF(fast moving) should be kept near to issue counter and less weight (slow moving) SPF is to be placed far from counter.

In comparing total transport work and travel distance with the data of the year 2007, it is found that for existing system for 56 engine parts SPF total transport work is 704,097.77 feet and total travel distance is 9,746.43 feet in year 2007 but for the proposed allocation system total transport work is only 168,951.16 feet and total travel distance is 4,015.70 feet in year 2007 which reduce transport work by 535,146.61 feet and travel distance to half. So we can say that if we implement this new system transport work will be reduced by 76% and travel distance by 50% as compared to the present system.

If implemented this optimal planning of store allocation and assignment of spare parts in the plant, it will cover the following things:

- Proper allocation of spare parts causes a reduction of time for parts finding.
- The application of the model will reduce storing cost.
- It will reduce labor cost, increase storage capacity and materials handling becomes easier.
- Will be geared up warehousing activities in issue / retrieval.
- The expected model will conform the superior quality of service.

In this research work, identifying of spare parts family, distance calculation of each spare parts family, weight calculation of each spare parts family or items, assignment of spare parts family to shelves and comparison of total transport work for each spare parts family are done manually. Moreover, following recommendations may be considered for further improvement.

1. The Plant can follow zoned location for spare parts family (SPF). Each SPF should be kept in one shelf for reducing total transport work.
2. By considering weight, higher weight spare parts family should be kept near to issue counter and less weight spare parts family to be placed far from the counter.

3. The plant can follow size system, the smaller items at the front and the largest items at the back.
4. Through FSN, analysis the plant can be made to weed out unwanted materials and parts which results in reduced stock.
5. Through VEIN/VED analysis the plant can handle some most critical parts more effectively.

REFERENCES

[1] Silver, E., Pyke, D. and Peterson, R., Inventory Management and Production Planning & Scheduling, John Wily & Sons, New York [1998].

[2] PE, Leland Blank, Statistical Procedures for Engineering, Management and Science, Mcgrow-Hill International Book Company, New Delhi.

[3] Dervitsiotis, Kostas N., Operation Management, Megraw-Hill International Book Company, New Delhi.

[4] Gopalakrishnan, P. Hand book of Material Management, Prentice Hall, New Delhi-110001.

[5] Telsang, Martand, Industrial Engineering and Production Planning, S. Chand & company Ltd. Ram Nagar, New Delhi-110055.

[6] Dutta, A., K., Material management, Prentice Hall of India Private Limited, New Delhi-110001.

[7] Banerji, A., K., Maintenance and Spare parts Management, Prentice Hall, New Delhi, [1991].

[8] Wattsup, Wartsila's Personnel Magazine, Wartsila Corporation, 00530Helsinki, Finland.

[9] Logon, Newsletter of Wartsilla Bangladesh Ltd., Iqbal Centre, (14^{th} floor), 42, Kamal Ataturk Avenue, Banni C/A, Dhaka-1213, Bangladesh.

[10] User's Guide, Maintenance Management, Datastream Systems, Inc., 50 Datastream Plaza, Greenville, SC 29605.

[11] P.Groover Automation, production systems and computer Integrated Manufacturing, Prentice, Hall of India private Limited, New Delhi-110001, 1992

[12] J.P. Van den Berg, W.H.M.Zijm, Journal on Models for warehouse Management: classification and examples.

[13] K.H.Chow, K.L.Choy & W.B.Lee, Journal on Design of a knowledge based Logistics management system: a case-based RFID approach.

[14] K.C.Jain, Dr.L.N. Agarwal, Production Planning control and Industrial Management.

[15] Spare parts catalogue (2C) for Wartsila 18 V 32 Engine.

[16] Wikipedia.org/wiki/Warehouse Management System a registered trademark of the Wikimedia Foundation, Inc., a U.S. registered 501 (c) (3) tax-deductible non profit charity.

[17] M. Yang, Analysis and optimization of class-based dedicated storage systems, Ph.D Thesis, Georgia Institute of Technology, Atlanta, GA, 1988.

[18] J.P. van den Berg, G.P. Sharp, Forward-reserve allocation in a warehouse, European Journal of Operations Research 111 (1) (1998) 98Ð113.

[19] J.P. van den Berg, Class-based storage allocation in a single command Warehouse with space requirement constraints, International Journal of Industrial Engineering 3(1) (1996) 21Ð28.

[20] J.P. van den Berg, Planning and Control of Warehousing Systems, Ph.D Thesis,University of Twente, 1996.

APPENDIX

Table 3.4: Statement for SPF-100 in year 2007

Sl No. of SKU	SKU Number	Description	Shelf number	L_d, average distance travel, ft	Weight in 2007, R_f
1	WD100109-001	O-ring	E2a4		123
2	WD100111-001	D- Seal	E1c2		83
3	WD100093-002	Protection Cap	G1d		13
4	WD100088-001	O-ring for side screw	E1a1		12
5	WD100156-002	Antipolishing ring	C2d		11
6	WD100095-002	O-ring	E2a2		9
7	WD100085-001	STUD 20 X 75 mm	J2b1		8
8	WD100090-002	Protection Cap	G1d		5
9	WD100096-007	Main bearing shell, upper	A1a2		4
10	WD100097-008	Main Bearing Shell, Lower	A1a2		4
11	WD100098-003	Stud M16X122mm	A1b3		4
12	WD100100-001	Stud M16x140mm	A1b1		3
13	WD100110-007	Cylinder Liner	C3a		2
14	WD100153-002	O-ring	E3a3		2
15	WD100003-004	O-ring	E3a3		1
16	WD100004-005	Hexagonal Screw M10 X20mm	A1b1		1
17	WD100010-002	Allen Screw 12x50mm	J3c1		1
18	WD100025-002	O-ring	E1a2		1
19	WD100026-003	Hex.Screw 12x25mm	J3b2		1
20	WD100064-001	Hexagonal Lock Nut M16mm	A1b1		1
21	WD100091-001	Round Nut	A1b1		1
22	WD100099-001	Hexagonal Lock Nut16mm	A1b2		1
23	WD100103-001	Screw12x30mm	J3b2		1
24	WD100154-002	Allen Socket Screw 8 x30mm	A1b3		1
SPF	**100003,100004,100010,100025,100026, 100064,100085,100088,100090,100091, 100093,100095,100096,100097,100098, 10099,100100,100103,100109,100110,1 00153,100154,100156**		**G1d,E1a 1,E1a2,E 1c2,E2a2 ,E2a4,E3 a3,J3b2,**	**204.48**	**293**

		J3c1,J2b 1,C2d,C3 a,A1a2,A 1b2,A1b 3,A1b3,A 1b1		

Table 3.5: Statement for SPF-107 in year 2007

Sl No. of SKU	SKU Number	Description	Shelf number	L_d, average distance travel, ft	Weight in 2007, R_f
1	WD107007-003	O-Ring for rocker arm	A1a1		19
2	WD107015-003	Hand Wheel	A1a3		9
3	WD107011-002	Hose Gasket	E1a4		6
4	WD107013-002	Stud for Side Cover	A1a3		6
5	WD107040-001	Hose Gasket	E1a4		5
6	WD107017-001	Hex. Screw 8 x25mm	J3b2		4
7	WD107041-001	Nut 20 mm	J2b1		3
8	WD107009-002	StudM16X160mm	A1a3		2
9	WD107080-002	Gasket	E3b2		2
10	WD107003-002	Allen Screw 12 x30mm	J3c1		1
11	WD107004-002	Casing for cylinder head	A3d		1
12	WD107010-002	Stud M16X180mm	A1a3		1
13	WD107028-002	Allen Screw 10 x40mm	J3c2		1
14	WD107035-002	Rubber sealing	E1a4		1
15	WD107044-001	Hexagonal Screw 8 x12mm	J3b2		1
16	WD107081-002	Hex. Screw 12 x20mm	J3c1		1
17	WD107082-003	Allen Screw 16 X40mm	A1a3		1
18	WD107134-002	Gasket	E3b2		1
19	WD107191-004	Gasket	E3c1		1
20	WD107272-001	Gasket	E3c1		1
21	WD107273-001	Hex. Screw 16x35mm	J3c1		1
SPF	**107003,107004,107007,107009,107010, 107011,107013,107015,107017,107028, 107035,107040,107041,107044,107080,**		**J3c1,A3d, A1a1,A1a 3,E1a4,J3**	**217.78**	**68**

	107081,107082,107134,107191,107272, 107273	**b2,J3c2,J 2b1,E3b2, E3c1**		

Table 3.6: Statement for SPF-110 in year 2007

Sl No. of SKU	SKU Number	Description	Shelf number	L_d, average distance travel, ft	Weight in 2007, R_f
1	WD110017-003	Allen Screw 8x25mm	J3b2		2
2	WD110024-012	STE Vibration Damper	C2a		2
SPF	**110017,110024**		**J3b2,C2a**	**141.40**	**4**

Table 3.7: Statement for SPF-111 in year 2007

Sl No. of SKU	SKU Number	Description	Shelf number	L_d, average distance travel, ft	Weight in 2007, R_f
1	WD111004-019	Big end bearing shell upper	A2a		16
2	WD111005-018	Big end bearing shell lower	C2a		16
3	WD111002-002	Gudgeon Pin Bearing Bush	C4c		9
4	WD111019-001	Shim(Pressure plate) 4mm	A1b3		8
5	WD111015-001	Screw to Conecting Rod	A3b1		4
6	WD111013-002	Connecting rod, lower part	A3a		3
7	WD111017-001	Cylindrical pin	A1b3		3
8	WD111008-006	Big end bearing screw	C2c1		1
9	WD111012-002	Connecting Rod, Upper Part	A3a		1
10	WD111016-001	Conecting rod Nut	A1b3		1
SPF	**111002,111004,111005,111008,111012, 111013,111015,111016,111017,111019**		**C4c,A2a, C2a,C2c1, A3a,A3b1, A1b3**	**156.58**	**62**

Table 3.8: Statement for SPF-113 in year 2007

Sl No. of SKU	SKU Number	Description	Shelf number	L_d, average distance travel, ft	Weight in 2007, R_f
1	WD113013-019	Piston Ring Set 32LN	C3d		21
2	WD113001-015	Piston Crown 32LN	A2a		19
3	WD113021-012	Piston Skirt 32LN	A2a		7
4	WD113010-003	Retaining/Circlip ring	A3b3		3
5	WD113014-003	Gudgeon Pin	A3a		3
6	WD113025-029	Piston	A2a		2
7	WD113008-004	Elastic Screw	A3b3		1
SPF	**113001,113008,113010,113013,113014, 113021,113025**		**A2a,A3b3, C3d,A3a**	**123.96**	**56**

Table 3.9: Statement for SPF- 114 in year 2007

Sl No. of SKU	SKU Number	Description	Shelf number	L_d, average distance travel, ft	Weight in 2007, R_f
1	WD114001	Flywheel		-	0
SPF	**114001**			**0.00**	**0.00**

Table 3.10: Statement for SPF- 120 in year 2007

Sl No. of SKU	SKU Number	Description	Shelf number	L_d, average distance travel, ft	Weight in 2007, R_f
1	WD120022-001	Valve Guide	A3b1		71
2	WD120027-001	O-ring	E2a1		40
3	WD120009-002	Seat Ring, Exhaust	A3b1		23
4	WD120062-001	Cylinder head gasket	E1b2		21
5	WD120065-001	Sealing set	D1d		15
6	WD120012-003	Seat Ring, Inlet	C3d		14
7	WD120011-004	O-ring	E1a3		10

8	WD120010-004	O-ring	E1a3		9
9	WD120003-004	Sleeve for Cylinder Head	A3b2		5
10	WD120028-002	Allen Screw12X120mm	A3b3		4
11	WD120031-004	Stud16X130mm	A3b2		4
12	WD120041-002	Angle union, 8mm	E3a2		4
13	WD120006-002	O-ring	E2a4		2
14	WD120049-001	Hexagonal Screw 8x16mm	J3c1		2
15	WD120018-002	Nut14mm	A3b3		1
16	WD120024-001	Seal ring	E2a3		1
17	WD120032-002	Lock Nut16mm	J2c1		1
18	WD120061-001	Yoke	A3b3		1
SPF	**120003,120006,120009,120010,120011, 120012,120018,120022,120024,120027, 120028,120031,120032,120041,120049, 120061,120062,120065**		**A3b2,E2a 4,A3b1,E1 a3,C3d,A3 b3,E2a3,E 2a1,A3b2, J2c1,E3a2 ,J3c1,E1b 2,D1d**	**205.10**	**228**

Table 3.11: Statement for SPF- 121 in year 2007

Sl No. of SKU	SKU Number	Description	Shelf number	L_d, average distance travel, ft	Weight in 2007, R_f
1	WD121006-009	Exhaust Valve Nim.	A2b		72
2	WD121010-001	Inlet valve	A2b		42
3	WD121062-002	Ball 5/16"	A3c1		15
4	WD121004-002	O-ring	E2a2		12
5	WD121033-002	Disk	A3c1		6
6	WD121061-002	Spring	A3c1		6
7	WD121063-001	Retainer ring	A3c1		4
8	WD121065	Disk	A3c1		1
SPF	**121004,121006,121010,121033,121061, 121062,121063,121065**		**E2a2,A2b, A3c1**	**148.16**	**158**

Table 3.12: Statement for SPF- 123 in year 2007

Sl No. of SKU	SKU Number	Descriptions	Shelf number	L_d, Distance travel, ft	Weight in 2007, R_f
1	WD123035-001	Seal Set for Starting Valve	E1b1		41
2	WD123001-001	O-ring	E2b2		9
3	WD123010-001	O-ring	E2b2		1
SPF	**123001,123010,123035**		**E2b2,E1b 1**	**71.40**	**51**

Table 3.13: Statement for SPF- 125 in year 2007

Sl No. of SKU	SKU Number	Description	Shelf number	L_d, average distance travel, ft	Weight in 2007, R_f
1	WD125445-001	Indicator Valve, Complete	A3b2		20
2	WD125447-003	Sealing Set	E2b1		17
3	WD125025-001	Seal ring	E2a3		12
4	WD125010-001	Cylinder Head Safety Valve	A3b2		2
SPF	**125010,125025,125445,125447**		**A3b2,E2a 3,E2b1**	**145.16**	**51**

Table 3.14: Statement for SPF- 131 in year 2007

Sl No. of SKU	SKU Number	Description	Shelf number	L_d, average distance travel, ft	Weight in 2007, R_f
1	WD131023-001	Thrust Bearing for Intermediate Gear	A4a		11
2	WD131030-002	O-ring	A4a		11
3	WD131007-003	Bearing Bush for Intermediate Gear	A4a		10
4	WD131031-002	O-ring	A4a		10
5	WD131033-001	Allen screw 8x65 mm	A4a		9
6	WD131032-002	Allen Screw 10x20mm	A4a		8
7	WD131020-001	Shaft for Int. Gear	A4a		1

8	WD131021-001	Extension Shaft for Intermediate Gear	A4a		1
9	WD131036-001	Cylindrical Pin	A4a		1
SPF	**131007,131020,131021,131023,131030, 131031,131032,131033,131036**		**A4a**	**135.16**	**62**

Table 3.15: Statement for SPF-143 in year 2007

Sl No. of SKU	SKU Number	Description	Shelf number	L_d, average distance travel, ft	Weight in 2007, R_f
1	WD143003-002	Adjusting Screw	B2c2		3
2	WD143004-004	Hexagonal Nut 24 mm	J2b1		3
SPF	**143003,143004**		**B2c2,J2b 1**	**250.76**	**6**

Table 3.16: Statement for SPF-145 in year 2007

Sl No. of SKU	SKU Number	Description	Shelf number	L_d, average distance travel, ft	Weight in 2007, R_f
1	WD145008-004	O-ring	E2a2		9
2	WD145003-007	O-ring	E2a4		2
3	WD145005-001	Hex. Screw 10x35 mm	J3c2		1
SPF	**145003,145005,145008**		**E2a4,J3c2 ,E2a2**	**122.80**	**12**

Table 3.17: Statement for SPF- 148 in year 2007

Sl No. of SKU	SKU Number	Description	Shelf number	L_d, average distance travel, ft	Weight in 2007, R_f
1	WD148011-005	Camshaft Bearing Bush	A4b		12
2	WD148013-001	Allen Screw M12x35mm	A4b		11
3	WD148077-001	Gasket	E3b2		11
4	WD148072-001	O-ring	E1a2		10
5	WD148073-001	O-ring	E1a2		10

6	WD148075-003	Hex. Screw 10x25mm	J3c1		10
7	WD148071-002	Bearing Bushing	A4b		9
8	WD148014-001	Allen Screw M12x80mm	A4b		6
SPF	**148011,148013,148014,148071,148072, 148073,148075,148077**		**A4b,E1a2, J3c1,E3b2**	**241.76**	**79**

Table 3.18: Statement for SPF- 156 in year 2007

Sl No. of SKU	SKU Number	Description	Shelf number	L_d, average distance travel, ft	Weight in 2007, R_f
1	WD156015-008	Gasket(C-version)	E3c2		16
2	WD156016	Gasket	E3c1		10
3	WD156009-003	Hex. Screw12x35mm	J2c2		4
4	WD156012-003	O-Ring	E2b2		2
5	WD156201-001	Hex. Screw 16x60 mm	J2b1		2
6	WD156003-013	Gasket	E3c1		1
7	WD156081-003	Hexagonal Screw16X45mm	C1c2		1
8	WD156088-001	Hex. Screw 8x20 mm	J3c2		1
9	WD156111-003	Hexagonal Screw 20x90mm	C1c2		1
10	WD156202-001	Nut 16 mm	J2b1		1
SPF	**156003,156009,156012,156015,156016, 156081,156088,156111,156201,156202**		**E3c1,J2c2 ,E2b2,E3c 2,C1c2,J3 c2,J2b1**	**146.10**	**39**

Table 3.19: Statement for SPF-165 in year 2007

Sl No. of SKU	SKU Number	Description	Shelf number	L_d, average distance travel, ft	Weight in 2007, R_f
1	WD165173-001	Spring	B2b3		92
2	WD165174-001	Shot 5mm KL III	B2b3		91
3	WD165175-001	Limiter	B2b3		61
4	WD165014-002	O-ring	B2b1		49
5	WD165004-005	O-ring	B2b1		48

6	WD165003-006	O-ring	B2b1		47
7	WD165105-002	O-ring	B2b2		47
8	WD165267-001	Sealing Ring	B2b3		47
9	WD165020-005	Seal ring	B2b1		46
10	WD165200-002	Supporting ring	B2b3		41
11	WD165018-003	Cylindrical Pin	B2b1		39
12	WD165108-004	Adapter	B2b1		32
13	WD165109-001	Spring	B2b2		25
14	WD165031-001	O-ring	B2b1		9
15	WD165280	Teflon Ring	B2b3		9
16	WD165122-001	Retainer ring	B2b2		6
17	WD165129-001	Allen Screw	B2b2		5
18	WD165107-003	Allen Socket Screw 14 X70 mm	B2b2		3
19	WD165159-001	Seal ring	B2b2		3
20	WD165042-002	Pin	B2b2		2
21	WD165084-003	Slotted Head Pin 4*10mm	B2b2		2
22	WD165190-004	Calibrating disc 11.00mm	B2c2		2
23	WD165037-002	Seal ring	B2b2		1
24	WD165102-016	Pump Element	B2d		1
25	WD165106-004	Allen ScrewM12X60mm	B2b2		1
26	WD165130-	Screw locking	B2b2		1
27	WD165191-004	Calibrating disc 11.05mm	B2c2		1
SPF	**165003,165004,165014,165018,165020, 165031,165037,165042,165084,165102, 165105,165106,165107,165108,165109, 165122,165129,165130,165159,165173, 165174,165175,165190,165191,165200, 165267,165280**		**B2b1,B2b 2,B2d,B2b 3,B2c2**	**172.76**	**711**

6	WD181176-002	Distance ring or Pair of friction rings	A2c2		10
7	WD181177-001	Pair of friction rings	A2c2		10
8	WD181178-001	Pair of friction rings	A2c2		10
9	WD181193-001	Allen Screw 10 x 45mm	A2c2		10
10	WD181162-001	Seal ring	A2c1		6
11	WD181163-001	Spring	A2c1		4
12	WD181174-001	Nut12mm	A2c2		1
13	WD181175-001	Hex.Screw12 x 45mm	A2c2		1
14	WD181192-002	Clamping Ring	A2c2		1
SPF	**181153,181157,181160,181162,181163, 181166,181171,181174,181175,181176, 181177,181178,181192,181193**		**A2c1,A2c 2,E2b2,**	**128.78**	**110**

Table 3.23: Statement for SPF- 182 in year 2007

Sl No. of SKU	SKU Number	Description	Shelf number	L_d, average distance travel, ft	Weight in 2007, R_f
1	WD182092-	Gamma ring	I2b1		9
2	WD182063-006	Bearing 6306	F1a1		7
3	WD182055-005	Gasket	I1a2		2
4	WD182058-003	Gasket	I1a2		2
5	WD182064-007	Shaft Seal	I2b1		2
6	WD182087-004	Distance Ring	I2b1		2
SPF	**182055,182058,182063,182064,182087, 182092**		**I1a2,F1a1, I2b1**	**36.50**	**24**

Table 3.24: Statement for SPF- 183 in year 2007

Sl No. of SKU	SKU Number	Description	Shelf number	L_d, average distance travel, ft	Weight in 2007, R_f
1	WD183024-005	Gasket	E4c2		12
2	WD183025-001	LO Thermostatic Element 54C	V1d		7

SPF	**183024,183025**	**E4c2,V1d**	**154.40**	**19**

Table 3.25: Statement for SPF- 184 in year 2007

Sl No. of SKU	SKU Number	Description	Shelf number	L_d, average distance travel, ft	Weight in 2007, R_f
SPF	**WD184001-002**	**Dipstick**	**A2c3**	**129.56**	**2**

Table 3.26: Statement for SPF-191 in year 2007

Sl No. of SKU	SKU Number	Description	Shelf number	L_d, average distance travel, ft	Weight in 2007, R_f
1	WD191052-001	O-ring	D1b2		48
2	WD191050-004	HT-water Pump	B1a		12
3	WD191051-002	LT-water Pump	B1a		12
4	WD191043-002	Hexagonal Screw Dry Lock Type	D1b1		4
5	WD191009-004	Bearing RHW 33	D1b1		3
6	WD191015-003	Shaft seal	D1b1		3
7	WD191044-001	Pair of friction rings	D1b2		3
8	WD191045-001	Pair of friction rings	D1b2		3
9	WD191054-002	Flinger	D1b2		3
10	WD191010-005	Bearing NU 209	D1b1		2
11	WD191068-001	Male Stud	D1b1		2
12	WD191013-004	Radial seal	D1b1		1
13	WD191042-001	Clamping Ring	D1b1		1
14	WD191048-001	Drive gear wheel	D1b2		1
SPF	**191009,191010,191013,191015,191042, 191043,191044,191045,191048,191050, 191051,191052,191054,191068**		**D1b1,D1b 2,B1a**	**112.50**	**98**

Table 3.27: Statement for SPF- 196 in year 2007

Sl No. of SKU	SKU Number	Description	Shelf number	L_d, average distance travel, ft	Weight in 2007, R_f
1	WD196251-001	O-ring	D1b1		33
2	WD196273-002	Gasket	E4c2		13
3	WD196258-003	Gasket	E4c2		10
4	WD196264-004	HT Thermostatic Element 86.5 C	V2d		10
5	WD196266-009	LT Thermostatic element 37.5 C	V3d		6
6	WD196271-001	Sleeve	E2a4		5
SPF	**196251,196258,196264,196266,196271, 196273**		**D1b1,E4c 2,V2d,V3d ,E2a4**	**184.00**	**77**

Table 3.28: Statement for SPF- 200 in year 2007

Sl No. of SKU	SKU Number	Description	Shelf number	L_d, average distance travel, ft	Weight in 2007, R_f
1	WD200026-004	Allen Screw M10X130mm	A1c1		30
2	WD200015-002	Allen Screw 10 X 70mm	A1c1		15
3	WD200016-002	Lock Nut10mm	A1c1		15
4	WD200137-001	Bellows	A1c3		8
5	WD200357	Sealing Ring	A1c1		8
6	WD200011-004	Gasket	A1b3		6
7	WD200014-004	Two-part ring	A1c1		6
8	WD200138-001	Stud12x90mm	A1c1		6
9	WD200139-003	Lock Nut12mm	A1c1		6
10	WD200358	Sealing Ring for exh.	A1c1		4
11	WD200163-001	Bellows	A1c2		3
12	WD200028-001	Hex. Screw 8x16mm	J3b2		2
SPF	**200011,200014,200015,200016,200026, 200028,200137,200138,200139,200163, 200357,200358**		**A1b3,A1c 1,J3b2,A1 c3,A1c1,A 1c2,**	**179.08**	**109**

Table 3.29: Statement for SPF- 205 in year 2007

Sl No. of SKU	SKU Number	Description	Shelf number	L_d, average distance travel, ft	Weight in 2007, R_f
1	WD205115-	Hex. Screw 16x35mm	J3c1		2
2	WD205014-001	Hex. Screw 12x30mm	J3c1		1
SPF	**205014,205115**		**J3c1**	**121.60**	**3**

Table 3.30: Statement for SPF- 211 in year 2007

Sl No. of SKU	SKU Number	Description	Shelf number	L_d, average distance travel, ft	Weight in 2007, R_f
1	WD211016-001	O-ring	E1a2		12
2	WD211009-004	Allen Screw 8x25 mm	J2c2		1
3	WD211011-004	Allen Screw 10x70 mm	J2c2		1
SPF	**211009,211011,211016**		**J2c2,E1a2**	**125.60**	**14**

Table 3.31: Statement for SPF- 213 in year 2007

Sl No. of SKU	SKU Number	Description	Shelf number	L_d, average distance travel, ft	Weight in 2007, R_f
1	WD213007-003	Compression Spring	C3b1		3
2	WD213008-003	Stop Lever	C3b1		2
3	WD213006-003	Bearing Ball	C3b1		1
SPF	**213006,213007,213008**		**C3b1**	**93.00**	**6**

Table 3.32: Statement for SPF-214 in year 2007

Sl No. of SKU	SKU Number	Description	Shelf number	L_d, average distance travel, ft	Weight in 2007, R_f
SPF	**WD214021-002**	**Tab washer**	**C3b1**	**93.00**	**1**

Table 3.33: Statement for SPF- 217 in year 2007

Sl No. of SKU	SKU Number	Description	Shelf number	L_d, average distance travel, ft	Weight in 2007, R_f
1	WD217046-002	Spare parts and sealing set	E3b1		13
2	WD217008-003	Spool Assembly	E3b1		5
3	WD217029-001	Seal	E3a4		5
4	WD217038-001	O-ring	E3b1		5
5	WD217021-002	O-ring	E3b1		4
6	WD217033-002	Ball	E3b1		4
7	WD217003-004	Sealing	E3b1		2
8	WD217025-004	O-ring	E3a4		2
9	WD217012-003	Seal	E3b1		1
10	WD217030-001	Spring	E3b1		1
11	WD217031-001	O-ring	E3b1		1
12	WD217032-001	O-ring	E3b1		1
13	WD217034-001	Filter	E3b1		1
SPF	**217003,217008,217012,217021,217025, 217029,217030,217031,217032,217033, 217034,217038,217046**		**E3b1,E3a 4**	**83.20**	**45**

Table 3.34: Statement for SPF- 223 in year 2007

Sl No. of SKU	SKU Number	Description	Shelf number	L_d, average distance travel, ft	Weight in 2007, R_f
1	WD223041-001	Gasket	C4b1		13
2	WD223054-001	Pipe 6mm	D2c3		12
3	WD223044-001	Pipe, 6mm	D2c3		4
4	WD223079-001	Fixing Collar	C4b1		3
5	WD223003-002	Bearing bushing	C4b1		2
6	WD223007-003	Hexagonal Screw	C4b1		1
7	WD223022-003	Stud 12X40mm	C4b1		1
8	WD223035-004	Drive shaft	C3b3		1
9	WD223036-001	Shelter	C4b1		1

SPF	**223003,223007,223022,223035,223036, 223041,223044,223054,223079**	**C4b1,C3b 3,D2c3**	**136.70**	**38**

Table 3.35: Statement for SPF-224 in year 2007

Sl No. of SKU	SKU Number	Description	Shelf number	L_d, average distance travel, ft	Weight in 2007, R_f
1	WD224089-002	V-Ring	C1b3		11
2	WD224017-002	Bearing bush	C1b2		6
3	WD224006-003	Hex. Screw 8x30 mm	J2c2		5
4	WD224073-001	Hex. Screw 6x25mm	J2b2		5
5	WD224052-002	Locking Plate	C1c1		4
6	WD224055-001	Spring retainer	C1c1		4
7	WD224090-003	Bearing bush	C1b3		4
8	WD224092-003	Spring retainer	C1c1		4
9	WD224007-002	Lock Nut 8mm	C1b2		2
10	WD224040-002	Lock Nut12mm	C1b3		2
11	WD224111-001	Bearing bush	C1b2		2
12	WD224015-002	Screw12x30mm	C1b2		1
13	WD224034-005	Bearing bracket with bear.	C1b3		1
14	WD224076-003	Taper pin	C1b3		1
15	WD224095-002	Hexagonal Screw 10*50mm	J2b2		1
16	WD224096-002	Lock Nut	C1c1		1
17	WD224103-002	Allen Screw10*65mm	C1b3		1
18	WD224104-001	Bearing housing	C1c1		1
19	WD224157-003	Cylindrical pin	C1b2		1
SPF	**224006,224007,224015,224017,224034, 224040,224052,224055,224073,224076, 224089,224090,224092,224095,224096, 224103,224104,224111,224157**		**J2c2,C1b 2,C1b3,C1 c1,J2b2,**	**139.50**	**57**

Table 3.36: Statement for SPF- 228 in year 2007

Sl No. of SKU	SKU Number	Description	Shelf number	L_d, average distance travel, ft	Weight in 2007, R_f
1	WD228176-004	Pipe to Overspeed Trip Device	D4b1		19
2	WD228003-005	Hex. Screw 10x60mm	J2b2		15
3	WD228042-001	O-Ring	C2c3		15
4	WD228043-001	O-Ring	C2c3		13
5	WD228024-002	O-Ring	C1c2		11
6	WD228046-001	Gasket	C2c3		11
7	WD228019-002	O-Ring	C1c3		10
8	WD228174-002	Male Stud 8mm	E3a3		8
9	WD228162-001	Straight Union, 18mm	E4a1		7
10	WD228105-002	Angle Union, 8mm (Benju bolt)	E3a2		6
11	WD228201-002	Angle Union, 6mm(Benju bolt)	E3a4		6
12	WD228204-001	Male Stud, 6mm	E3a3		6
13	WD228160-005	Pipe 6mm	D2c3		4
14	WD228163-008	Air Pipe	D3b3		4
15	WD228241-003	Limit Switch-Mech. O/S	V3c		4
16	WD228032-003	Spring	C1c3		3
17	WD228120-001	Hex. Screw M8*30mm	J3b2		3
18	WD228262	Air Pipe	D4b3		3
19	WD228279-001	Repair Kit	E4c1		3
20	WD228280-	Ball Valve	C2c3		3
21	WD228018-004	Outer Work Spring	C1c3		2
22	WD228041-001	Housing	C1b1		2
23	WD228164-002	T-Union 18mm	E4a1		2
24	WD228203-001	Male Stud, 6mm	E3a4		2
25	WD228215-001	Angle Union, 18mm	E4a1		2
26	WD228239-004	Spring Guide	C1c3		2
27	WD228025-002	O-Ring	C1c2		1
28	WD228101-002	O-Ring	E1a3		1

29	WD228106-002	Sliding O-ring	E1a3		1
30	WD228171-004	Pipe Clamp	C2c3		1
31	WD228186-001	Pipe Union	E5a4		1
32	WD228190-001	Angle Union, 18mm	E5b1		1
33	WD228196-001	Non-return Valve	E5b1		1
34	WD228237-002	Cutting Ring, 18mm	E5b1		1
35	WD228240-004	Spring, Inner V32,	C1c3		1
36	WD228249-002	Hexagonal Socket(Allen) Head Screw	C1c3		1
SPF	**228003,228018,228019,228024,228025, 228032,228041,228042,228043,228046, 228101,228105,228106,228120,228160, 228162,228163,228164,228171,228174, 228176,228186,228190,228196,228201, 228203,228204,228215,228237,228239, 228240,228241,228249,228262,228279, 228280**		**J2b2,C1c 3,C1c2,C1 b1,C2c3,E 1a3,E3a2, J3b2,D2c 3,E4a1,D3 b3,E4a1,E 3a3,D4b1, E5a4,E5b 1,E3a4,E5 b1,C1c3,V 3c,D4b3,E 4c1**	**200.90**	**176**

Table 3.37: Statement for SPF- 231 in year 2007

Sl No. of SKU	SKU Number	Description	Shelf number	L_d, average distance travel, ft	Weight in 2007, R_f
1	WD231035-002	Speed pickup-T/C	V3c		8
2	WD231037-002	Speed sensor-DESPEMES	V3c		2
SPF	**231035,231037**		**V3c**	**90.40**	**10**

Table 3.38: Statement for SPF-350 in year 2007

Sl No. of SKU	SKU Number	Description	Shelf number	L_d, average distance travel, ft	Weight in 2007, R_f
1	WD350018-002	O-Ring	E2a2		42
2	WD350184-001	O-Ring	E2a2		36
3	WD350167-001	O-Ring	E2a2		18

4	WD350421-002	Allen screw 8x30 mm	J2b1		18
5	WD350025-002	Lock Nut 10m	C2b2		14
6	WD350021-003	O-Ring	E2a2		7
7	WD350024-004	Stud10 X70mm	C2b2		6
8	WD350137-004	Cover	V4d		6
9	WD350428-002	Cover	V5c		6
10	WD350019-003	Allen Screw 8x30mm	C2b2		3
11	WD350027-003	Allen screw 8x40 mm	J2b1		3
12	WD350199-002	Gasket 2)	H2a3		3
13	WD350424-001	Hex. Screw 8x40 mm	J2c1		3
14	WD350134-002	Stud M10x260mm	C2b2		2
15	WD350175-001	Hexagonal Socket10x55 mm	J3c2		2
16	WD350419-001	Hexagonal Screw M10X35mm	C2b2		2
17	WD350431-001	Cover for Fuel Pipe	V5c		2
18	WD350432-001	Stud M10 X100mm	C2b2		2
19	WD350016-011	Pipe	D4b2		1
20	WD350039-001	Hexagonal Screw M12x30 mm	C2b2		1
21	WD350060-004	Pipe Clamp	C2b2		1
22	WD350132-002	Clamp for 35mm Pipe	C2b2		1
23	WD350133-002	Clamp for 35mm Pipe	C2b2		1
24	WD350555-001	Hex. Screw 12x70 mm	J2b2		1
25	WD350556-001	O-ring	E1a2		1
26	WD350559-001	Stud 10*120mm	C2b3		1
SPF	**350016,350018,350019,350021,350024, 350025,350027,350039,350060,350132, 350133,134,137,167,175,184,199,419,42 1,424,428,431,432,555,556,559**		**D4b2,E2a 2,C2b2,J2 b1,V4d,J3 c2,H2a3,J 2c1,V5c,J 2b2,E1a2, C2b3**	**248.50**	**183**

Table 3.39: Statement for SPF-352 in year 2007

Sl No. of SKU	SKU Number	Description	Shelf number	L_d, average distance travel, ft	Weight in 2007, R_f
1	WD352676-001	Angle union, 10mm	E4a4		33
2	WD352075-002	Pipe Union, 8mm	E3a2		20
3	WD352687-002	Flexible Hose	D4b3		12
4	WD352107-004	Lub. Oil Pipe	D4c1		10
5	WD352027-002	Straight Union, 22mm	E5a3		9
6	WD352165-001	Male Stud 22mm	E5a3		8
7	WD352478	Lube Oil Pipe	D4c1		8
8	WD352182-015	Oil Pipe	D1b3		5
9	WD352163-002	Ball valveDN20	C2b3		4
10	WD352176-003	O-ring	E2a4		4
11	WD352245-003	O-ring	E1a1		4
12	WD352087-002	Male stud, 8mm	E3a3		3
13	WD352114-004	Lube Oil Pipe	D4b1		3
14	WD352183-008	Oil Pipe 3V35C2843	D4b2		3
15	WD352476-002	Pipe Union	E5a2		3
16	WD352704-001	Pipe clamp	C2b3		3
17	WD352776-001	Pipe	D4b3		3
18	WD352013-	O-ring	E2a2		2
19	WD352117-003	Male stud, 12mm	E4a2		2
20	WD352238-001	LO Pipe	D4c1		2
21	WD352267-002	Gasket	E1a3		2
22	WD352295-001	O-ring	E1a2		2
23	WD352459-001	O-ring	E2a2		2
24	WD352460-003	O-ring for flap	E2a3		2
25	WD352705-001	Hex.Screw10 x60mm	J2b2		2
26	WD352115-004	Pipe union, 22mm	E5a3		1
27	WD352116-002	Pipe union, 28mm	E5a1		1
28	WD352123-003	T-fitting, 28mm	E5a1		1
29	WD352125-002	Stud 10 X85mm	J2b1		1
30	WD352152-001	Pipe	D4b2		1
31	WD352180-003	Pipe 8mm	D4b1		1
32	WD352188-001	Pipe	D2c2		1

33	WD352237-001	T- union, 8mm	E3a2		1
34	WD352239-002	Lube Oil Pipe	D4b1		1
35	WD352269-001	O-ring	E2a2		1
36	WD352458-005	Non-return valve	C1b1		1
37	WD352688-001	Hose	D4b3		1
38	WD352708-001	T-fitting 22mm	E5a3		1
39	WD352777-001	Pipe union	E3a2		1
SPF	**352013,352027,352075,352087,352107, 352114,352115,352116,352117,352123, 352125,352152,352163,352165,352176, 352180,352182,352183,352188,352237, 352238,352239,352245,352267,352269, 352295,352458,352459,352460,352476, 352478,352676,687,688,704,705,708,77 6,352777**		**E2a2,E5a 3,E3a2,E3 a3,D4c1,D 4b1,E5a1, E4a2,J2b1 ,D4b2,C3b 3,E5a3,E2 a4,E1a1,E 1a3,E2a2, E1a2,C1b 1,E2a3,E5 a2,D4c1,E 4a4,D4b3, C2b3,J2b 2,E2a2**	**137.80**	**165**

Table 3.40: Statement for SPF- 354 in year 2007

Sl No. of SKU	SKU Number	Description	Shelf number	L_d, average distance travel, ft	Weight in 2007, R_f
1	WD354001	Gasket	E2b1		58
2	WD354100-004	Gasket	E3d		27
3	WD354064-002	Gasket	E2b2		22
4	WD354238-001	Straight union, 12mm	E4a2		7
5	WD354102-001	Gasket	E4c1		6
6	WD354040-006	Pipe	C3a		3
7	WD354229-001	Connection piece	E4a3		3
8	WD354095-001	Gasket	E2b1		2
9	WD354024-018	Pipe Clamp	C2c2		1
10	WD354099-002	Hex. Screw16x75mm	C2c1		1
11	WD354173	Allen Screw for LT Line12x50mm	J2b2		1

SPF	**354001,354024,354040,354064,354095, 354099,354100,354102,354173,354229, 354238**	**E2b1,C2c 2,C3a,E2b 2,C2c1,E3 d,E4c1,J2 b2,E4a3,E 4a2**	**118.50**	**131**

Table 3.41: Statement for SPF- 355 in year 2007

Sl No. of SKU	SKU Number	Description	Shelf number	L_d, average distance travel, ft	Weight in 2007, R_f
1	WD355112-002	O-Ring	E1a1		137
2	WD355109-001	O-Ring	E2b2		45
3	WD355011-002	Gasket	E2b1		16
4	WD355519-005	Gasket	E3d		15
5	WD355002-003	Gasket	E2b1		12
6	WD355155-002	Gasket	E2b2		11
7	WD355025-004	O-Ring	E1a1		9
8	WD355031-004	Hex.Screw 10x25mm	J2b2		5
9	WD355479-003	Gasket	E2b1		5
10	WD355252-003	O-Ring	E2a4		4
11	WD355347-002	Gasket	E2b1		4
12	WD355113-001	Allen Screw 12x30 mm	J2b1		3
13	WD355356-003	Reduction Ring	C2c1		2
14	WD355020-	T- Union 12mm	E4a3		1
15	WD355107-001	Allen screw 12x45 mm	J2b1		1
16	WD355117-001	Gasket	E4d		1
17	WD355165-001	Gasket	E2b1		1
18	WD355188-001	Screw Plug	C2c1		1
SPF	**355002,355011,355020,355025,355031, 355107,355109,355112,355113,355117, 355155,355165,355188,355252,355347, 355356,355479,355519**		**E2b1,E4a 3,E1a1,J2 b1,J2b2,E 4d,C2c1,E 2a4,E3d,E 2b2**	**167.30**	**273**

Table 3.42: Statement for SPF- 357 in year 2007

Sl No. of SKU	SKU Number	Description	Shelf number	L_d, average distance travel, ft	Weight in 2007, R_f
1	WD357012-003	O-ring	E1a3		15
2	WD357018-002	Gasket	E2c1		12
3	WD357007-002	O-ring	E1a2		10
4	WD357077-001	Seal Ring	E2a3		2
5	WD357118-001	Pipe union	E5a2		2
6	WD357021-001	Seal ring	C2c1		1
7	WD357076-001	Hollow screw	E4a1		1
8	WD357078-001	Straight union, 10mm	E4a4		1
9	WD357081-001	Stud 10X84mm	C2c1		1
10	WD357163-002	O-ring	E2a1		1
11	WD357208-003	Angle union	E5a2		1
SPF	**357007,357012,357018,357021,357076, 357077,357078,357081,357118,357163, 357208**		**E1a2,E1a 3,E2c1,C2 c1,E4a1,E 2a3,E4a4, E5a2,E2a 1**	**157.30**	**47**

Table 3.43: Statement for SPF- 358 in year 2007

Sl No. of SKU	SKU Number	Description	Shelf number	L_d, average distance travel, ft	Weight in 2007, R_f
1	WD358403-002	Leak Metal Hose12mm,L=43cm	D4b1		16
2	WD358004-002	O-ring	E1a1		9
3	WD358404-001	Angle union	E3a2		6
4	WD358156-001	Connection piece	C2c2		5
5	WD358169-001	Male stud, 22mm	E5a3		5
6	WD358514-001	Ball Valve DN20	C2c2		5
7	WD358010-002	Gasket	E2c1		2
8	WD358154-003	O-ring	E2a1		2
9	WD358520-001	Leakage oil tank	E4b1		2
10	WD358014-003	Throttle Free Banjo Fitting	E5a3		1

11	WD358213-001	Level switch- Fuel Leakage	V3c		1
12	WD358401-001	T- union	E3a2		1
13	WD358515-001	T- Union EVT 22-L	E5a4		1
14	WD358530-001	Connecting piece	E4a3		1
15	WD358531-001	Leak Oil Pipe	D3c3		1
SPF	**358004,358010,358014,358154,358156, 358169,358213,358401,358403,358404, 358514,358515,358520,358530,358531**		**E1a1,E2c 1,E5a3,E2 a1,C2c2,V 3c,E3a2,D 4b1,E5a4, E4b1,E4a 3,D3c3**	**228.80**	**58**

Table 3.44: Statement for SPF- 372 in year 2007

Sl No. of SKU	SKU Number	Description	Shelf number	L_d, average distance travel, ft	Weight in 2007, R_f
1	WD372209-002	Cutting ring, 6mm	E3a4		12
2	WD372185-002	Evce union, 6mm	E4c1		7
3	WD372136-002	Valve	E4c1		6
4	WD372208-001	Connecting Nut	E3a4		5
5	WD372225-001	3-Way CockDN10	E4c1		5
6	WD372153-003	Adj.Angle union, 6mm	E3a3		4
7	WD372206-001	Ball Valve DN04	E4c1		4
8	WD372002-002	Seal ring	B1b3		2
9	WD372038-002	Water Container	B1b2		1
10	WD372149-001	Pipe(1) 12mm	D2c3		1
11	WD372242-001	Quick Coupling	E4b2		1
SPF	**372002,372038,372136,372149,372153, 372185,372206,372208,372209,372225, 372242**		**B1b3,B1 b2,E4c1, D2c3,E3 a3,E4c1, E3a4,E4 b2**	**205.80**	**48**

Table 3.45: Statement for SPF- 377 in year 2007

Sl No. of SKU	SKU Number	Description	Shelf number	L_d, average distance travel, ft	Weight in 2007, R_f
1	WD377002-003	O-ring for crankcase cover	E2a1		4
2	WD377003-001	Gasket	E4b2		4
SPF	**377002,377003**		**E2a1,E4b 2**	**105.80**	**8**

Table 3.46: Statement for SPF- 378 in year 2007

Sl No. of SKU	SKU Number	Description	Shelf number	L_d, average distance travel, ft	Weight in 2007, R_f
SPF	**WD378002-002**	**O-ring of breather pipe**	**E1a1**	**49.60**	**20**

Table 3.47: Statement for SPF- 470 in year 2007

Sl No. of SKU	SKU Number	Description	Shelf number	L_d, average distance travel, ft	Weight in 2007, R_f
1	WD470200-001	Fuel filter cartridge	Cont.		26
2	WD470241-001	Set of sealings for fuel filter	E1d		8
3	WD470255-001	Drain Plug	E3a3		2
SPF	**470200,470241,470255**		**Cont.,E1d ,E3a3**	**1,090.20**	**36**

Table 3.48: Statement for SPF- 471 in year 2007

Sl No. of SKU	SKU Number	Description	Shelf number	L_d, average distance travel, ft	Weight in 2007, R_f
1	WD471196-003	LO Filter Insert	Cont.		18
2	WD471235-001	Sealing set for LO filter	E1e		4
SPF	**471196,471235**		**Cont.,E1e**	**1,051.80**	**22**

Table 3.49: Statement for SPF- 473 in year 2007

Sl No. of SKU	SKU Number	Description	Shelf number	L_d, average distance travel, ft	Weight in 2007, R_f
SPF	**WD473003-001**	**O-ring**	**E2b1**	**66.40**	**1**

Table 3.50: Statement for SPF- 476 in year 2007

Sl No. of SKU	SKU Number	Description	Shelf number	L_d, average distance travel, ft	Weight in 2007, R_f
1	WD476005-011	Gasket	E2c2		4
2	WD476001-002	Screw Hexagonal Head, 12 X70mm(Half thread)	E3a1		2
3	WD476003-003	Seal Ring	E3a1		2
SPF	**476001,476003,476005**		**E3a1,E2c 2**	**84.20**	**8**

Table 3.51: Statement for SPF- 483 in year 2007

Sl No. of SKU	SKU Number	Description	Shelf number	L_d, average distance travel, ft	Weight in 2007, R_f
1	WD483040-001	Limit switch-Turning Gear	V3c		9
2	WD483081-002	Shaft seal	C3b2		1
3	WD483082-001	Shaft Seal	C3b2		1
4	WD483084-001	O-ring	C3b2		1
5	WD483085-001	O-ring	C3b2		1
6	WD483115-001	Locking device	C3b2		1
SPF	**483040,483081,483082,483082,483084, 483085,483115**		**V3c,C3b2**	**140.00**	**14**

Table 3.52: Statement for SPF- 501 in year 2007

Sl No. of SKU	SKU Number	Description	Shelf number	L_d, average distance travel, ft	Weight in 2007, R_f
SPF	**WD501100**	**Connection Box**		**-**	**0**

Table 3.53: Statement for SPF- 506 in year 2007

Sl No. of SKU	SKU Number	Description	Shelf number	L_d, average distance travel, ft	Weight in 2007, R_f
1	WD506068-003	Temperature sensor, douple	V3a		14
2	WD506213-002	Cable for exhaust sensor	V2c		3
3	WD506069-003	Protecting well, for douple	V2c		1
SPF	**506068,506069,506213**		**V3a,V2c**	**90.40**	**18**

Table 3.54: Statement for SPF- 507 in year 2007

Sl No. of SKU	SKU Number	Description	Shelf number	L_d, average distance travel, ft	Weight in 2007, R_f
1	WD507810-001	Exhaust gas temp. sensor,	V1c		6
2	WD507755-002	Hex. Screw 6x40 mm	J2c1		1
3	WD507811-001	Protecting Well - T/C Sensor	V1c		1
SPF	**507755,507810,507811**		**J2c1,V1c**	**188.60**	**8**

Table 3.55: Statement for SPF- 508 in year 2007

Sl No. of SKU	SKU Number	Description	Shelf number	L_d, average distance travel, ft	Weight in 2007, R_f
1	WD508022-001	Cutting ring, 10mm	E4a4		2
2	WD508027-001	Hex.Screw 5x25 mm	J2b2		1
SPF	**508022,508027**		**E4a4,J2b2**	**121.60**	**3**

Table 3.56: Statement for SPF- 511 in year 2007

Sl No. of SKU	SKU Number	Description	Shelf number	L_d, average distance travel, ft	Weight in 2007, R_f
1	WD511132-001	Thermometer	V1c		7
2	WD511136-001	Thermometer	V1b		2
SPF	**511132,511136**		**V1c,V1b**	**87.40**	**9**

Table 3.57: Statement for SPF- 516 in year 2007

Sl No. of SKU	SKU Number	Description	Shelf number	L_d, average distance travel, ft	Weight in 2007, R_f
1	WD516028-002	Vibration Damper-Local RPM Panel	A3c2		10
2	WD516025-001	Hose	D4c1		4
3	WD516023-002	Air Hose	D4c1		3
4	WD516007-005	Manometer, 60bar	V2b		1
5	WD516009-010	Manometer, 6bar	V3b		1
6	WD516019-001	Ball ValveDN04	E5c1		1
SPF	**516007,516009,516019,516023,516025, 516028**		**V2b,V3b,E 5c1,D4c1, A3c2**	**284.00**	**20**

Table 3.58:Statement for SPF- 600 in year 2007

Sl No. of SKU	SKU Number	Description	Shelf number	L_d, average distance travel, ft	Weight in 2007, R_f
1	WD600002-006	Gasket for Exhaust Gas Pipe	M4e		8
2	WD600007-005	Gasket for Turbocharger	B1b2		8
SPF	**600002,600007**		**M4e,B1b2**	**148.00**	**16**

Table 3.59: Statement for SPF- 604 in year 2007

Sl No. of SKU	SKU Number	Description	Shelf number	L_d, average distance travel, ft	Weight in 2007, R_f
1	WD604068-001	Ball ValveDN40	V3b		7
2	WD604069-001	Quick Coupling	A3c2		5
3	WD604070-001	Protection Cover	A3c2		5
4	WD604103-003	Hexagonal Screw M16X140mm	J2c1		5
5	WD604095-002	O-ring	E1a3		2
6	WD604076-001	Gasket	E3c1		1
7	WD604084-001	Gasket	E2a4		1
8	WD604088-001	Gasket	E3c1		1
9	WD604093-001	O-ring	E2a4		1
10	WD604101-001	Gasket	E2b1		1
11	WD604104-001	Clamp	E5b2		1
SPF	**604068,604069,604070,604076,604084,604088,604093,604095,604103,604104**		**V3b,A3c2,E3c1,E2a4,E1a3,E2b1,J2c1,E5b2**	**276.80**	**30**