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Optimal maintenance system for coast guard patrol crafts : policies and strategies

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OPTIMAL MAINTENANCE SYSTEM FOR COAST GUARD PATROL CRAFTS

POLICIES AND STRATEGIES

BY

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THE KINGDOM OF SAUDI ARABIA

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I certify that all material in this dissertation which is not my own work has been identified and that no material is included for which a degree has been previously conferred upon me.

The contents of this dissertation reflect my personal views and are not necessarily endorsed by the University.

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DEDICATION

TO MY COUNTRY

THE KINGDOM OF SAUDI ARABIA

AND

TO MY FAMILY

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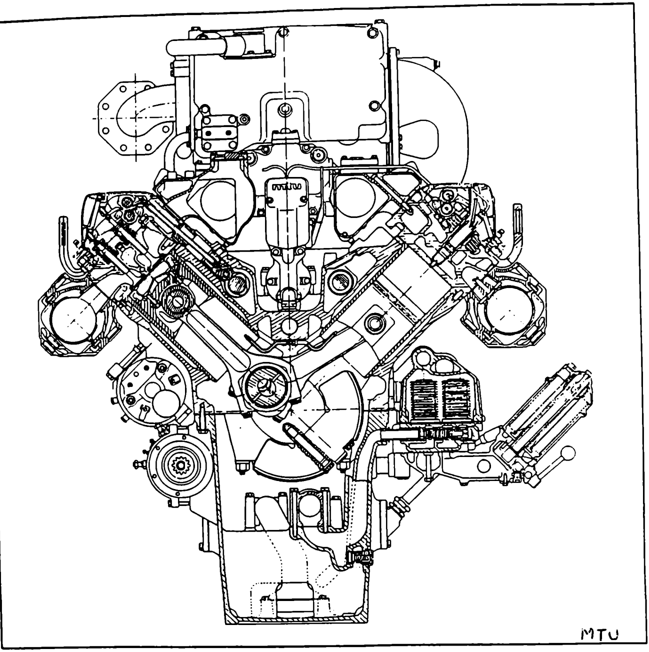


IN THE NAME OF ALLAH

THE BENEFICENT, THE MERCIFUL

ABSTRACT

The present dissertation examines the most common maintenance and repair policies and strategies of an organisation with special emphasis on those systems and methods suitable for the maintenance of high speed patrol craft.

The dissertation discusses the selection and implementation of the optimal policy for the maintenance of patrol crafts operating in the special conditions of the Kingdom of Saudi Arabia territorial waters.

The dissertation considers several definitions of maintenance and repair from main authors as well as the technical and economic reasons for the maintenance work. It describes the overall cycle of maintenance and types of maintenance. Special consideration is given to planned maintenance, its aim and criteria. It evaluates four basic maintenance policies and its implications for the organisation; e.g. the repair only policy and its implications, preventive maintenance, the use of management techniques to improve the system. The optimal policy is considered in detail from its definition to the steps in the implementation process.

The maintenance system described in the dissertation is based, primarily on the TSAR Maintenance System. IMO recommends this system for its maintenance courses around the world. Simplicity and flexibility characterises the system.

In addition the dissertation pays attention to the problem of inventories and spare parts control. It presents recent developments on high speed craft technology, safety, operational standards and the most frequent causes for breakdowns. Repair methods are described and discussed. To contribute to the planning and analysis processes, a chapter is dedicated to repair records.

Finally, recognising that the complexity of new crafts and modern equipment requires standard procedures and a systematic control of spare parts' stocks, and a good training scheme, both technical and administrative schemes, the dissertation recommends the adoption of the TSAR integrated maintenance system in used in all kind of maintenance departments around the world.

INTRODUCTION

Maintenance is regarded as the most important factor in the upkeep of modern society. Because maintenance is also expensive, it is very tempting to put it off until tomorrow in order to either show a positive result in the balance sheet or just to save money.

"It is better to prevent than to cure" says an old Arab proverb. To prevent or to correct a failure is the dilemma. Thus, for preventing equipment from failing, to cure, correct or rectify the failure are all complementary and part of the same process. Sometimes, the former leads to the latter.

Maintenance in general is performed to help achieve the goals and objectives of any organization. In the case of a manufacturing enterprise, the objective is to produce and sell a product at a profit. In other organizations, the objective is simply to perform a mission, in most cases in a cost-effective manner.

Regardless of the nature, the organization adopts certain strategies or policies in regard to expenditures and costs. Maintenance is often the area where management adopts the stricter measures. It is also the first area to be scaled down when things are not so bright for the organization.

Thus the need for optimizing maintenance in general. Although sometimes it is overlooked by management, optimal maintenance is vital for the organization. Reliability of plants and equipment, the overall performance of the organization, state of readiness, etc. all depend on how well maintained the equipment is. Optimizing maintenance is just performing maintenance within a set of budgetary constraints, in a way that best achieves the goal of the organization.

The above is also applicable to maritime equipment, plants and vessels in all its forms and sizes. There is no proof to support any argument that ship maintenance on average is performed or managed any better - or worse- than its industrial counterparts.

The objective of maintenance in any organization should be to achieve the correct level of operational reliability and best possible personal safety at minimum cost. This objective can also be described as an attempt to achieve the optimum or best possible operational reliability, i.e. the most economical operational reliability at as low a cost as possible.

Another reason to pay greater interest in maintenance is the steady mechanisation and automation in both shipping and industry. Vessels and plants are becoming more complicated and thus require more advanced maintenance. The demands made on skilled maintenance personnel increase, and maintenance work is tending to occupy a growing proportion of the total activities of a company. The quality of the work carried out by maintenance personnel has a growing effect on a company productivity. It is expected, therefore, that interests in improving maintenance grow within the organization.

Recognizing the need for approaching maintenance in a more rational and optimized way, many maintenance systems have been developed and are available in the market.

The present dissertation addresses the problem of systematizing and standardizing maintenance procedures and classification and identification of spare part stocks for high speed crafts, serving in the coasts of the Kingdom of Saudi Arabia.

The modernisation of patrol crafts and equipment in the Kingdom is a reality. In line with the latter, the problem of maintaining vessels and equipment in excellent conditions should be addressed in order to comply with the mission assigned to the Coast Guard.

Considering current technology, and based on existing maintenance systems, this dissertation examines a maintenance scheme or system for patrol crafts. The system examined here seeks to minimise maintenance down-time and also costs while maximising or optimising mission readiness, availability and reliability. The system also considers the standardization of the workshop-administrative procedures. A spare parts computer control and classification system is also considered.

The maintenance scheme examined consists of the following components:

- Development of a preventive maintenance schedule, conditional and breakdown maintenance for patrol crafts.
- Development of a spare parts inventory and control.
- Development of an organisational plan for the maintenance department.
- Development of a training policy and program for maintenance personnel.

The dissertation is organized in the following chapters: Chapter 1 gives a brief description of the Coast Guard, legal standing, functions and organization. Chapter 2 examines the types of maintenance, various maintenance policies and strategies, criteria for a good maintenance system, and implications when choosing a particular strategy. Chapter 3 considers the maintenance system, subsystems, description of the system and procedures. Chapter 4 shows the inventory and spare parts policy, its requirements, a comparison between a manual Vs a computerized systems and advantages and disadvantages of both systems. Chapter 5 describes repair methods. Chapter 6 points out the need for repair records. Chapter 7 examines safety, education and training in maintenance department and Chapter 8 is dedicated to the conclusion and recommendations.

Most of the measures described in this dissertation are intended to result in less time and material being required for maintenance, leading to reduced costs for the organization, in an improved working environment, improved human safety and reduce human stress. Energy consumption and capital costs can also be reduced through proper maintenance.

CHAPTER 1

FUNCTIONS AND ORGANISATION OF THE SAUDI COAST GUARD

The Coast Guard of the Kingdom of Saudi Arabia was founded in 1353 H, (1934 AD). Royal Ordinance No. M/26 on Borders Security of 24 06 1394 H (1975 AD) and Royal Ordinance No. M/27 on Ports and Marine Lighthouses of the same date created the Frontier Forces, redefined and broaden Coast Guard functions. Resolution No. 1407 places the responsibility to make rules and regulations in the Ministry of the Interior.

1.1. Functions of the Coast Guard

Article 3 of the Boarder Security Royal Ordinance of 1975 defines the functions of the Coast Guard as follows:

1. Security control of the Kingdom coastlines.
2. Early warning of unusual movements on border lines.
3. Marine search and rescue operations, assistance to shipping, navigational aids.
4. Rendering assistance to persons in border areas.
5. Surveillance of all border movements and its adherence to the laws governing such movements.
6. Co-ordination with other departments according to rules and functions of the Coast Guard.
7. Enforcement of fisheries regulations.
8. Security inspections to vessels in the territorial sea.
9. Detection and arrest of smuggler.
10. Casualty and criminal investigation onboard vessels.
11. Marine surveillance (long, medium and short range)

1.2. Requirements of Patrol Craft

The following functions are carried out:

1.2.1 Marine surveillance.

Patrol crafts of different sizes carry out the responsibilities in the territorial waters.

a. Long range marine or territorial sea surveillance is carried out with long range crafts. Responsibilities include, among others:

i. Early warning for any abnormal activity in the territorial sea.
ii. Enforcement of security legislation.
iii. Enforcement of fisheries regulations.
iv. Search and rescue.
v. Protection and preservation of marine resources.
f. Detection of oil spills and any other substance classified as pollutant to the marine environment.

b. Medium range surveillance is meant for the territorial sea and internal waters. Functions are similar to the long range surveillance.

c. Short range surveillance is meant for the internal waters surveillance. Responsibilities include:

i. Security protection for vessels and facilities.
ii. Marine search and rescue, esp. in recreational areas.
iii. Enforcement of the security legislation.

1.3 Types of Patrol Craft

The functions and responsibilities of the Coast Guard are carried out using long, medium and short range multipurpose vessels. The crafts are fitted with fire fighting and search and rescue equipment. Crafts are grouped into six types:

Fire fighting boats	25.05m	Patrol Boats	38.6m
Rescue boats	17.5m	Hovercrafts	
Small boats	8-12m	Training ships	

These crafts have been designed for long operational endurance and high speed under the extreme environmental conditions of the Arabian Gulf and the Red Sea, i.e. high ambient temperature, high humidity, high sea water temperature and dusty winds. They operate in various missions in shallow as well as in deep sea waters.

1.4 Organization of the Maintenance Department

The organization of maintenance and repair for crafts and equipment is in line with the overall organization. Central workshops and small unit workshops along both coasts of the country.

Daily and minor maintenance of crafts and equipment takes place in decentralized-basic workshop units sitting along the coasts. When requiring specialized maintenance and/or repairs or when the date for schedule maintenance arrives vessels are taken to central or regional workshops. The present structure has required the displacement of human and material resources in mobile units, whenever necessary. This has created the need to standardize procedures, methods and spares and equipment supply.

The complexity of the new crafts in the fleet and their modern equipment require standard procedures and a systematic and speedy control and availability of spare parts in order to respond to any emergency.

Most units are aware that the growing complexity of modern equipment and vessels requires a systematic approach to the function of maintenance and repair of such large quantity of equipment in order to standardize procedures and a unified identification system for spare parts.

1.5 Organizational Structure

The organizational structure of the Coast guard, shown in Fig. 1.1 reflects the increasing importance of maintenance within the organization.

1.5.1 Functions of the Maintenance Manager

The manager of the maintenance function - whether the job title is chief engineer, plant engineer, or maintenance manager - is attracting more attention than ever before as the importance of cost-effective maintenance is understood.

Maintenance managers range from promoted members of the maintenance staff to specially recruited professional managers. Their qualifications range from a National Certificate to academic degrees, many of them are chartered engineers. A number of successful maintenance managers have come from engineer/officer posts in the armed services

Typical functions of a chief engineer will include:

1- Responsibility for the plant maintenance department.
2- Responsibility for buildings and services maintenance.
3- Responsibility for workshops (repairs, overhauls, welding, retooling, spares manufacture).
4- Planning and supervision of capital work (construction, installation, removals, commissioning).
5- Planning of utilities (steam, electricity, oil, air, waste, effluent)
6- Responsibility for plant engineering (transport, instrumentation, machines, control systems, modifications, modernization, replacement policies, operational developments).
7- Fire precautions, safety, technical personnel, in-plant research and development, security, staff facilities.

1.5.2- The Maintenance Planning Engineer

The maintenance planner can be an in-plant engineer and must be capable of:

1- Extracting maintenance schedules from vendor manuals to form the basis of a master maintenance schedule.
2- Obtaining additional technical information so that the schedule is complete.
3- Making his own assessment of the daily, weekly and other activities necessary for an asset, working from his own experience and a study of the asset, its drawings, and specifications.

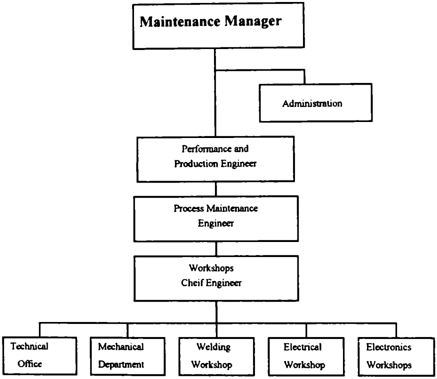


Fig. 1.1 Maintenance Department Organizational Structure

CHAPTER 2

MAINTENANCE POLICIES AND STRATEGIES

Any machine, equipment or parts is subject to failures and break-downs. These breakdowns could be of different nature: mechanical and electro-mechanical wear and tear, chemical or thermal causes. Others causes could be poor construction, faulty assembly, damage due to vibration or shock, or mishandling and operational errors.

Organizations establish their long term objectives almost taking for granted that the machinery will last its useful life. They take measures, in the form of contracts, insurance, in-house arrangement, etc. to ensure that machinery, equipment and all production assets work properly and do not hinder the achievement of the organization's goals. In spite of all these machinery and equipment do breakdown.

Kalland and Wilhelmsen (1990) recognize that maintenance is the most important factor in the upkeep of a modern society, but there are few areas in which it plays such a dominant role as in shipping. 1/

The task of any maintenance department is to provide a proper service at the lowest cost. For that management has to find out what the optimum strategy is. Management usually does this through the examination of costs and losses involved. Little attention is paid to alternative procedures or strategies.

The present chapter examines maintenance policies and common strategies, taking into account that every vessel, equipment or plant has its optimum strategy, since crafts differ in use, age and functions.

2.1 Definition of Maintenance and Repair

Kelly (1984) defines maintenance as a combination of actions carried out to return an item to, or restore it to, an acceptable condition. 2/ It is important to recognize that maintenance is not an end in itself.

Thomas (1980) stresses keeping standards. He defines maintenance as the work done in order to keep or restore a facility or equipment at an acceptable standard. 3/

The task is a complex one, for it is difficult to verify whether the standard has been met or not and if it is acceptable to everyone involved.

Thus, in both definitions the organization faces the task of defining maintenance standard. This definition should be as clear, simple and flexible as possible for all workshops and units to understand and eventually meet.

It seems convenient to distinguish between maintenance and repairs, since repair is carried out as the consequence of imperfect components and construction or of an imbalance in the system to which the components belong. Craft repair in particular refers to very old, run-down vessels, and this is not the case in consideration.

As mentioned above there is a wide variety of causes for maintenance and repairs. Most failures are unpredictable, unless there is a very rigid system of control and monitoring. Control and monitoring systems are expensive and they are drawn according to the aims set for by the organization.

2.2 Purposes of maintenance

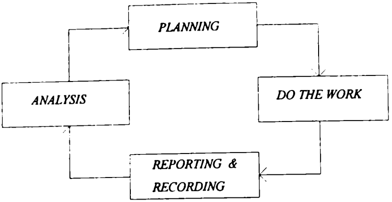
The purpose of maintenance is to control or reduce the rate of deterioration of the fleet or the system. When done properly maintenance enables an organization:

a. To maintain the levels of safety to fulfil the obligation in terms of seaworthiness of vessels.
b. To comply with the objectives of the organization. To preserve the invested and the economic life of assets (vessels, equipment, tools, installations, machinery).
c. To keep good levels of performance and availability of vessels equipment and machinery.
d. To maintain an optimum of preparedness to assure reliability, in case of emergencies. Such as the case for naval, marine and civil defence units.
e. To comply with international rules. The world community requires safer ships and cleaner oceans as stated in the IMO objectives.
f. To reduce technical costs. It requires a good maintenance system and good control of repair and maintenance costs.

2.3 The Maintenance Cycle

The basic steps in maintenance work are shown in Fig. 2.1

A. Analysis and Planning: due to high cost of maintenance work and the serious consequences of breakdowns, the emphasis nowadays is on analysis and planning, taking into account the operational constraints.



Source: IMO Model Course 2.01 Compendium

Fig. 2.1 Maintenance work

B. Reporting and recording: these make possible an analysis which may lead to improved planning and design in the future. It is important that the experience gained in maintenance work be systematically recorded in order to provide continuity in maintenance activities.

2.4 Maintenance Strategies

Maintenance can be classified and subjected to various control criteria. One of this criterion divides maintenance into planned and incidental, as in Fig. 2.2. Planned maintenance can be divided into:

i) Preventive maintenance is aimed at preventing failures or the development of failures, or discovering a failure at an early stage. It is carried out either in the form of periodic adjustments, reconditioning or replacements, or it is based on condition monitoring.

ii) Corrective maintenance is aimed at repairing failures that were expected, but were not prevented because they were not critical for safety or economy. This type of maintenance requires frequent assessment of costs and availability.

Preventive maintenance usually involves the periodic opening of machinery and equipment in order to decide if adjustments and replacements are required. The intervals for such inspections are normally based on operating time or calendar time.

2.4.1 Planned Maintenance

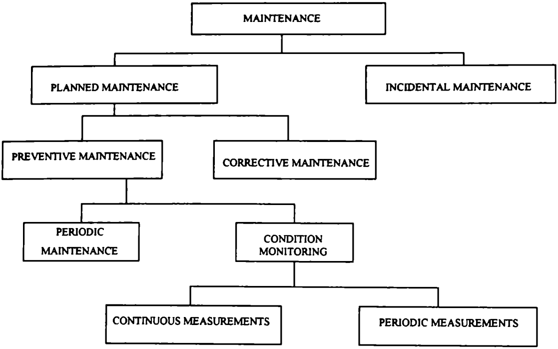
a. Definition

Shields (1975) defines planned maintenance as the work organized and executed with forethought, control and records which is the minimum necessary for the prevention of breakdown of equipment. It is aimed at the reduction of unscheduled repair work to maintain vessel's performance and availability for operations. A planned maintenance system will result in:

1. Reductions in total operating costs.
2. Increase the effectiveness of the work force of the organization, with consequent reductions in the amount of work carried out.
3. Likewise, spare gear costs would fall due to the reduction in compound failures, etc.

The introduction of a planned maintenance system is seen as a first step towards achieving the optimal maintenance policy. Some factors are essential in choosing a general policy for planned maintenance:

- Age of the vessels.
- The availability of spare parts.
- The variation of spare parts costs.
- Availability of shipyards facilities



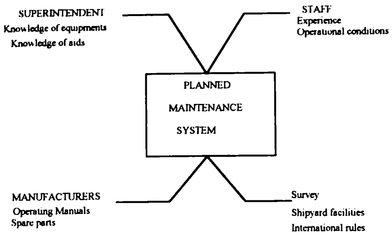
Source: IMO Compendium 1-4, Model Course 5.03

Fig. 2.2 Types of Maintenance

The planned maintenance system is essentially based on four functions as shown in Fig. 2.3.

2.5 Maintenance Policies 6/

It is important to note the interdependence between planned and incidental maintenance, and also the need to optimise technical costs against availability and reliability. Such optimization must also include the control of spare parts.



Source: Course material handouts. Without reference.

Fig. 2.3 Planned Maintenance Main Functions

Maintenance departments are faced with the problem of choosing between frequent inspections and maintenance made at periodic intervals. On the one hand frequent inspections reduce availability of vessels and or equipment and also increase the danger of erroneous reassemble. On the other hand less frequent inspections may lead to unacceptable incidents or breakdowns.

To solve this dilemma a general maintenance policy should be drawn. This has been based on accumulated experience and judgement.

2.5.1 Basic Policies of Maintenance

A description of maintenance policies follows indicating the strengths of each policy. General management has to choose among four basic policies:

P.1 A repair only policy
P.2 A Preventive maintenance policy

P.3 A basic maintenance policy which is improved using management service techniques.

P.4 An optimal maintenance policy.

The reason for choosing an optimal maintenance policy is quite simple. On the one hand the normal breakdown (P.1) and scheduled maintenance systems (P.2 and P.3) are based solely on subjective judgement which ensures that breakdowns are kept at an acceptable and apparently reasonable level. On the other, the optimal policy (P.4) is based on facts and guarantees that exactly the best balance between breakdown and scheduled maintenance is achieved. This strategy is overall cheapest to the organisation. 7/

2.5.1.1 P.1: A repair only policy or corrective maintenance

P.1.1 Breakdown Repair Policy

P.1.2 Breakdown Replacement Policy

Corrective maintenance is the maintenance carried out to restore an item which has created operating problems to meet an acceptable condition.

In this maintenance policy no preventive maintenance is carried out except essential lubrication and making a few re-adjustments. When a fault develops or a breakdown occurs then a repair (or replacement) is made. An analysis of this Strategy indicates: 8/

(i) Most equipment suffer a large number of break downs. Many of the breakdowns developed from minor initial faults but since no maintenance or inspections were carried out the minor faults were allowed to develop until they became serious and break-downs consequently occurred.

(ii) In a few cases the number of breakdowns would be small. This could be explained by the fact that preventive maintenance would be a waste of time and any preventive work or inspections made on the equipment would upset perfectly good settings. Since these machines obtained no preventive maintenance there was no opportunity to meddle with them and consequently few break downs occurred.

(iii) Since work is only performed on the equipment when breakdowns do occur and these occur apparently at random, then the demand for maintenance services will be peaked. If there are sufficient men to cope with the worst situation then there will be numerous periods when these men will be idle. If the opposite holds true there will be periods of excessive downtime.

Obviously some intermediate level of staffing is required to cover average situations. With this intermediate level of staffing there will not be excessive idle time although there will be times when there is insufficient staff to cope with the breakdowns and queuing for maintenance services occurs.

Costwise this is a very expensive method of working in that no account is taken of a timely remedy or repair. Staffing and/or downtime costs are very high.

2.5.1.2 P.2 : A Preventive Maintenance Strategy

P.2.1 Preventive Maintenance Strategy
P.2.2 Preventive Replacement Strategy

Preventive maintenance is the maintenance carried out at predetermined intervals, or to other prescribed criteria, and intended to reduce the likelihood of an item not meeting an acceptable condition. In general, preventive maintenance increases the profitability of an enterprise.

A preventive maintenance system must incorporate various kinds of planned activities: 9/

- Specifically designed service routines,

- Methods of checking the condition of each component, overhaul, adjust, renew or replaced parts and so on,
- The frequency with which it has to be done.

In this policy there is a programmed maintenance and inspection system to complement the repair system. Preventive maintenance is carried out in an attempt to cut down on the number of breakdowns which occur and the frequency of these breakdowns will be substantially reduced.

An analysis of this Strategy indicates: 10/

(i) Most machines will have fewer breakdowns compared to P 1. This is because many faults have been detected and inmediately corrected before they could result in break downs.
(ii) Few machines will actually suffer more break downs compared to P.2.1. Other machines will suffer the same number of breakdowns. As pointed out already, this is because in these machines preventive maintenance is able to catch only a few faults in the bud and the preventive maintenance work upsets the machine settings, which in turn results in more stoppages and breakdowns.
(iii) Although less time overall has been consumed in rectifying breakdown, a great deal of time has been spent in preventing other breakdowns. The breakdowns occur often without warning and a number of these will result in the vessel reducing speed or stopping engine.
Preventive work can be planned to coincide with idle times (craft in berth, having other repair carried out, etc.) so that the minimum down-time cost is incurred.

This seems a more intelligent policy than P.1 in that many faults are detected when they can be rectified cheaply, quickly and at a convenient point in time. However, since so many man-hours are spent (possibly more than P. 1) is the overall policy any cheaper? To answer this questions the cost of the two policy have to be considered.

2.5.1.3 P.3: An Improved Basic Maintenance Policy by using management services techniques 11/

Here there is a basic maintenance system (either policy P.1 or policy P.2) which is improved by using various management services techniques. A few of the many management services techniques available to improve the methods of planning, performing or controlling various tasks are:

(a) **Work Study Breakdown work** (and preventive maintenance if carried out) is performed more efficiently by doing the work in the most efficient way so that the time to perform each job is minimised.

(b) **Organization and Methods** (O & M) ensure that paperwork systems necessary to back up the physical work are performed more efficiently.

(c) **Budgetary Control** can be set to expenditures in various categories and control kept on actual expenditure in an attempt to keep this within the planned limits.

Management services techniques improve the methods of carrying out the various tasks. They alone do not solve, however, the main questions:

- Should the jobs be performed at all? That is, choosing between P. 1 or P. 2, and if the latter,
- How much preventive maintenance should be done?

2.5.1.4 P.4: The Optimal Maintenance Policy 12/

The concern with this policy is to resolve the basic problem of performing preventive maintenance, and how much? Once this problem is resolved then the various jobs to do may be performed most efficiently. The appropriate management services technique(s) can be used.

It is worth noting that the decision as to which management services techniques to use in any particular circumstances is not necessarily a simple one, but at least one requiring only a common sense analysis of the factors involved.

To resolve the main question of whether preventive maintenance should be done at all, and if so at what level, requires a mathematically oriented analysis and a deeper insight of the problems faced.

The optimal policy is the one with a specified amount of preventive maintenance which results in the minimum TOTAL cost plus downtime.

Ideally we would like to determine exactly what this level of preventive maintenance should be. The concept is quite straightforward but the determination of this level in practice can be quite complex. The main problem is one of data.

To determine the relationship between "cost" and "level of preventive maintenance" requires a large amount of field data. This may be obtained from a number of shipyards ad contractors.

2.6 Choosing the Optimal Maintenance Policy 13/

First it must be recognized that any optimum is always elusive. This is the reason for using Petersen definition of optimal maintenance. Optimum maintenance is one which minimises the total cost of operation of the maintenance activity and hence of the organization as a whole. Choosing an effective maintenance policy must be based on:

a. Rational deductions
b. Service efficiency and
c. Cost analysis

These three factors together induce certain types of maintenance application in preference to others, while giving proof of flexibility, and since each vessel differs in type of service, use and age.
The cost areas of a shipping organisation are made up broadly of:

(a) Loss of availability of vessel due to breakdown of equipment.
(b) Cost of repairs,
(c) Cost of spare gear and supplies.

The above cost areas, loss of availability of vessel due to breakdown seems to be the most significant. Hence a maintenance police which would reduce the number of breakdowns and hence idle time is desirable. In the case of naval units, the number of breakdowns decreases reliability of operations which results in turn in low grade of readiness. A policy, closer to the optimal one can be defined using a similar process.

The optimal maintenance policy requires a strategy and a planning effort in order to achieve the desired vessel reliability and the balance between breakdown and schedule maintenance.

2.6.1 Steps in the Implementation of the Optimal Policy

The optimal policy is implemented using a three step plan.

Step 1
A good practical maintenance system which may be implemented with the minimum of work. This system will be as near optimal as may be reasonable expected. The efficiency of the system will vary from vessel to vessel but can be expect to be within a percentage of the optimum.

Step 2
An integrated preventive maintenance system which ensures that the present maintenance programme is performed as efficiently as

possible. This includes accurate control of spare gear and use of management services techniques.

Closely linked with this integrated system is a data collection method which gathers the data necessary for the detailed analysis. This detailed analysis will in turn determine the optimal preventive maintenance level.

Step 3

A survey of standard scientific techniques which may be usefully applied to maintenance problems, and special techniques and methods of analysis which have been developed for the solution of marine maintenance problems. These techniques will help in two ways:

- To determine the optimal preventive maintenance level once the data collection programme has been completed;
- They may be applied to small sections of the total maintenance area when only a small amount of data is available. Hence they can be used to continuously improve the "good" maintenance system and the answers obtained by this sub-optimisation will be further improved when sufficient data becomes available.

CHAPTER 3

A MAINTENANCE SYSTEM FOR PATROL CRAFTS

3.1 Maintenance Subsystems

A complete maintenance system for patrol crafts should include the following sub-systems:

A. A preventive maintenance system.
B. Purchasing/stock control systems for essential maintenance.
C. Workshop and decentralised units files.
D. A document location system.
E. A maintenance planning and preparation system.
F. A work order system.
G. A technical and/or economic analysis system.

Experience has shown that to obtain an efficient maintenance procedure, it is vital to have the following components:

1. A flexible arrangement that takes into account ,
   a. The changing conditions of the components with time
   b. The influence of the environment on their operational life.
2. Easy implementation of the system.

3.2 General Description of the Maintenance System

Fig. 3.1 shows the interrelationship between subsystems of maintenance. The maintenance system is divided into two basic subsystems: A) preventive maintenance and B) corrective maintenance.

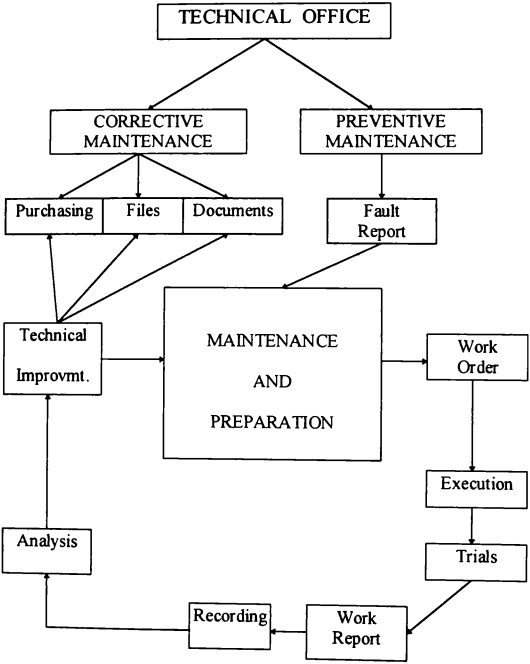


Fig. 3.1 Maintenance Sub-systems Interrelationships

The administration of preventive maintenance requires the application of a planned maintenance system (PM hereafter) to ensure that the correct work and condition checks are carried out at the right time by the right personnel in the right way. The PM system is intended to result in faults and fault trends being detected. The output are fault reports which are sent to the maintenance planning department.

The faults and fault trends detailed in the fault reports must be dealt with. Planning for corrective maintenance requires the existence of purchasing/stock control system, a plant and unit file and a system for documentation location.

The maintenance planning office also receives orders for maintenance work directly from vessels. The department co-ordinates the organization maintenance planning and the various maintenance workshops and units (mechanical, electrical, electronic, etc.)

Information must be rapidly accessible, if maintenance planning and preparation is to be efficient, making optimum use of every planned and unplanned stops to carry out maintenance work. It is necessary, for example, which spare parts are available, who can supply those not in stock, delivery times and so on, and such information is available from the stock control system.

It is also necessary to know the up-to-date situation concerning special tools, safety requirements, parts incorporated in equipment, etc. This information is obtained from the plant and units files.

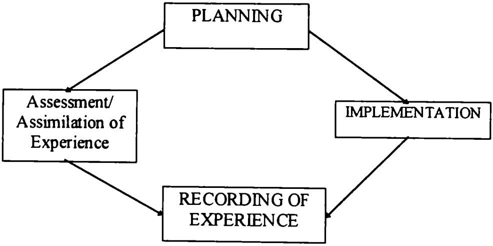
Preparation of drawings, instructions and other documentation is simplified if there is a system for document location.

Maintenance planning produces work orders, which are written instructions containing the information that maintenance personnel need for their work. On completion of the work, the work order should be complemented by a work report.

Experience from the work report is extracted and recorded for subsequent analysis in a technical and/or economic analysis system. A list can be prepared showing information such as which equipment have had the greatest number of faults, the highest maintenance costs, etc. This technical/economic analysis is also used in current planning and preparation work to improve future maintenance.

3.3 A Manual Maintenance Planning and Follow-up System

Rational maintenance requires some form of organised system for planning and following up work. The system described here is based on the principle shown in Fig. 3.2.



Source: From course handouts.

Figure 3.2 Principle of a Manual Maintenance System

The main documentation of the system consists of a card file containing a maintenance card for each machine or part of a machine maintained. The card should contain the following information:

(1) The name of the machine or part maintained.
(2) The identification number of the machine or part.
(3) Recommended maintenance work.

(4) Numbers of the work descriptions concerned with the recommen-ded measures, and
(5) Recommended intervals for each measure.

The back of the cards are used for recording various information about each item and can therefore be regarded as constituting a machine file.

3.4 Planned Maintenance System

As noted earlier the main purpose of a planned maintenance system is to provide a tool for better management and increased safety for both personnel and equipment.

The elements required in any plan maintenance system are:

1. Determination of items to be maintained.
2. Determination of frequency of carrying out particular maintenance jobs.
3. Determination of the jobs to be carried out on particular patrol craft.
4. Issue the work programme.

The following check list is suggested, before the work programme can be developed and/or implemented.

1. Items of machinery or structure to be maintained.
   a. Is it worth maintained? and
   b. Penalty for not maintaining?
2. Maintenance to be carried out.

The assessment should be carried out based upon operating experience and makers recommendations. Tasks to be carried out:

(1) Inspection .... visual examination
(2) Minor overhaul .... partial strip down of machinery item.
(3) Major overhaul .... full strip down of machinery item
(4) Survey .... full strip down of machinery item then examination by surveyor.

3. How often should maintenance be carried out.

Since one of the aims of a planned maintenance system is to produce organised work schedules, these should be drawn up using calendar time intervals, rather than running hours. Frequency of overhaul data should be generated in calendar times.

Before the determination of times between successive maintenance operations the following should be considered:

(1) Inspection or survey cycle maximum length.
(2) Relationship between calendar time and running time.
(3) Number and magnitude ofj obs in individual maintenance schedules.
(4) Number of units
(5) Time interval required for the control function.

Having answered the above check list the total planned schedule can be drawn up in Fig. 3.3.

Boat				**Type**				**1**	**9**	**9**	**4**					
No.	**T**	**L**	**Unit**	**Maint.**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**

Fig. 3.3 Example of planned maintenance for one year

3.5 Maintenance Planning and Control System

There are many maintenance systems in the market, but the most modern being used more frequently by shipping companies, regardless of their size, is the TSAR system (hour registration, systematic maintenance, filing and spare system). This is the model system chosen by IMO for its module courses around the world. It seems appropriate to summarise the system and try to determine its applicability to the Saudi Coast Guard.

3.5.1 Objectives of the TSAR System

1. To make possible regular vessel operation and increase safety for both personnel and equipment.
2. To help vessel's officers plan and manage better, thus improving vessel performance, and to be of help in meeting the objectives set by the organisation.
3. To highlight those items of work which are most expensive in terms of time and materials, so that they may be critically examined and improvements made in the method in order to reduce the cost.
4. To make it possible to carry out work in a systematic manner and without overlooking items, and to do the work in the most economical way.
5. To provide continuity so that when crew changes officers are aware of what has been done and what remains to be done.
6. To provide information which may be used for training, and to enable people to carry out more responsible tasks.
7. To afford flexibility so that it may be adapted to different ships with different organisation and crew.
8. To provide feedback of reliable information to head office for improvement in the supporting services, vessel design, etc.

3.5.2 The following are the major functions affected by the system:

a. Filing (drawing, instruction material, etc.)
b. Labelling (spare parts, etc.)
c. Work load (estimation, registration)
d. Maintenance and repair (specification, scheduling).

The main concern in this dissertation is with maintenance and repair so the emphasis will be placed in this aspect of the system.

Most organisations apply the SFI Group System as a technical account number system for the budgeting and accounting of vessel operational costs. Instructions as to what to do in maintenance and repair work can be coded to the same system.

The fact that the SFI Group System is used by shipyards, shipping companies, suppliers and consultants simplifies the establishment of routines for maintenance repairs and the management of spare parts. A general classification code will make it possible to have all the basic maintenance information - specification, drawing, instruction material and list of spare parts - coded by the yard or by sub-contractors, according to the owner's maintenance system's code. Thus recording or the use of convention lists can be avoided, reducing the work and the frequency of error.

Equally, repair specifications and objectives can be classified in accordance with the standard group system. If the yard and the owner use the same system, many possibilities of error and misunderstandings can be avoided. Re-coding will be eliminated and time will be saved.

3.5.3 Requirements of the Maintenance Planning System

The maintenance planning system should fulfil the following requirements:

A. Minimum requirements:

(i) Technical information
(ii) Maintenance history
(iii) Overall view
(iv) Work planning facilities

B. Additional requirements:

(v) Flexible planning
(vi) Incorporation of al types of maintenance work

(vii) Adjustability to other systems

C. Practical requirements:

(viii) Simple recording

(ix) Suitable filing

Such a system may be manually operated or data-based, if the complexity of the information and the communication between decision-makers so demand.

3.5.3.1 Technical information

All relevant technical information and registration for each unit of equipment requiring maintenance may be contained in a maintenance book. The book is edited according to the classification code system and contain forms with information on makers, type, serial number, capacity, etc., as is required for identification of the unit. The forms also give a listing of the various types of maintenance job, with estimated intervals and references to instruction materials.

Technical information can be contained in a programmed book. In this case all components are listed together with a group for identification. Each item has a brief description of maintenance and a maintenance description number which refers to the maintenance record book where a more detailed account of the work required will be listed. As shown in Fig. 3.4. The program book will also include intervals for maintenance and a date and follow-up scheme.

3.5.3.2 Instruction material

Instruction materials from manufacturers and yard are filed systematically according to the classification code system for easy retrieval. References are made to the relevant parts of the material. Descriptions of the spare parts and tools to be used for the various maintenance jobs should be part of this material.

Description of unit	Code No.
Manufacture, Type, Specifications, No.	

Job No.	Description of work	Ref. Instr.	Month Interval	No. of men	Man-hrs.

Source: Adapted from Model Course 5,03

Fig. 3.4 Technical Information Form

3.5.3.3 Scheduling facilities

Scheduling facilities will vary with type of maintenance system. Some systems will contain maintenance books, job cards and planning boards.

For each job specified in the maintenance book a job card is made and displayed in a rack system mounted on a bulkhead. The number of job cards used ranges from 400 to 800, depending on vessel complexity.

The job cards should have different colours to signify the type of work, responsibility, priority, work to be done in harbour, classification, certification, etc.

The rack system or planning board is arranged as a calendar, thus providing a very flexible facility for both short-range and long-range planning jobs. The rack system can also accommodate jobs which are necessitated due to failures or discoveries of imminent failures. A special display board is arranged for scheduling of jobs which depend on machinery running hours.

Other manual systems will contain maintenance descriptions cards. Every component in the system has a card with a maintenance description and frequency for overhaul and examination.

The planning of the maintenance is carried into effective operation on the special planning cards which are kept in a case divided into sections of two by twelve months, plus two years. When the system starts, the Chief Engineer must work out the cards, using the programme book to obtain the intervals between overhauls.

3.5.3.4 Maintenance records

Maintenance records are normally kept on the form in the maintenance book, Thus, every unit form carries the maintenance history of the unit. Only exceptional situations are described, otherwise just the job number and date are entered. The amount of reporting from the vessel varies according to the organisation policy. Fig. 3.5.

Code No.		Boat No. ______ Equipment:		
MAINTENANCE RECORD				
Date	Men	Man-hrs	Job	Cause Comments/descrip.

Source: Adapted from Compendium 2,01

Figure 3.5 Maintenance Record

3.5.3.5 Feedback information

The aim of the reporting procedure may be stated as:

1. to provide operation and control data for the office;
2. to provide information to vessel staff of the past maintenance

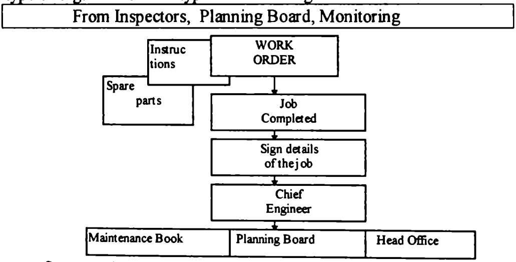
history of particular pieces of equipment; and
3. to provide a means of continuously updating maintenance schedules in the light of experience.

In designing the reporting procedure to meet these aims, it should be remembered that the weakest link in the maintenance control chain is the method by which information is transferred. It is essential that the design of the paper work should make for easy handling, yet be comprehensive in its coverage.

The form has columns for the name of the vessel, the month and the year. There is also space for the code number, job number and day and a description of the cause, the damage, the exchange parts, etc.

3.5.3.6 Cycle of operations

The operation of the system depends on the policy of the company. The maintenance philosophy in a company owning small coasters will be different from that of the owners of tankers sailing all over the world. The total management system must therefore be adjusted to the type of organization and type of vessel. Fig. 3.6.



Source: Adapted from IMO Compendium 3,5

Fig. 3.6 Cycle of Operations

The Work order is shown in Fig. 3.7.

WORK ORDER

No________ Date:______

Workshop:	Boat Type No.	Unit:

	Repair	Starting	Finish	No.	
No.	Requirement	Date	Date	Hours	Remarks

Chief Engineer:_____________ Copy to
Boat file
Technical Office

Fig. 3.7 Example of a Work Order

3.6 A Computerised Preventive Maintenance Systems

The decision to computerise a maintenance control system should not be taken lightly. A good manually operated system gives more useful results than a poorly developed computer system.

If a PM system is to operate smoothly, the information stored in the system must be up to date and must reflect the true situation. This means that the system must be such that it can always accommodate new methods, changed intervals, changes to equipment and so on. A system which can not adapt will soon become out of date, and personnel will have no motivation to operate it.

If the system can be quickly and properly updated, personnel concerned soon realise that they can exercise a considerable influence on it, and thereby their own work situation. The system comes to be regarded as an excellent working aid.

A good PM system should provide:
(1) Simple updating.
(2) Flexibility (it should accommodate the requirements of the various technicians, electricians, mechanics, etc.)
(3) Minimum administration.

These requirements can often be fulfilled using a computerised system. It is not the size of workshops that determines whether a PM system should be computerised or manual, but rather the quantity of changes that are expected.

3.6.1 Main benefits of the computerised system

1. Storage and access to information can be achieved very easily.
2. Extensive analysis of functional performances and condition control can be made.
3. Updating of maintenance programme and printing of requisitions can be carried out automatically.
4. Computerised systems can be extended readily to include other areas of maintenance control, i.e. spare parts, budgetary control, comparisons, etc.

Computer-based systems can be used for more complex installations, fleets of boats with computerised management, or when several parties are involved in control or in decision-making.

In connection with maintenance planning, a computer system should handle the following items:

1. Manpower analysis.
2. Maintenance costs.
3. Prediction of consumption of spare parts.
4. Identification of component with expensive maintenance.
5. Failure statistics.

6. Reports of maintenance jobs.
7. Short-term and long-term work, scheduling, and
8. Internal control according to authorities' requirements.

At the start of a planning period, a job programme is printed. This is the basis for manual ranking and scheduling of the work. Here the manpower and time available for maintenance work are the crucial factors. For each job a job sheet in two parts is printed. The top part has a detailed description of the work, a list of relevant spare parts and references to drawings and instruction manuals; the bottom part consists of a simple report form to be filled in by the repair man when the work is completed. Once a day, or when it is convenient, the information from all the forms of that particular day is entered into the computer.

The computer system can distinguish between four different types of work: jobs triggered by running hours, periodic jobs at fixed intervals, periodic jobs with due dates determined by the calendar, and unpredictable jobs. It is also possible to distinguish between different job types or locations, such as deck, machinery, electronics.

As mentioned above, it has been found very convenient to use computers for a fleet of boats for easy administration and retrieval of data related to maintenance planning. By use of modern telecommunication systems via satellite, a two way communication will be installed both in the head office and on board each of the selected ships. Both preventive maintenance and spare parts control systems can be included in a shore system.

CHAPTER 4

INVENTORIES AND SPARE PARTS POLICY

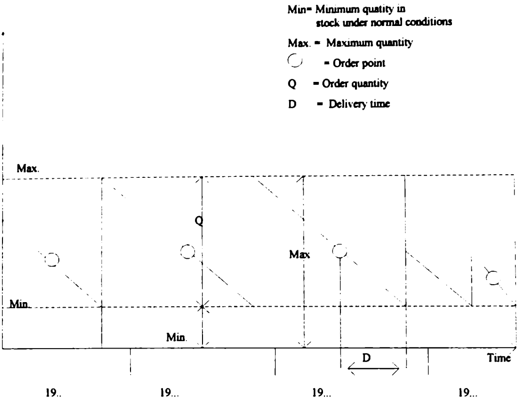
The holding of spare parts in stock is an important sub-system of the maintenance system. The non-operational time of a patrol craft can be reduced if there is suitable stock of spare parts, so it has to be possible to obtain them promptly from stock at the workshops, from a central stock or from suppliers.

It is a good policy of the organization to keep track of their requirements, because spare parts bind capital, require space and demand administration. A well defined spare parts system should enable the spare parts stock to be controlled, and since it takes a great deal of effort to set up and operate such a system it must be simple.

To take care of spare parts, it is necessary to use a system. This system must contain information regarding handling and quantity of spares in stock, location of parts, minimum and maximum stock, delivery time, ordering particulars and record of orders. The spare parts system must be also arranged and labelled according to the SFI Group System, the classification code consider in this dissertation.

A large maintenance department needs a more precise monitoring of stocks. It is necessary to strike a balance between holding excessive stocks, and so tying up capital unnecessarily, and being without vital parts when they are needed.

Fig. 4.1 shows the relationship between spare parts consumption, the order point, delivery time, and changes in quantity.



Source: IMO, Model Course 5.03 Compendia 1-4

Figure 4.1 Stock Control

The order point is that point in time when a spare part has to be ordered so as to avoid falling below the limit for minimum quantity.

4.1 Determination of Stock Levels

The correct level of spares is a function of:

1. Number of vessels
2. Vessel age.
3. Operation hours.
4. Crew competence.
5. Availability.

A spare parts system enables control to be exercised over:

1. which parts must be kept in stock to avoid shut down time,
2. what are the technical requirements,
3. what is the level of consumption,
4. what is the delivery time of parts.

The amount of spare parts in stock depends on:

1. Demand generated by the maintenance workshops. This demand for spare parts arise either:
   a. through failure of equipment, (because of bad design, bad operation of the equipment, bad maintenance, age of the equipment, etc., giving rise to replacement) or
   b. through frequent maintenance of the equipment requiring replacement (the setting of wrong levels of maintenance due to lack of knowledge on the operating characteristics of the equipment or how it functions).

The stock levels is determined considering the following:

(1) Demand or number of times maintenance is carried out.
(2) Availability of stock
   a. Time taken by the manufacturers to deliver the component
   b. The service pattern of the vessel.
(3) Expected life of the component, the shorter the life expectancy the higher the stock.
(4) Expected life of the vessel in the organisation

Any excess amount of spares means capital tied up while too low a stock could cause delay and produces shut-downs.

It is convenient to classify levels of spares in two categories:

(1) Stock in transit: which are those parts for the date of overhaul,
(2) Guarantee stock: a protection against unpredictable wear.

4.2 Control of inventories or stocks

Although it is not the intention of the present dissertation to describe in full any spare parts system, it is important to note some of the advantages of such systems in order to increase efficiency.

There are many systems available for administering spare parts. The important point is that whichever the system this should be used with accuracy and persistence in order to prevent both lack of spares or excessive stock expenses.

In many situations it is found convenient to have separate stores located in different departments to provide maintenance parts and equipment to maintenance departments. This arrangement has particular advantages, when properly done. Reducing time to obtain spare parts and also providing a specialist service, in the form of keeping records and accounting.

It is argued, especially by maintenance personnel, that it requires technical knowledge of parts themselves in order to provide a good supply service. This problem can be avoided by training supply personnel on a proper system of supply and stores-control as well as in inventory and accounting techniques.

4.3 General Requirements of a Spare Parts System

A spare parts system in order to result in better management and increase efficiency should contain information regarding: spare parts in stock, store room, spare parts order/reconditioned, order data, vendor specification, and vendors.

A spare parts store should give a good overall view and be easy to operate.

Most of the time the problem mentioned above arises when stores become so complex that personnel can no longer keep track of stocks. In this way all advantages are lost and the whole system comes to a halt. However, this needs not be necessarily so. Computerised techniques are readily available and could help to overcome this situation.

Stock control should be based on analysis of the different groups of spares discriminated by value and their usage due to the impossibility to have a 100 percent control of all the spare parts on board, at the office or purchased during the year.

E. A. Cameron (1989) suggests to classify stocks according to a Pareto curve. This technique helps to identify the areas of greatest cost and so determine where the greatest emphasis should be placed. By so doing the following categories can be identified:

Category A. In this category of stocks should be included all those items with high value (spares exceeding x amount of $), and low level of inventory. (Example: main engine cylinders, pumps, etc.).
Category B. This category should include items which require periodic renewal (Items costing in excess of x $).
Category C. Items frequently used and requiring high levels of stock (Items costing less than x $), sealing rings, gaskets, etc.

4.4 Manual Vs Computerised Spare Parts System

4.4.1 Manual Spare Parts System

In a decentralised manual system, the chief engineer manages transactions, both purchasing and receiving, and documents these through the use of an order file and a spare parts control file. Other staff may or may not be informed of transactions.

Most manual spare parts systems available in the market contain the same information about spare parts identification, storing, supplier, etc. Some systems are based on the collection of information

- using folders, and in other systems the information is store
- using cabinets.

4.4.2 System Advantages

- Simple, proper working method for purchasing and for monitoring the purchasing and usage of parts.
- Effective method of keeping records for future use. Offers workshop personnel easy access to the location of spare parts.
- Provides usage data for future computer-aided system implementation.
- Provides readily available information on file of vendors and required lead time for ordering of spare parts.
- Provides information about possible excessive usage of items by any one vessel in particular or by the entire fleet.

4.5 Spare Parts Manual Ordering System

Spares are very seldom ordered directly from the vendor. Normally, superintendents review the purchase order, and approves or rejects the order. After approval, the purchase order is sent to the vendor.

Workshops can order spare parts in different ways. A possible order procedure may be that of a requisition to the supply department. This is filled out on the workshops in four copies:

- original to vendor,
- copy to General Management,
- workshop copy placed temporarily in "on order" file; after receiving spares, this copy is sent to the purchasing department.

When spare parts are used and reach the order-point level in connection with repair or maintenance action, a spare part requisition/purchase order is prepared. The equipment code number and spare part number are obtained from the spare parts system. Both the number of parts used and the quantity as replacement are entered.

The purchase orders have to be filled with continuous order numbers. In addition to vendors in a warehouse. When the relevant vessel is in position, the goods can be transported collectively.

Consumables can be ordered in the same way as the spares, or a more suitable system- for the ordering of paint, provisions, etc. may be used.

4.6 Computerisation of Spare Parts System

For complex installations, fleets with centralized management or when several parties are involved in control or decision-making, it has been found convenient to use computers for easy administration and retrieval of data for spares, Fig. 4.2.

Computers can be used either on workshops or in the administration or in both places, depending on the communications facilities.

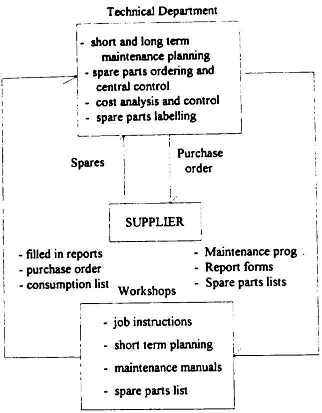
Introducing a computer should be as a result of an evaluation of overall ship operation policy. A manual system may be most suitable for one workshop, whereas a computer system in the office may be most suitable for another.

4.6.1 Advantages of a Computerized Spare Parts System

A shore-based computer-aided spare parts system is suitable for a shore management who must manage several ships and must have immediate update information regarding spare parts status.

- easy access to all technical information regarding spares;
- cost control of spares
  - consumption data for a particular part, etc.
  - labelling of spares;
  - automatic spare parts ordering system; and
  - prediction of consumption of spare parts.

A computerized spare parts system should contain a complete listing of all machinery and spare gear on board vessels, together with full re-ordering information, including approved minimum and maximum levels. This provides an automatic re-ordering capability as minimum stock levels are reached. A suitable computer system should also be integrated with the maintenance planning system such that documentation can be utilised.



Source: Own elaboration based on IMO Compendium 2.01

Fig. 4.2 A Computerised planning System for Patrol Crafts.

This system should perform all functions related to spare parts support. These functions include spare data for the entire fleet, spare parts ordering, and control of the transfer, receipt and issue of parts. Computer print out reports provide information about quantity on-hand, on-order data for vessel and warehouse, plus information on usage and costs.

In this case the central computer must hold spare parts and maintenance data for the entire fleet. As far as spare parts management is concerned, a central store may be used to hold parts for all ships. Each ship may then be regarded as having a local store. The first character in the spare part number may be used to indicate which vessel a part belongs to. Thus, parts beginning with A are for vessel ship type A or a specific vessel, spare parts beginning with B are for vessel type B, etc.

The number for parts in the central store may beginning with O. In this way it is easy to find out what parts have been sent to a workshop, to a vessel during some time period and to take out various stock report and tools for each vessel. The account number structure has to be recorded for each vessel.

4.6.2 Information to the Patrol Craft

Periodically, stock lists should be printed out for each vessel and let them be available to commanders. Printing of paper labels can also be done through the system. Each time spare parts are taken out from the central store and sent to a workshop, paper labels may be printed, one for each part. The labels should be attached to the respective spare parts and sent to the workshop together with a list.

Periodically, a job programme (job list) for some future time period should be sent to the workshop. For each job in the list a job sheet consisting of two parts may be used. The upper part may contain a description of the job, estimated man-hours, reference to instruction books and drawings, the qualifications required for doing the job, and a list of parts which may be required. The lower part may contain a simple report form, with entries for description of work, actual man-hours, spare parts used and the initials of the person responsible.

CHAPTER 5

REPAIR METHODS

5.1 Determining the Reason for Failure

It is of great importance to determine the reason(s) for the failure of the particular part once it is identified. The reason, in most of the cases can be any one (or more) of the following:

- Improper preventive maintenance
- Incorrect intervals of preventive maintenance
- Previous repair faulty
- The selection of equipment not proper
- Incorrect design
- Bad reputed manufacturer
- Negligence or mistake by operator.

One should not lack interest in the reason for failure. The biggest error is to avoid identifying the cause of damage or failure. For maintenance improvement, one must learn the reason for the malfunction, breakdown or failure of particular part of machinery or whole system. Foremen and the maintenance analyst must be indoctrinated in being inquisitive about the reason for failure on all breakdowns they are involved in.

Maintenance analysis and optimization functions should be directed towards achieving one of the levels as shown in Table 5.1.

Item	Cause of Failure	Corrective Action
1.	Faulty design	Redesign
2.	Faulty manufacture	Warranty action
3.	Incorrect equipment	Modify equipment
	selection	Replace equipment
4.	Incorrect operating	Correct operating
	practices	errors
5.	Faulty breakdown	Train maintenance
	Repair work	craftsman.

Table 5.1 Causes of failures.

It is a fact that the solution to the majority of repetitive failures is automatically found when the reason for failure is discovered.

For example if the fuel valve pipe of a diesel engine is failing very frequently, the following questions might be asked.

a) What was the injecting pressure ?
b) What was the design pressure ?
c) What were the pipe fitting specifications ?
d) Were incorrect pipe and fitting used ?
e) Were they assembled properly ?
f) Did the pipe failed from overpressure or old age ?
g) Is the pipe subjected to excessive vibration ?
h) Who fixed the pipe and when?
i) Was the proper fuel used?

These are some of the questions that might be asked. The answer to these questions should lead to the reason for failure.

5.2. Determining Correction Action

As it is stated in above section, the majority of solutions to highly repetitive problems are found automatically the same time the reason for failure is determined. To demonstrate this, a few actual examples are given.

Problem 1

Frequent fuel oil pipe failure

Cause

Pipe subjected to overpressure due to faulty operation of fuel pump.

Solution

Repair fuel pump. Adjust spring tension of the fuel pump.

Problem 2

Frequent pump stoppages.

Cause

Fuses blowing in control circuit. Fuse was of incorrect size and type.

Solution

Install correct size and type of fuse.

Problem 3

Frequent hydraulic hose failure on heavy equipment.

Cause

Foreman has substituted 2-ply plain hose with manually installed fittings instead of original design which was 5-play armoured hose with machine swedged fittings because new hose was easier and simpler to install.

Solution

Purchase swedging machine. Use specified hose and fittings. Examine the foreman's expertise.

The solution to some problems may be above the skill or responsibility level of maintenance foreman either because of technical complexity, large purchasing amounts required for the fix or because of the need

for a process modification. These problems should be handled by the maintenance or engineering staff as directed by the maintenance manager. In some cases, the problem may not be
solvable by the company's staff. If the consequences of the repetitive failure are serious enough by reason of cost and lost production, consideration may be given to the use of outside consultants.

There are several pitfalls that the analyst must guard against in his problem solving function.

1. The tendency of many analysts to leave interest if their solution is turned down. When an idea is turned down, the following questions must be asked:
- Was it turned down for cost or lack of funds?
- Was it turned down because the responsible person didn't think it would work?
- Can it be done cheaper?
- Can it be done differently?
- Can the scope of the solution be reduced to save cost?
- Was the savings justification adequate?

2. The tendency of some analysts to show no interest if the fault lies outside of their department, i.e., operational abuse, incorrect equipment, problem is electrical, or a training or personnel problem.

Analysts must be prepared to cross organisational or functional lines when necessary to solve a problem.

5.3. Preventive Maintenance

A machinery maintenance programme which schedules repairs and/or replacements to avoid failures is preventive maintenance programme. A preventive maintenance programme may be based upon monitoring of signs of deterioration or upon a schedule based or running time.

The determination of which equipment items should be included in the preventive maintenance program and the degree of preventive maintenance is part of the maintenance optimisation program.

All members of a task force charged with designing and implementing a new preventive maintenance program should be aware of the following facts:

- All effort expended on designing a new preventive maintenance program is an expense subtracting from profit.

- Preventive maintenance tasks will increase maintenance costs when first initiated, until the beneficial effect of the preventive maintenance task has time to take effect.

- A preventive maintenance task may permanently increase costs, if the author of the task doesn't know enough about maintenance. (This point is made because some organizations assign the function to unknowledgeable or clerical personnel under the mistaken theory that all they have to do is copy the instruction from the manufacturers maintenance manuals).

- Finally, at the start of the preventive maintenance programme, people must be selected to both design and implement the programme. Normally these people already have jobs and there may be pressure, in some cases, to assign the least competent personnel available. This tendency must be vigorously combated, particularly in the case of people assigned to design the system, who should be the most competent people in the organization.

With these points in mind, management should proceed as follows:

- Assign the most competent people to design the system.
- Start with the most critical equipment (determined from a computer printout by criticality code), and schedule, the instruction writing and implementation tasks in accordance with the manpower

available, incrementally, so as not to overtax the available manpower.
- The implementation rate should be designed to give time for the preventive maintenance instruction to reap its benefit in reduced labour, material and production loss costs.

Ideally, the preventive maintenance task labour added should equal the savings from previously installed preventive maintenance. In this manner, the only additional effort required is for the first small group of preventive maintenance tasks implemented. In other words, preventive maintenance labour is substituted for breakdown maintenance labour on an incremental and equal basis. By the time the entire preventive maintenance is implemented, a net savings in total maintenance cost should be realized.

Optimization of the preventive maintenance instruction is covered in detail in Chap. 2. The following paragraphs give examples of the different choices available when making the decision on the degree of thoroughness varying from zero preventive maintenance to a preventive maintenance programme that is designed for zero failures.

5.3.1 Minor Preventive Maintenance

Many maintenance experts advocate use of this system exclusively which consists of:
- Necessary lubrication of the equipment or part.
- Preventive maintenance inspection, adjustments and repair limited to a maximum time per machine of say, ten minutes. Anything over this time will be reported to the foreman and be covered by a special work order.

The number of trouble calls and reports of problems during the inspection serve as an indicator of the adequacy of preventive maintenance instruction.

5.3.2 Major Preventive Maintenance

This system is normally used on critical equipment and includes in addition to the items listed in Minor Preventive Maintenance, periodic parts replacements and periodic overhauls.

5.4 Corrective Maintenance

Corrective maintenance covers all maintenance which is carried out in order to correct or repair a fault in equipment. It may either be carried out as a unplanned event as a response to observations during condition monitoring. In everyday language, such maintenance is generally referred to simply as "repair work": the abbreviation CM is also used.

The maintenance system is divided into two main branches: preventive maintenance, and Corrective Maintenance as described in Fig. 2.2. All maintenance performed with the object of rectifying faults after they have occurred. Corrective maintenance can be sub-divided, according to priority, as follows:

i) Emergency work - high priority, off-line (less than 24 hours notice).
ii) Deferred work - lower-order priority, off-line.
iii) Removed-item work - reconditioning (further divided into major and minor items).

Corrective maintenance arises not only when an item fails but also when indicated by condition monitoring. The first task is to establish the most economic method of restoring the failed unit/plant to an acceptable state.

Only after the maintenance causing event the influencing factors (cause of failure, cost of replacement or repair, availability of resources, cost of unavailability), can be assessed (Fig.5.2) and the type of repair determined. This is a particularly difficult task when the failure has occurred as a result of an operate-to-failure policy and results in an engine or plant shutdown.

Some failures of parts do not stop the whole plant immediately and allow time for decision making. Once such work is identified (sometimes called "deferred jobs") it can be scheduled for the most suitable time.

Accepting that corrective work occurs, it is essential to plan for it. This means deciding on the type of corrective maintenance actions (and resources) needed.

Clearly, corrective maintenance via replacement of complex items, in the light of the predetermined guidelines, will be reserved for critical units since item holding costs are high. A critical item in this context is one which (when adopting an operation-to-failure policy) might fail with little warning and where the unavailability costs are high.

5.5. Drydock Planning

To enable a specification to be compiled, the following information is required:

i) A comprehensive list of Routine Items of equipment and structure requiring Survey.
ii) A comprehensive list of Work Items necessary to maintain Mandatory Certificates.
iii) Items of equipment on which Planned or preventive maintenance or inspection is considered essential or desirable.
iv) Work requirements to rectify damages and special repairs.
v) Capital expenditure items, Owner's policy requirements, international legislation.
(vi) Defect reports from the boat.

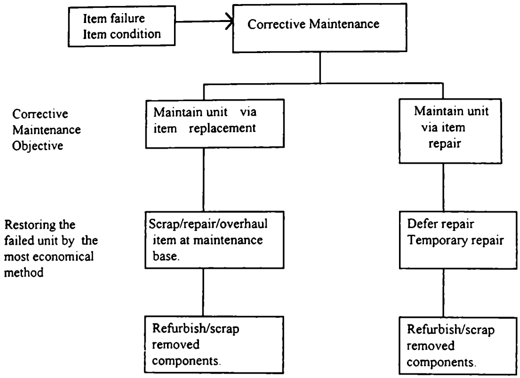


Figure 5.2 Alternative corrective maintenance actions for a complex replaceable item.

Preparation of a Repair Specification should be an "on-going" exercise and it should be started soon after completion of the previous dry-docking, i.e. a continuous running record should be available.

This will help to prevent unnecessary work finding its way into Dry Docking lists, and at the same time make more use of riding squads and the engineers.

1. The dry-docking of the ship and associated routine work (excluding repairs)
   - 1.1 Hull Cleaning
   - 1.2 Painting
   - 1.3 Anode Renewal
   - 1.4 Gratings
   - 1.5 Sea Chests
   - 1.6 Suctions and Discharges
2. Hull Steelworks
   - 2.1 Shell Plating
   - 2.2 Rudders, etc.
3. Hull Internal - Deck Repairs
   - 3.1 Accommodation
   - 3.2 Store Rooms, etc.
4. Deck Machinery
5. Tanks
   - 5.1 Opening
   - 5.2 Cleaning
   - 5.3 Coating, etc.
6. Main Engines
   - 6.1 Shafting
   - 6.2 Propellers
   - 6.3 Thrusters
7. Boilers
8. Auxiliary Machinery
9. Domestic Machinery
10. Systems
    - 10.1 Pipework
    - 10.2 Associated Valves
11. Electrical
    - 11.1 Generators
12. Navigational/Communication Equipment
    - 12.1 Radio
    - 12.2 Radar, chargers and generators.
13. Damages
    - 13.1 Collision
    - 13.2 Heavy Weather, etc.
14. Capital Account Repairs
    - 14.1 Owner's Policy
    - 14.2 International Legislation, etc.

Most existing reporting systems require boat's officers to submit periodical reports of repair requirements and associated spare gear requirements. Frequency of reporting varies, depending on the boat's employment.

It is suggested that all Repair Requirements should be submitted initially in writing to the Chief Engineer's department. Low priority items and/or those which can be done by ship's staff will be included in the programme of shipboard maintenance as the discretion of the Chief Engineer.

High priority items should be similarly extracted. If assisted voyage repairs are necessary immediate notification to management and implementation under normal company practice should be unchanged.

A standard "Repair Requirement" Reporting Form such as shown in Fig. 5.3, is recommended for facilitating work. Any suggested repair can be written on this form. It is of little value to know of a defect if it is not accurately specified so that Work Content and Time can be estimated.

The following minimum information is required if a defect is to be properly specified:

The Defect:
- What is it ?
- equipment concerned
- detail of sub-assembly or component
- documentation reference
- Where is it ?
- location on board by compartment or location reference
- What is wrong ?
- precise details of defect
- What is required to rectify ?
- repair by replacement
- renewal
- shop repair required, etc.
- Supporting Information:

5.6 Carrying-Out Maintenance Work

The aim of a Maintenance Department should be to provide an efficient service in order to achieve as high a plant availability as possible at the cheapest cost.

To achieve the above, periodic servicing must take place and normally falls under the following items:

(1) Planned Maintenance - Major repairs, overhaul calibration (planned factor).

(2) Preventive Maintenance - Necessary servicing of plant or equipment to prevent failure (corrective factor).

(3) Emergency Maintenance - Repair or rectification as soon as possible depending on failure.

If high equipment availability is to be achieved, maintenance work should be accomplished while the equipment is in operation. Units should only be shut down to rectify a particular defect if that defect affects the safety of personnel or equipment or leads inevitably to loss of availability. First aid or emergency maintenance measures should be put into operation whenever possible to keep the equipment running. Defects requiring a unit outage but not causing embarrassment should be left until a sufficient number have occurred and the plant then taken off load at a suitable production time. Work-shops efficiency is also a major object of the Maintenance Department and it is the duty of the Chief of Maintenance to keep a close contact with the Planning and Operational Departments in observing trends in worships performance. On the basis of these observations, maintenance should be arranged on workshops falling short of its rated efficiency so that the cost of operation and maintenance is minimized.

Repair Requirement Form	
	Repair Spec. Code _______
Ref. No. ____	Date _______
Unit: ____	Boat No. _____
Boat Name: __________ Type ________	
Equipment: __________	
Failure description ________________________________	
____	
____	
Location ________________________________	
Material Requirement ________________________	
____	
____	
Cause of Failure: ___________________________	
____	
____	
Comments: ________________________________	
____	

Source: Own elaboration

Fig. 5.3 Repair Requirement Form

A close watch must also be kept for faults which are inherent in the design on any equipment. These are generally known as type faults. They should be carefully studied so that modifications may be introduced until satisfactory solutions are reached.

CHAPTER 6

REPAIR RECORDS

6.1 Work Order System

The Work Order Form is the document used to record equipment maintenance tasks, and provides the most important source of information for maintenance analysis, and the writing of preventive maintenance instructions. In order to show how the work order is used as a maintenance record, this chapter describes a specific work order form. Each organisation has its own particular needs which may dictate a different type of form. Particular emphasis is given to the work performed box, which is where the repair record goes, and the failure code, which is the device for entering this information into computer.

6.1.1 Basic purposes of the Work Order System

a) To provide a means for screening and authorising work.
b) To provide cost data segregated in a logical manner.
c) To provide feedback information on repetitive failures for analysis.
d) To provide a tool to facilitate planning and scheduling of maintenance work.
e) To facilitate control of productivity.

Figure 6.1 shows a typical work order form. This form is used in two ways, as
A. Blanket Work Order and
B. Special Work Order.

A. Blanket Work Orders: The concept of blanket work orders is used for two purposes:

1. On routine repetitive small jobs, when the cost of processing an individual work order may exceed the cost of the job. For example, a call to replace a single fluorescent light tube. The blanket work orders are normally written only once per year. When a man does work under this order, he merely charges the work order for the time he spent at the end of the day, thereby saving time and cost.

2. In routine jobs, such as the pre-planned janitor's job. The reporting of what he does on individual work orders by task would result in useless and costly information.

B. Special Work Orders: A special work order is written for all other individual jobs. Implied in the writing of a special work order is the fact that the particular individual job is important enough to warrant separate individual approval and reporting of all pertinent facts about the job.

6.2 Work Requested

In each box of the work order, insert a description of work requested. The description should be as explanatory as possible. For example, if a production foreman noticed something wrong with a pump, this box might read "Please fix bad leak in pump shaft seal". If the job was a pre-planned job written by the Chief-Planner Scheduler, the box might read "Perform complete overhaul on pump. Renew seals, all gaskets, broken nuts and bolts, clean thoroughly inside and outside. Renew gear; if necessary, repaint".

Machine Number: Enter machine number.
Machine Description: Enter machine description, such as
Fuel transfer pump
Cost Centre: Enter appropriate cost centre numbers of the department requesting and performing the work.
Requested By: Enter signature of person requesting work.

WORK ORDER No. ______ BOAT No. ______ UNIT ______	DATE ________
WORK REQUESTED __________	MACHINE NUMBER MACHINE DESCRIPTION CC REQ CC PERF REQUESTED BY DATE PRIORITY WORK TYPE
WORK DESCRIPTION ________	TOTAL HOURS
REMARKS ______________	
JOB TITLE ____________ APPROVED BY__________ DATE _______	FAILURE CODE

Source: Adapted by the author from IMO Compendium 5.03

Fig. 6.1 The Work Order Form

Request Date: Enter date of request.
Work Order Number: Enter work order number.

6.3 Priority Code

The priority number is of major importance. It indicates about how much time is left before a repair need becomes a serious problem. A repair need becomes a serious problem when it:
1. is likely to stop production,
2. is likely to injure someone; and
3. is likely to damage equipment.

The priority system plays a vital role in communicating urgency in establishing criterion for manpower allocations and workload balancing. The Chief-Planner Scheduler shall enter the appropriate priority code shown in Fig. 6.2.

NO.	NAME	PRIORITY NUMBERS CRITERION	ACTION
1	EMERGENCY	Production stops unless repaired at once. An extremely hazardous condition exists. Equip. will be damaged unless repair at once.	Repair at once. Paper work to follow.
2	URGENT	A serious safety hazard exists and must be repaired before the end of the week an on the next shift, if possible. Production will stop unless repaired before next week.	Interrupt weekly sched. and place on next available daily schedule.

3	NORMAL	A defective condition has been identified. This condition will most likely not stop production, cause damage, or injure someone if corrected during the next week to four weeks.	Interrupt monthly sched. and place on next available weekly sched.
4	Programmed	Predetermined repetitive repairs, period inspections, major maintenance repairs and construction will normally have this priority.	Place on next available monthly schedule.
5	Fill-in	Work assigned this priority has little or no time requirements.	Complete as time permits.

Fig. 6.2 Priority Code

6.4 Estimate

The Chief Planner Scheduler (CPS) shall enter a rough estimate of the labour required to do the job in the space provided. It is not intended that an exclusive and very accurate estimate be attempted, but that a reasonable estimate be made based upon sound judgement. This will naturally require that the Chief Planner Scheduler be a person of considerable experience in all types of work.

Great care shall be made in selecting the most efficient crew size for the job because of the great effect this has on labour efficiency.

As can be seen from the estimating box on the work order, two quantities are required for each trade used, crew size and hours required per crew, i.e.,

2 R 4

This means 2 repairmen are needed for 4 hours.

6.5 Job Title

The Chief Planner Scheduler shall enter a short accurate description of the job for input into the computer after the job is complete.

The reason for this step is to provide a meaningful job title in the computer reports.

For example, it is possible that the work requested box might read "Please fix slurry pump, it doesn't work". This is not a meaningful title. A meaningful title in this case might be "Replace motor overload elements", since it describes the work actually performed.

6.6 Work Performed

The foreman, upon completion of the job shall enter the actual work performed, including:

- Part that failed
- What corrective steps were taken?
- What caused the failure?
- What preventive steps should be or were taken ?

Because the failure of one part frequently causes a chain reaction of failures, the part failing first must be identified. The information put in this box will vary depending on the circumstances.

Case 1 - Preplanned Work: When a job is preplanned in advance, for example, on a construction or modification job or on a planned overhaul; the work is completely described in the "Work Requested" box. The "Work Performed" box shall be left blank if the job is performed according to plan.

Case 2 - Preplanned Work - Changed: If in the course of performing a preplanned job the work is modified in process, then a description of the change shall be entered in the "Work Performed" box.

Work Requested
XYZ
Work Performed
Job cancelled due to supply problems.
Repaired damaged splice No. XYZ.

Case 3 - Breakdown Job or Trouble Call: In the case of a break-down job or a trouble call, the work requested is frequently, of necessity, vague, i.e.,

Work Requested
Fan # XYZ is vibrating badly,
please repair.

After the fan is inspected and the fault isolated and repaired, the foreman knows the detailed cause and what was done.
Since this represents valuable feedback information for use in maintenance analysis, it must be recorded. It should be recorded in the work performed box as follows:

Work Performed
Main bearing on Fan XYZ
dry of oil and burned up.
Replaced burning

The recording of accurate feedback information on failures is one of the most important functions of maintenance foremen. Good feedback will normally not be put on the work order without a strong campaign to achieve this by the maintenance manager, including lots of instruction and follow-up.

6.7 Completion Date

When the job is completed, the foreman shall sign his name in the completion approved box. The signature will verify that he has inspected the completed work and that the work has been done in accordance with the plan (or modified plan) and that it is of proper quality. After signing completion, the foreman should enter the date completed.

6.8 Failure Code

A four digit failure code shall be entered after the job is complete and after all other entries are made. It is important that a person knowledgeable about the entire maintenance program make this entry since the information will be the main tool for maintenance failure analysis and a valuable tool for writing and updating PM instructions. A description of this coding system follows.

The system starts with a 4 digit failure code. The failure code is designed as follows:

X X XX
1 2 34
Component Code
Action Code

The definition of the Action Code is shown below. The definition are self explanatory.

Code	Description
R	Replace
M	Repair
A	Adjust
C	Modification

These codes are a suggestion. Each maintenance organization may have need for more or different codes. The last three digits are used to describe the component that failed.

6.9 Surfacing Highly Repetitive, Critical Failures

Now that the staff of the maintenance section have all the necessary information to analyse failures on the work order, what remains to do is to extract the information from the work order in such a way as to pin-point the most critical and most highly repetitive failures. A computer program can do this very simply. The program makes use of the following information that is on the work order:

- Failure code
- Equipment number and name
- Critically code
- Work order cost
- Date

With this information, the computer with various programmes can print different reports.

- Report can be programmed to print out only those equipment items that are the most critical (or any other degree of criticality).
- Equipment printouts can be made in descending order according to the equipment item having the highest number of failures.
- Failures can be printed out in descending order of number of occurrences.
- Number of occurrences this month and year to date total are shown.

Thus one can deduce from the informatio:

- The equipment that has the highest number of failures in plant and other information.

6.10 Use of Summary Reports

Summary reports can be of great use to the maintenance manager. The information for these reports is obtained from the work order system and is printed in useful form by the computer. Examples of useful summary reports are:

- Maintenance Cost - $/Ton
- Maintenance Cost - $/Unit produced
- Costs by work type code, including percentage each type is of total
- Parts used

The reports should be subdivided by maintenance organisation units. Standards and improvement goals should be set on the above indicators. Figures outside of standard should be further investigated by referring to the individual work order. Some other examples of such reports are as following:

i) Annual Equipment Report: This report summarises work order costs for the year by equipment number and is given in the following format:

Equipment No.					
Work				**Outside**	
Order		**Labor**	**Parts**	**Service**	**Total**
No.	**Description**	**Hrs. ($)**	**($)**	**($)**	**($)**

This report should be printed in descending order of the total dollars column.

ii) Monthly year-to-date Major Problem Reports: The following two reports are recommended as quick and easy means of surfacing principle maintenance problem areas:

Report # 1

Equip.		YTD	YTD	% Col. 4
No.	Description	Downtime	Maintenance	to Total
		Occurrences	Costs	Col. 4

Report #2

Equip.		YTD	YTD	% Col. 4
No.	Description	Maintenance	Downtime	to Total
		Costs	Occurrences	Col. 4
xxxx	-----------	xxxxxxxxx	xxxxxxxxxx	xxxxxxxxx

The preventive maintenance supervisor should be particularly on the lookout for equipment items that account for a major percentage of costs or downtime occurrences. For example, if the two reports showed that only ten equipment numbers accounted for 90% of the maintenance costs and downtime occurrences, then quite obviously these ten items should receive close to 90% of the maintenance analysis time. The intent is to prevent squandering of valuable analysis effort on an across-the-board effort with proper relationship between effort and return on effort.

It should also emphasised that maintenance cost and downtime are not the only barometers of an effective maintenance programme. There are many other factors that must be considered: for example, production loss and safety, to name a few.

iii) Monthly Parts Usage Report by Equipment: Another valuable tool for surfacing maintenance problems can be obtained by arranging the annual issues per stock item in descending order as follows:

Equipment Number: XXXXXX						
		No. of	Total	Av.		
Acc.		Work	Qty.	Unit	Total	
#	Descrip	Orders	Issued	Price	($)	%
xx1	Gears	x	x	x	3000	67
xx2	Rollers	x	x	x	1000	22
xx3	Bearings	x	x	x	460	10
xx4	Rope	x	x	x	20	0.6
xx5	Nuts	x	x	x	10	0.2
xx6	Bolts	x	x	x	10	0.2
	TOTAL				4500	100

This report shows that the major parts problem with this machine is gears.

CHAPTER 7

SAFETY AND TRAINING

7.1- Safety of Workers

Whether onboard crafts or in the workshop the safety of workers is necessary to protect them from injury or death. A serious safety incident may cause:

- Production loss
- Low morale
- Low labour productivity
- Labour relation problems

Foremen or supervisor should work with the safety department in eliminating safety hazards.

Secondly, foremen should discuss safety when briefing the workers on jobs and alert them to unusual hazards of a particular job and what he wants them to do to conduct the work safely.

Safety engineers will, when investigating all accidents, determine if the men have been briefed on unusual safety hazards for the specific job they were working on when the incident occurred.

Foremen should see to it that certain equipment items necessary for the safe conduct of a job are available to the men. Examples include:

Protective clothing	- Breathing apparatus
Safety glasses	- Masks
Hard hats	- Safe ladders
Safety shoes	- Spark proof equipment

7.2- Plant Cleanliness

Plant and workshop cleanliness is an important responsibility of everyone. An unclean plant may cause one or more of the following problems:

- Low Morale - Nobody likes to work in an unclean environment.
- Production Loss - Ore spillage, for example, may result in damage to bearings, belts, skirts, etc., and eventually cause a shutdown.
- Health Hazard - Uncollected fumes, dust from spillage, may result in medical problems.
- Safety Hazards - Fuel or oil leaks may result in slipping and falling.
- Fire Hazards - Uncollected trash, papers, oily rags, or other combustibles may create a fire hazard.
- Low Productivity - An unclean plant creates an atmosphere of disorderliness and confusion and may lead to low productivity.

For these reasons it is important that each maintenance foreman makes his contribution to keeping the plant neat, clean and orderly and that he invite his men to do the same.

He should do this by developing a plan. The following suggestions are offered:

(a) Shop orderliness - Foremen should outfit themselves with whatever bins, cabinets, tool racks, necessary to insure an orderly shop arrangement.
(b) Workers should be instructed to keep shop neat and clean.
(c) Workers should be instructed to clean up after each job, i.e., return tools and equipment to shop and clean up dirt, trash and debris generated during job.
(d) Foremen should evaluate the problems or damage to equipment caused by uncleanness, spillage, etc., and co-ordinate with production on eliminating the problem. If

foremen have difficulty in solving this problem, they should alert the Maintenance Manager to the problem. The Manager should then try to resolve the problem with the Chief Engineer.

7.3- Safety during Installation, Operation and Maintenance

Good design and correct installation can be ensured during commissioning (particularly if reliable commissioning consultants are employed) and the operation of a planned maintenance system is a constant safeguard during operation. Items to be considered on new-plant safety courses are listed below:

7.3.1 Planned safety

- Good layout providing access, egress, etc.
- Careful planning of services.
- Route planning for machine deliveries.
- Environmental planning - heat, light, air, etc.
- Scaffolding, ladders, etc. provisioning.
- Interpreters for installation of foreign plant.
- Clear definitions of responsibility and management.
- Specification of requirements for interlocks, guards, etc. on plant.

7.3.2 Installation

- Delivery check for requirement 8, above.
- Installation and operating instructions availability.
- Competent supervision for plant handling.
- Isolation of services during installation.
- Prohibition of temporary service connections.
- Fire and glare protection when welding.

7.3.3 Commissioning

- Specification and procedure agreed in advance.
- No connection of services until approved.
- Slow-speed start with full check on safety features.
- All overload devices calibrated.
- Control and shutdown procedures verified.
- Working positions and visibility checked.
- Safety training given.

7.3.4 Planned maintenance

- Maintenance information available.
- Maintenance planning introduced.
- Safety shutdowns agreed.
- Priorities for maintenance of safety features.
- Statutory tests performed to schedule.
- Correct tools and access equipment supplied.
- Ancillary equipment maintained also.

7.4- Safety on- new projects

At the planning stage of a new project number of aspects of industrial safety require attention. These are:

- The provision of services (gas, water, etc.) must be planned with safety in mind.
- Plant layouts must provide for safe working space.
- Appropriate floor, ventilation and lighting standards must be maintained.
- Delivery routes for plant must be planned for safety.
- Adequate and safe arrangements must be made for plant handling.
- Scaffolding, lifting gear, etc. must meet accepted standards.

- Suitable arrangements must be made for alarming workers in unsafe conditions.
- Interpreters must be provided to prevent accidents when plant of foreign manufacture is installed by engineers using a foreign language, if communication becomes difficult.
- Requirements for safety (interlocks, guards, etc.) must be established and implemented.
- A definite chain of responsibility to a single project head must be enforced to prevent duplicate or wrong instructions being used.
- The procurement specification should include this or similar wording: The plant must comply with all statutory requirements.
- During installation the following points are important:
- Lifting and moving must be supervised by a competent person.
- Instructions for installation and operation must be supplied and verified before use.
- All supplies should be isolated until connection to the machinery is authorised.
- Temporary supplies should not be used.
- Before use, the plant must be examined for
- Adequate safety interlocks.
- Adequate guards.
- Adequate safety procedures.
- Precautions against fire and against glare must be taken if welding techniques are used.

7.5- Training

For every organization training is very important. No doubt training requires money (input) only. The output is not immediately visible but it certainly contributes to greater productivity. It is a famous saying that "the money spent on training is not money wasted but invested".

The first priority in any maintenance organisation is to insure the availability of technically competent mechanics who can repair anything that breaks down. This need and priority is obvious. The function that insures this capability, as the plant is modified and updated, is training.

For the purpose of training there is lot of material available, i.e.: textbooks, plant engineering manuals, apprenticeship programme, supervisory training, etc. Usually there are dozens of special maintenance tasks in a plant that are not only critical to production, but also difficult to perform from manual proficiency and technical skill aspect. These type of tasks can be taught with the aid of sound movies or video tape.

A movie film may be taken when some specialist is performing some difficult job. And then same movie can be shown again and again to non-skilled or less experienced mechanics. The good thing about this type of training is that it is not expensive at all. The only expense is the cost of film and time of camera man.

The following list of courses can be a reminder for maintenance managers seeking to develop incoming or existing staff members as a maintenance improvement plan.

7.5.1 Introduction training

New entries to the maintenance department can benefit from an induction course, designed to speed their adoption of the best working methods and of the approved communication channels. Typical subjects may be included are:

a- Welfare and personnel functions.
b- Management hierarchies and family trees.
c- Documentation and paperwork.
d- Technical information, manuals, drawings, etc.

e- Liaison with production.
f- Stores, test gear and access equipment procedures.
g- Planned maintenance procedures and routes.

7.5.2 Repair Technician Courses

In a suitable environment repair technicians may be trained to specialise in repair and servicing of vital machines, particularly when multi-discipline working is necessary. Training begins with the development of suitable charts, manuals, etc. and a thorough understanding of engineering drawings and other available information. Training in the various disciplines is then necessary followed by analysis of fault-finding and repair work across the disciplines.

7.5.3 Fault Diagnosis Training

Fault-finding and repair training may be general or specific in nature. General training courses include:
a- Refresher lectures on basic disciplines.
b- Use of drawings, recognition of symbols.
c- Development of fault diagnosis methods.
d- Use of charts and other aids.

7.5.4. Advanced Skills Training

Courses within this category may be selected to improve the performance of existing staff in fault-finding and repair or in coping with new plant employing new or advanced control or instrumentation techniques. Typical examples are:
7.5.4.1. Simple Programming Course. For electronic technicians engaged in the maintenance of plant which is computer controlled and on which the first line of repair involves the use of test programs.

7.5.4.2. Hydraulic or Pneumatic Systems Training. For use where the introduction of these systems, or the use of more complex systems, is causing repair delays related to inexperience.

7.5.4.3. Electronic Appreciation Courses for Electricians. These have been applied successfully in industries where the basic product (e.g. office machinery) now operates electronically.

7.5.4.4. Systems Appreciation Training. Courses designed to encourage system thinking in technicians called upon to maintain systemized plant rather than individual machines.

7.5.4.5. Introduction to Computers. When computer systems are considered for asset management applications it is essential to prepare staff at all levels by suitable introductory courses. This applies not only to asset managers and maintenance managers but also to supervisors, foremen and trades union representatives. Managers and supervisors from other departments affected by the computer system should also be informed. Course contents should include:

a- Brief history of computers.
b- Introduction to computer terminology.
c- Why computers are used.
d- The computer as an aid to maintenance.
e- The computer in feedback analysis.

7.6- Causes of Accidents

In order to prevent accidents from taking place it is necessary, first of all, to gain an appreciation of the causes of accidents. Accidents may at times seem to occur because of chance factors that are unavoidable. But digging beneath the surface one will find that in nearly every instance measures could have been taken to prevent the accident.

Accident causes can be classified into two major categories:
a) Unsafe chemical, physical, or mechanical conditions.
b) Unsafe personal acts.

Examples of unsafe chemical, physical, or mechanical conditions are the following:

- Inadequate mechanical guarding.
- Defective condition of equipment or tools (for example, worn electrical insulation, cracked ladder, split drive belt).
- Unsafe design or construction (for example, a pressure vessel that is too weak).
- Hazardous atmosphere (for example, toxic substances in air, poor ventilation).
- Inadequate or improper personal protective equipment.
- Examples of unsafe personal acts are as follows:
- Failure to follow established safe working procedures.
- Horseplay, fighting.
- Taking an unsafe position, such as under a suspended load.
- Failure to use designated protective clothing.
- Removing safety devices or making them inoperative.
- Sometimes the physical or mental condition of the person involved may contribute to the accident. Thus, a worker may be emotionally upset, inattentive, or fearful. Or he may be extremely fatigued or suffer some physical defect that makes an accident more likely.

7.7- Safety Education

Safety education for all levels of management and for employees is a vital ingredient for any successful safety program. Education in this context concerns the development of proper perspective and attitudes toward safety. It deals with basic fundamentals and the reasons why. Training is more concerned with immediate job knowledge, skills, and work methods.

Top and middle management require education in the fundamentals of safety and the need for an effective accident prevention program. The costs of accidents, both human and dollar costs, must be brought to the attention of line management. Top management in large- and medium-sized companies does not need to concern itself with the detailed mechanics of accident prevention, but it must acquire a sufficient awareness of safety fundamentals so that it will actively support the work of the safety department and of middle and lower management in carrying out the program.

The safety director and his staff must undertake to provide extensive education and training for first-line supervisors. The supervisors must understand their key role in the safety effort, namely, that they are primarily responsible for preventing accidents (assuming they have adequate support from above). Each supervisor must conduct his own safety training for his employee. This takes the form of both individual on-the-job training and periodic safety meetings held right in the department.

At the employee level there are two principal objectives

(1) to develop safety consciousness and favourable attitudes toward safety and

(2) to achieve safe work performance from each employee on his job. To achieve these goals, a number of things must be done.

At the time a person is hired, orientation by both the personnel manager and the person's supervisor should cover such areas as the need for safe work performance, the hazards in his own department and job, the necessity for prompt reporting of any personal injuries, desirability of reporting unsafe conditions to the supervisor, and the general causes of accidents. Each new worker must be taught how to perform his job safely. This frequently takes the form of on-the-job training. Instruction in safe working procedures must be integrated with instruction designed to achieve acceptable output and quality performance.

In addition to individual on-the-job training, successful safety practice in countless organisations has demonstrated the value of periodic safety meetings conducted by the supervisor. Among the topics that may be covered are the following: how to prevent accidents, accident causes, importance of good housekeeping, handling materials safely, first aid, machine hazards, fire prevention, use of hand tools, and protecting the eyes.

CHAPTER 8

CONCLUSION

The main purpose of this dissertation was to provide basic information on scheduled maintenance. The explicit intention was to propose a system that can be adapted to the Saudi conditions. The complexity of modern crafts and equipment requires this systematic approach to the problem of maintenance. The second intention was to encourage the Coast Guard to adopt this type of preventive maintenance, the methods, the documentation and logistics described throughout the dissertation. All of this is aimed at planning engineers, to help them establish a system able to provide a high equipment availability factor, while keeping the system simple and flexible.

The basic objectives of the maintenance department stated here include:

- To obtain minimum total operating costs.
- To keep facilities and equipment operating in good condition.
- To keep facilities and equipment operating the optimum period of time.

The principles of optimum maintenance delineated in this dissertation are:

- Maintenance is an integral part of the organisation.
- Maintenance is a service function, backing up operations.
- Maintenance work must be controlled at its source. A foreman, must be responsible for the facility and control its cost. Only foremen and supervisors can authorise work in the facility.
- The work load must be controlled so that work is balanced in relation to manpower. Backlogs should be determined periodically, and reassignments make possible, to alleviate it.

- Except in emergencies, maintenance work is planned before work starts by someone other than the foreman. The originating Supervisor or Engineer obtains a cost estimate before authorising routine maintenance work.
- The work of every maintenance man should be always scheduled, taking flexibility into account.

Maintenance management is considered part of the maintenance science scenario. It is critical that plant and equipment information be available so that sound management policies could be applied.

Planned and Preventive Maintenance System must be simple but effective and should consist of the following interrelated requirements:

- A programme of operation covering inspections adjustment, rectification of faults and periodic overhauls.
- Means of ensuring that these operations are carried out in accordance with the programmes.
- A method of recording the work done and assessing the results.

Taking these points into consideration, the first step is the compilation of the inventory to establish what has to be maintained and from that the programme.

Effective co-ordination (liaison) between operating managers and maintenance planners is essential to operations. In workshops this is generally accepted as long as it encourages more efficient planning..

The maintenance book and record system provides a flexible method for producing maintenance work lists which in turn permits a detailed appraisal of the programmes.

Today, when a variety of computers programmes are readily available in the market the recommendation is to take advantage of such tools as to facilitate the job and provide facilities for the asset registers, work control, manpower resource, stock control, maintenance accounts and in some systems, analyses of feedback and costs. . No doubt there is always high initial cost for such systems but it can easily be recovered in the long run.

This constitutes a recommendation, the details of which can be found in the relevant sections of the present dissertation.

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