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COMPARATIVE ANALYSIS AND IMPROVEMENT OF ONBOARD AND SHORE-BASED MACHINERY MAINTENANCE IN SIERRA LEONE

By

IBRAHIM C. SESAY SIERRA LEONE

A dissertation submitted to the World Maritime University in partial fulfilment of the requirements for the award of the degree of

MASTER OF SCIENCE

in

MARITIME EDUCATION AND TRAINING (ENGINEERING)

1998

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Declaration

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

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



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ABSTRACT

Title of dissertation: Comparative Analysis and Improvement of Onboard and Shore-based Machinery Maintenance in Sierra Leone

Degree:

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This study is based on the description of how machinery maintenance can be improved in Sierra Leone. The study explains the development that has taken in current years on machinery maintenance. It also analysis the previous methods dominating maintenance and the changes that are presently taking place in upgrading maintenance to meet crew reduction and technology advances.

The author also looks at the management system of the shore-based and shipboard segments of the shipping industry and describes how responsibility should be distributed for an effective maintenance process. Responsibility should not be centralised but decentralised and evenly distributed throughout the organisational pyramid. The use of computers in machinery maintenance assists in the following areas:

- Implementation of the modern maintenance methods (Reliability Centred Maintenance).
- · Communication to transmit maintenance information from onboard to shore.
- · Documentation of repair work and inventory of spare parts.

The objectives of IMO and other international organisations also are important components in a quality maintenance program.

The marine engineer not only keeps machinery effective and reliable but also plays a role in protecting the environment, keeping people safe and protecting property.

This dissertation is a guide for the onboard shipboard maintenance team, the top management team and people involved in port and shore machinery maintenance. **KEYWORDS:** Engineer, Machinery, Maintenance, Reliability, Repair, Shipboard.

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LIST OF ABBREVIATIONS

HFO	Heavy Fuel Oil
ICMES	International Co-operation on Marine Engineering Systems
IMarE	Institute of Marine Engineers
IMO	Internation Maritime Organisation
ISM	International Safety Management
MARPOL	Marine Pollution
MMIS	Maintenance Management Information System
MMS	Marine Management System
NAPETCO	National Petroleum Company
NOx	Nitrogen Oxides
PM	Preventive Maintenance
RCS	Reliability-Centred Stockholding
SOLAS	Safety of Life at Sea
so _x	Sulphur Oxides
STCW	International Convention on Standards of Training, Certification
	and Watchkeeping for seafarers

LIST OF DEFINITIONS

Condition-based maintenance: Performing maintenance tasks on the basis of equipment condition and performance.

Condition monitoring: Measurement intended to determine the condition of equipment, to asses its need of maintenance

Downtime: Period of time the ship or a system, or a piece of equipment is unusable while it awaits maintenance to be completed.

Maintenance: An action which is carried out to return or restore an item to an acceptable standard.

Reliability-centred maintenance: Process which considers the physical asset as a whole and the defines what needs to be done to ensure that it continuous to carry out it's required functions in its operational environment

Reliability-centred stocl holding: Rational methodology for determining the stock of spare parts need to hold to support your maintenance and production operations.

Ship machinery: Main propulsive system and various auxiliary systems supplying the necessary marine machinery and hull services.

Chapter 1

INTRODUCTION

Maintenance is the key concept in the availability of ships, their efficiency and service and, infact, in the operation of all physical assets in the marine industry. Lack or negligence of maintenance will not only result in disruption of services, but also in disastrous results to the marine and port industries and to the economic degradation of a nation. The need to keep within a set scheme in an unpredictable ocean environment and to complete a safe voyage calls for an appropriate maintenance method.

The efficiency and continuity of the shipping industry and port operations basically depend upon the availability and reliability of the machines and equipment used. Therefore, these machines and equipment should always be ready and in running condition.

Maintenance is a service that has specific value to the production process. It is an organisation that provides an increase in productivity and profitability. Therefore, the materials arranged in this dissertation should not only be the concern of those who are directly involved (shore-based and onboard maintenance staff) but also to those indirectly involved such as top management and decision makers.

1.1 Purpose of the Study

In previous years, there were more than five fishing companies in Sierra Leone. Each operated a fleet of more than a hundred vessels. There were a few oil companies operating oil tankers, barges and tugs of varying sizes and ages as well. At present these companies have only approximately 30 to 50 ships in their fleets in operation due to a number of reasons, but the major ones are:

- Lack of training: Training that could advance the skill level of personnel and cope with advances in technology is normally not provided to maintenance crew.
- Spare parts availability: It is always a problem to procure spare parts due to the foreign exchange rate and transhipment.
- Political stability: Changes of Government or the Government not being recognised by international committees has a negative effect on ship machinery maintenance.
- Lack of commitment; Because of the low wages and motivation maintenance crew or staff offer less priority to their work.

Ranking the contributing factors in terms of damage or total loss to a vessel lack of training is the highest. This paper will assist decision makers, planners and those who actually do the maintenance in minimising accidents, breakdowns and sinkings of vessels. This document will highlight the new development that has taken place in ship machinery maintenance pointing out necessary action that can be taken to move gradually from the traditional to the modern maintenance system. This paper also will provide materials to sensitise decision makers, planners and those who execute ship machinery maintenance to understand and provide answers to questions of this type:

- What is to be maintained?
- How is to be maintained?
- When is it to be maintained?
- · What maintenance system is most effective?

Shipping and fishing companies need to understand that the concept of maintenance is based on the assumption that maintenance does not start with activities to keep an existing machinery running/operating, but starts with the negotiations to purchase a vessel and ends after scraping.

The materials discuss in this dissertation will help maritime authorities understand how important the introduction of computers to ship machinery machinery. For the shipboard system this means training mariners beyond their traditional maritime skills if they are to develop the proper confidence to operate such systems reliably and safely.

The author has encountered a series of obstacles during the collection of the necessary materials, data and information. One of them was poor feedback from correspondence with consultants, companies and shipping agencies. As a result, no information or data from shipping companies, fishing companies nor Sierra Leone was gotten directly. Therefore, all the materials on this dissertation were written from experience and from materials collected and written about in maritime news letters, publications and sources from different countries.

1.2 Methodology

This study has been prepared using descriptive methods obtained by reference to books, lecturer handouts, reports from conferences, publications on marine engineering reports and experience gained during the field trips and in the work place.

Chapter 1 is a general introduction to the subject, purpose of the study and a description of the difficulties encountered during the collecting of material. Chapter 2 highlights the objectives and factors affecting maintenance and the functions of marine engineers. This chapter clearly explains that a marine engineer's function is not only to keep machinery running but also to meet international standards for safer shipping and cleaner oceans.

Chapter 3 gives an analysis of the different types of machinery maintenance in general. This chapter explains what is meant by "planned" and "unplanned" and explains the application of each on the job.

Chapter 4 describes the maintenance organisation of the National Petroleum Company and how it is structured. It explains the company policy and the maintenance problems encounted by the company.

Chapter 5 explains the difference between the traditional methods and the modern methods of maintenance and the role of shipboard and shore-based personnel. This chapter highlights the importance of using a network between shipboard and the shore-base in maintenance and also suggests ways maintenance can be improved in the industry.

Chapter 6 concludes the study and gives recommendations for an effective and efficient maintenance. The author gives his opinion on the use of low crew number and the composition of the crew.

Chapter 2

OBJECTIVES OF MAINTENANCE AND FUNCTIONS OF MARINE ENGINEERS

Why, after a machine is constructed and in use, is it left with no maintenance?. This chapter explains the need for maintenance every day at a given time or on the verge of failing or after failing. The basic objectives of maintenance are:

- · To manage the maintenance department so as to minimise total operating costs
- · To keep facilities and equipment operating in good condition
- · To keep facilities and equipment operating the optimum percentage of the time

 To avoid ship component failure, which, if failed, would affect the safety of the ship or might cause delays, damage to the cargo, or other serious losses like fines for pollution, legal costs, etc.

2.1 Objective of Maintenance

2.1.1 Prolong the Life Span of Machinery

Ship and shore based machinery is initially designed to fulfil designated efficiency requirements by the manufacturers. No matter what the technology of the system, it is impossible for it to operate and perform near to this level without maintenance. In the absence of maintenance the design efficiency parameters will fall below their expected value. A machine, therefore, must be maintained continuously to prolong its life span. Maintenance of machinery starts in the design stage and needs to be continued until the vessel is scraped. Therefore, to prolong the life span of machinery, all sectors of operation and maintenance considerations in the design of equipment is an important factor to bear in mind. From design to operation the equipment must undergo stringent quality control procedures. This factor must also be incorporated in planning maintenance strategy as it can make the equipment run almost indefinitely without major maintenance costs. The design from raw materials to the finished product must undergo strict quality control procedures. Lack of design consideration will cause endless work load maintenance tasks due to persistent breakdowns during the operation process. This is because the design of the equipment may not be able to carry the designed load. This in turn will cause excessive maintenance. Hence design is a vital factor to be considered to prolong the life of a vessel.

2.1.2 Reliability and Effectiveness

Ship machinery reliability is fundamentally important to all departments of the industry, not just the maintenance team. The RCM (Reliability Centred Maintenance) philosophy suggests that the overall requirement for the ship and it's systems (including machinery) should primarily be reviewed by a small team of not more than five or six people representing all departments involved in operating the ship. The starting point includes deciding what the objectives of the necessary maintenance are and what standards need to be applied. The team's function is to concentrate on analysing the maintenance requirements of each individual item of equipment or machinery, after looking first at the ship as a whole, and secondly at its systems. It also needs to consider what could go wrong with the vessel and its components. The logic is that if the ship and its machinery have been designed accurately, any problem with them must result from improper maintenance or lack of knowledge of the system.

The next point is to consider what the effect would be for each failure mode, and what processes and resources might be necessary to improve reliability. The advantages of this approach include not only the value of looking at the ship from an overall reliability view point but also the benefit of the inter-dependent team work involved.

Failures' modes can also be caused by poor communication and co-ordination between sea staff and the head office. Therefore, improving communication between sea staff and the head office (commercial and technical) reduces failure modes and increases reliability. This can also facilitate a better understanding of the organisation's objectives. If well-implemented individual departmental and organisational strengths and weaknesses are also highlighted, an increase in respect and understanding will be the result. (Dr. B. Butman 1998).

Reliability and effectiveness at the Sierra Leone National Petroleum Company are continuously deteriorating because the maintenance team is not committed for the following reasons :

- · Lack of communication between onboard staff and management ashore
- Lack of motivation
- · No defined responsibility between shore-based and onboard maintenance teams
- · Shore based staff have little or no marine background (Author's knowledge).

2.1.3 Environmental Protection

Environmental protection is presently the key burden issued for the marine industry. The challenge is to minimise pollution so that the environment will be friendly and safe to all its inhabitants.

Approximately 4% of gross sulphur oxides (SO_x) , together with nitrogen oxides (NO_x) , are thought to be responsible for some deforestation and extermination of fishes in lakes due to acid rain and discharges from national and international sea

born trade. (Nippon Kaiji Kyokai, 1996, 15). Research has shown that the pH value of drainage downstream of the scavenging air cooler is approximately 4 - 5 and this is caused by the souring of atmospheric air with rust generated in parts surrounding the scavenging air chamber. (Nippon Kaiji Kyokai 1996 15).

To minimise environmental pollution the main propulsion and auxiliaries should be maintained for less production of the above gases. All machinery must be maintained to avoid oil, dangerous gases and cargo from spilling into the sea and air.

2.1.4 Commercial point of view

Well-maintained machinery can run at a reasonable cost of operation and maintenance can keep it in service for a longer period of time. This scenario generates more revenue. To achieve this goal of a high profit margin the level of maintenance must be maximised. To achieve this goal maintenance availability and reliability must be optimal and maintenance personnel must be well trained and skilled. Each item in the machinery space needs to be maintained in good condition at all times. The aim is to maintain the voyage passage at reduced power, to avoid delay and eventual operation costs that develop from lack of maintenance.

Shipping companies are aware that ship maintenance is comprised of the costs incurred in the organisation, execution and control of all relevant work and measures undertaken to ensure the "totally efficient" operation of the ship. These costs cover everything that is directly and indirectly attributed to maintenance. This includes the work-force and materials resources, (spare parts, tools, etc.). Maintenance costs usually are second only to crew cost. They vary according to the type of ship, its design and the characteristics of structures and machinery space components. From the statistical figures in table 2.1 and 2.2 it can be seen that maintenance cost is between twenty-percent (20%) to twenty five-percent (25%) of the total operational costs (crew, technical, management and miscellaneous) of a sixteen year old tanker.

Table 2.1 Average operating costs for 130,000 dwt of a 16 year old tanker

Manning	Maintenance	Insurance	Administration	Stores lubes	Spares gears
32%	20%	17%	15%	8%	8%

Source: BP Shipping Consultants

Table 2.2 Typical operating costs for a product tanker

Personnel	Maintenance	Administration	Finance	Stores	Disbursement
48%	20.4%	13.4%	10%	7%	1.2%

Source: BP Shipping limited Engineering Division

Hence to minimise maintenance cost and optimise profit, routine maintenance is inevitable.

Maintenance reduces the capital cost of the ship. Capital cost of the ship per year equals the cost of the ship divided by its life span.

2.2 The Functions of Marine Engineers on Board Ship

Different people have different explanations about the functions of marine engineers. Some will say a person who works on board ship is a marine engineer. Others think that somebody whose job is only the maintenance on board the ship is a marine engineer. In fact, a marine engineer on board ship does not only concern himself with the maintenance of the machinery. His work extends further to the objectives of IMO and the shipping company. The IMO objectives are the safe operation of vessels and environmental protection and to the shipping company is objective are the safe and economical operation of its fleet.

2.2.1 Safety

Safety is watch-keeping, repairs and maintenance, inspections of the machinery system and the safety of equipment maintaining a clean ship to receive bunkers, etc. Safe equipment machinery must be paramount since too many lives are lost at sea and too many injuries are suffered. Technology is only one half of safety and competence of seafarers. The engineer on watch should maintain a proper watch inside the engine room and the deck staff also have to keep an eye on the deck machinery and make reports on any suspected malfunction or trouble shooting. The engineer has to make frequent checks on the instrumentation equipment to make sure that the readings are in accordance with the manufacturer test values. For readings that are above or below critical limits, the engineer on watch should trace the fault and rectify it. If dealing with the fault is beyond his expertise, such a fault needs to be reported to the second or chief engineer. Inspection of pipe lines net work, observation of any leakage that might occur on flanges, valves fitting and water hammer inside pipes, is also the duty of the engineer on duty.

Inspection for vibration on rotating shafts, reciprocating systems, or any stationary machinery is another important area that the engineer inspects (author's knowledge). Generally speaking, vibration phenomena on board ships affect:

- the endurance of various parts of the hull steel-work
- · the behaviour of different engines and apparatus installed on board
- the comfort of the crew

There are a number of other tasks that the engineer carries out on board ship. Inspection for a drop in the level of lubricating oil, fuel oil, circulating fresh water, hydraulic oil, stern tub oil, etc. If necessary the engineer on watch fills up the fluid (oil, cooling water, hydraulic oil, etc.) to prevent trouble shooting. He also inspects safety equipment to ensure that it can be operated safely and easily when needed for use. Inspection of electrical equipment, cable networks, electrical panels, electronics apparatus and tools used for repairs and maintenance. It is his job, as well, to inspect the pneumatic system for any air leakage along pipe line, valves, cylinder bottles, air throttline process. (Athors knowledge).

In general the marine engineer is responsible for the safe operation of the ship, to maintain the main propulsion plant, electrical power generation and distribution, refrigeration, air-conditioning and cargo handling machinery. He performs maintenance and repairs, and operates and manages the ship's machinery.

For safe operations the fuel quality must also be considered. It is the responsibility of the engineer to do secondary analysis to know whether the fuel is suitable for his engine for the following under mentioned reasons. Figure 2.1 shows how the sulphur content varies with wear.

Serious failures of the machinery plant in many cases are compound failures, in which chains of component parts failures are triggered by the sudden and exclusive wear of piston rings and cylinder liners that have been operating under stable conditions.

A ship's safety and seaworthiness and its ability to make regular sailings greatly depend upon the reliability of its main propulsion machinery. Damage statistics of "Nippon K. Kyokai" on the failure of diesel engines that constitute the majority of main engines of ships, shows that serious machinery damage is caused by the poor and unstable properties of heavy fuel oil. Many reports from shipping companies point out that these machinery failures were caused by the following abnormalities, on the basis of the results of analysis of the fuel oil used:



Source: Nippon Kaiji Kyokai 1996

- Engine operating parameters specifically connected to combustion such as cylinder pressures and exhaust gas temperature change significantly towards impairing operating performance. As a result, engine output is forced to be reduced.
- The specific normal operation can be impaired by unexpected failures of combustion chamber-related components. (Nippon Kaiji Kyokai 1996).

2.2.2 Economical Operation

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Before the seventies the economic operation of machinery was not considered to be a priority in the industry. The fuel crisis of 1973 changed that attitude. It was a hard blow to the industry when the price of fuel was forced up by OPEC countries. Due to the increase in price of fuel in 1973 engine development has been expanded. Finding ways to reduce fuel consumption rates has become a priority. The specific fuel consumption rate has been decreased by about 20% in the last 20 years (field study Poland 1997). At present the specific fuel oil consumption (SFOC) is still a key point for engine manufacturers and operators to reduce. Fuel costs are related to the followine factors:

- power/speed selection
- engine optimisation overload range
- recoverable waste heat
- auxiliary power need

It has been the function of the ship engineer to perform at the maximum level and at international standards, in maintaining machinery operation in order to maintain the design speed. Due to economic consciousness speed is not as much of a priority in the industry as reliability. With a proper maintenance system for machinery by the engineer economic functions are also achieved. Crew number is also a factor of economic operation but it is greatly influence by the level of automation present in a vessel, but safety considerations naturally impose a lower limit below which it is less certainly prudent to go. In practice, there is trade-off between crewing costs and maintenance costs. The value of experienced personnel on a ship are difficult to quantify but nevertheless there can be little doubt that there is considerable financial benefit in the long term, if experienced personnel are used, in term of reduced maintenance costs and reduced time of hired.

2.2.3 Environment

Waste oil is generated in machinery spaces by a number of sources, such as crank and gear cases and lubricating oil and fuel oil purifiers which create oily sludge. Hence, the marine engineer must maintain machinery space in order to meet the principle of environmental protection (MARPOL ANNEXE 1), which states that ships must:

- · Minimise the generation of oil and water mixtures
- · Separate oil from water where mixtures cannot be avoided
- · Set limits to the quality of oil which may be discharged into the sea
- etc.

The marine engineer's tasks also include responsibility for taking care of the oil discharge monitoring and control system, the incinerator (used to burn oil and other unwanted materials onboard), the oil-water separator and the oil water equipment to prevent pollution of the sea. He maintains the amount of oil discharge from the bilge's so that it does not exceed 15 PPM (part per million), (MARPOL regulation 16).

2.3 Maintenance in "ISM CODE"

The ISM Code is the international management code for the safe operation of ships and pollution prevention.

The objectives of the Code are to ensure safety at sea, prevention of human injury or loss of life, and the avoidance of damage to the environment, in particular to the marine environment and to property.

Therefore, it is essential to understand the Code as it relates to ship maintenance. By its provisions, procedures and drafts must be provided to onboard and shore based personnel dealing with the operation and maintenance of the ship machinery system. For the most appropriate methods of implementing the Code, the shipping company should establish the procedures by which its ships are maintained in conformity with the provisions of the rules and regulations. Therefore, the personnel in charge of the implementation of the maintenance of the ships (Chief engineer or shore based staff) should report the results of implementation and record them based on the plans.

Chapter 3

TYPES OF MACHINERY MAINTENANCE

The aim of the maintenance department on board and at shore is to provide an efficient service in order to maximise machinery availability at the cheapest cost. To achieve the above, periodic servicing must take place and is categorised as follows:-

- planned maintenance
- preventive maintenance
- corrective maintenance

3.1 Planned Maintenance

Major repairs overhaul, calibration (plan factor).

Planned maintenance systems, to a varying extent, have been in existence for many years in many properly organised shipping companies. In Sierra Leone National Petroleum Company there are no defined methods of implementation of the maintenance system (Author's knowledge). This failure is due to poor organisation and technical difficulties. In developed countries the availability of computer-based planned maintenance systems has, however, made their use both feasible and in many cases most advisable.

In theory optimum maintenance is achieved when the maintenance level is such that the cost of maintenance balances the costs arising from breakdown and delays. To be

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successful, and to avoid mistakes made in the past, a planed maintenance system must be fully integrated into the company. It must be flexible and the temptation to treat it as a prime target for cutting costs when times get hard must be avoided

An effective machinery maintenance programme depends for its success upon:

- · A complete knowledge of all the machinery to be covered
- The extent of maintenance required and how long it will take in each case, together with the facilities, materials, man power, skills and spare part's replacement required
- The frequently with which maintenance must be undertaken. How long it takes and how the work can be combined and accomplished with minimal adverse effect on the ship's operation

A shipping company that correctly implements a maintenance plan will reap the following benefits:

- · The efficiency of the equipment will increase
- There will be greater availability of equipment, less expensive emergency repair, proper coverage of machinery, effective use of labour, etc.

If maintenance work is planned the work load can be evenly distributed avoiding periods of high and low activity levels. Constantly varying peaks and troughs of maintenance activities, as well as not being sound economically is also unsettling to the work force as shown in figure 3.1. In figure 3.1 the area under S_1 and S_2 represents the total man-hours over the periods taken. Based upon investigations from other shipping consultants (Drewry shipping consultants, BP Shipping Company) and from the graph, the total man-hours with preventive maintenance are less than the total man-hours without preventive maintenance. The total work load is reduced by adopting preventive maintenance. Since, among other reasons, the right numbers of persons are available when required and are working within normal hours, the work load can be completed more efficiently. By planning maintenance the peaks and troughs are reduced as shown in figure 3.1.



Period (weeks)

Figure 3.1 Smoothing the Maintenance Work

Source: Drewry shipping consultants

Computer programmes play an ever increasing role in planing, starting from the initial stages throughout the organisation to the individual maintenance tasks. Figure 3.2 shows how a maintenance plan is implemented. The machinery space is analysed by automation sensing shock, temperature, pressure, etc. and the information can be displayed on the pulse's computer screen.





Source. Drewry shipping consultants

There are three elements of planning. They are:

- Inventory identify the total assets that need to have maintenance and put them into the maintenance programme
- · Identify identify machines and their space in order to provide easy access
- Scheduling- scheduling for maintenance tasks, inspection, lubrication, repair parts and replacement indicating their frequency
- Others- registration of machinery working characteristics schedule for personnel, lubrications, quantity control and allocation.

Good maintenance planned systems must:

- Be comprehensive
- Be flexible
 - -To allow unscheduled repair
 - -To allow changes of periodicity
- · Be simple to operate
- · Include spares parts and necessary stores management
- Have a reporting system that provides a continuous picture of the condition of all equipment
- · Provide information on costs to all concerned.

3.2 Preventive Maintenance

Preventive maintenance is a branch of planned maintenance tasks that is executed to prevent machinery failures and excessive running cost. Preventive maintenance includes:

- · Lubrication and minor adjustments
- Schedule and checking
- Repairs and overhauls

The main objective of preventive maintenance is to stop functional delays, reduce maintenance costs, increase the life time and also the operational safety and reliability of machinery.



Figure 3.3 Organising a Maintenance Task

Source: David Mottram Lecture on RCM, 1998, WMU.

There are two types of preventive maintenance: Periodic and Condition

Figure 3.3 shows how maintenance tasks are organised, the planned and unplanned maintenance and the types of preventive maintenance.

An example of preventive maintenance is the lubricating schedule. Failure to lubricate a space machinery part at the right interval of time will result in plant breakdowns. Oil and greases are specified by manufacturers after careful consideration of plant duties and ratings, and the way to use the specific and equivalent lubricate is outlined by them. Over greasing of all balls and roller bearings can cause serious problems and it is therefore important that oil and grease levels are strictly maintained. In most developing countries, or companies, lubrication is a function of the maintenance department. In other companies it is the responsibility of the operating staff.

Using a preventive maintenance form, the following items will be included:

- Plant item
- Plant number
- Location
- Point of lubrication
- Methods of lubrication
- Recommended lubrication
- Frequency of lubrication
- · Frequency of sample of oil change, etc.,

3.2.1 Periodic

Periodic maintenance is done on fixed calendar intervals or after achieving certain accumulated running hours specified by the maker. Maintenance and repair are carried out when the condition reaches a certain level. The period method is applied to those machinery components whose actual operational condition cannot be determined at any given moment by visual inspection or by non-destructive methods. Examples of preventive maintenance are routine checks and inspections of the machinery space.

The inspection relies mainly on the use of eyes, nose and hands, paying special attention to odour, abnormal sound, heat emission and instrumentation readings. Retightening loose bolts and nuts and checking of valves for abnormal sounds when the piece of machinery is in operation also is part of the inspection. Other specifics of a maintenance inspection include:

- · Checking for signs of rust
- · Checking for machinery overheating
- · Inspecting for cracked moulding
- · Checking the external terminals, of the electrical system
- · Checking for heating and abnormal sounds
- Checking for leakage or damaged pipes

Using specially designed wall charts and documentation of regular planning meetings (weekly) a record of work to be done can be kept. The chart is controlled by the chief engineer. Regular communication is important to the process of providing quality period maintenance. Documentation is required for present and future analysis of the system and for meeting international regulations. The wall chart may contain the following:

 A planning board that displays the maintenance routines for three months, one month, one week and one hour-runs. Work not completed in the period and work to be carried out onboard also can be shown here

- Documentation cards with details of items of equipment, work to be carried out, tools and spare parts required, the necessary safety precautions, records showing that the work has been done and notes for future reference
- · Work allocation board showing all operating staff on board and ashore
- Defect documents (defects recorded on the planning board that are outside the work schedule)

3.2.2 Condition Maintenance

Condition maintenance is designed to detect trends in the operating characteristics of equipment that indicate that deterioration has developed and therefore that maintenance is required. The equipment is monitored with periodic measurement of vibration and deterioration, slack nuts, the speed of the engine flywheel, gauge measurement of temperature and pressure, insulation testing to detect electrical insulation deterioration, and visual checks to detect wear, leakage, corrosion, etc.

An effective system of preventive maintenance will provide:

- Effective use of capital funds through tight budgetary control, with subsequent savings in maintenance and spare gear costs
- Greater availability of machinery and equipment with an eventual reduction in maintenance levels
- · Less expensive emergency repair and, where problems arise, quick diagnosis
- Proper maintenance coverage of the ships structures, accommodation, machinery and equipment
- · Effective use of plant, labour, time and maintenance of equipment.
- Increase in forecasting and plant planning ability and the highlighting of weaknesses or potential problems
- High staff morale, arising from increasing professional involvement and an increase in efficiency
- Effective and comprehensive monitoring and maintenance records with proof of effective operation
- A complete record of repairs and maintenance carried out onboard ship and ashore and a means of planning for the coming main event and voyage repairs with parts and service requirements, (Drewry: shipping consultancy)

3.3 Corrective Maintenance

Corrective maintenance is performed when the whole or part of the equipment fails. Figure 3.4 shows a technique for detailing the information stored for a corrective maintenance action. Before an equipment fails there will be a signal or notice of breakdown through information obtained by means of an electronic monitoring system. Corrective maintenance can best be implemented by using monitors to determine the performance of the machine. An example of this is the use of a vibrating monitoring instrument to determine the rate of vibration. Following the installation or overhaul of a machine, the overall vibration levels are recorded for selected points on the bearing caps. Points in the orientation vertical horizontal, and axial directions are recorded so that identical location readings are taken on a regular basis, for example bi-weekly. The vibration levels are compared to general data to provide an indication of sudden or gradual change in identically recorded vibration levels. If there is a change in the internal condition of the machine, it indicates a need to investigate it and correct the cause before damage occurs.



Figure 3.4 Corrective Maintenance Action

Source: ICMES 96, Safe and Efficient Ships.

3.4 Short Term Maintenance

Short term maintenance consists of general and detailed planned maintenance to achieve high availability and preparedness in a machinery plant for normal operation. It is also done in the case of disturbances as a result of a major overhaul or as major preventive maintenance. It is a safety maintenance system executed with the company's available resources. The company decides upon resource utilisation. Thus a maintenance policy is needed to ensure a high availability of equipment despite daily changes in plant output capacity. One major factor that can negatively influence short term maintenance is the mismanagement of the maintenance activities in the various sections of the maintenance department.

Delay in the procurement of materials is one of the main reasons maintenance tasks get slowed down. This problem affects most developing countries because most of the spares have to be purchased from foreign countries with foreign currency, causing delays. Meanwhile the plant suffers downtime and loss of service availability. The benefit of the short term maintenance policy is the continuity of plant operation with only minor interruptions. (Author's experienced.

3.5 Long Term Maintenance

Long term maintenance is a set of economic maintenance procedures and affects the operation costs in the long term. The benefit of a long term maintenance system is that it provides for a longer life of equipment. Therefore investment in new equipment will be unnecessary for a long time. The equipment will have a low depreciation value and a high second value when it becomes necessary to sell it.

3.6 Fault diagnosing

Fault-tracing constitutes an important part in the rationalisation of maintenance work. If repair has to be carried out quickly and efficiently, it is important that the fault is located and correctly diagnosed. Fault tracing time should be as short as possible. A fault tracer must work logically and methodically if time-consuming and expensive mistakes are to be avoided. A good fault tracer should have elementary knowledge in a wide area outside his area of competence. Figure 3.5 shows a typical fault-tracing flow chart for a hydraulic machinery system.



Figure 3.5 Typical fault-tracing flow for a hydraulic machinery system

Source: Maintenance and reliability Södertälje, February 1996.

Proper and successful maintenance programmes can provide excellent results in saving time, money, materials and effective utilisation of workmanship for the shipping industry. Below is a set of benefits and improvements that can be obtained from a properly implemented maintenance program:

Improvement of overall service quality

- · Increase in machinery availability
- · Improvement of safety and reliability of machines and equipment
- · Reduction in the number of down-times of machinery equipment
- · Minimisation of un-predicted machinery failure and unnecessary repairs
- Decrease in maintenance and operational costs
- Increase in the life span of machinery space and improvement in machinery space utilisation
- · Increase in the total production of the organisation
- · Increase in labour productivity
- Improvement in the working environment, human safety, etc. (David Mortram 1998)

CHAPTER. 4

MANAGEMENT AND MAINTENANCE STRUCTURE OF SHORE AND SHIPBOARD ORGANISATION

4.1 Management Organisation

The Sierra Leone National Petroleum company, the Sierra Leone Port Authority and the fishing companies are the largest companies in Sierra Leone with tankers, bergs, fishing vessels' tugs and ferries. The National Petroleum Company Marine Division (NAPETCO Sierra Leone Limited) is engaged in shipping and offshore bunkering. The organisation and administration are divided into shore management at the top level of management and shipboard management at the lower level of management. The top, or shore, management is headed by the Managing Director who is also the general manager of NAPETCO. He oversees all the activities of managers and administrators. Therefore both shore and ship engineering operations fall under his supervision. The functional divisions of the shore engineering operations are:

- Marketing Manager: takes care of finding cargo, arranging voyages, leasing and chartering of the four vessels owned by the company
- Operations Manager: deals with the ship's operations, maintenance and repair, plans ship vard repairs and also recruits, and arranges for contractors, etc
- Accountant: handles' allocations of funds, the budget, payments and financial controls including maintenance of separate accounts for every ship
- Others: include those who are responsible for the safe keeping of spare parts, the ship chandler, etc.

The ship management organisation includes direct engineering supervision by the Operations Manager and his team, comprised of mechanical and electrical engineers. The Operations Manager responsibilities also include:

- · Safe operation of the entire ship and machinery equipment
- Safe guarding normal operational conditions of every repaired maintenance at minimum cost and the lowest loss of the ship's operation time
- Co-ordination of the preparation and supervision of the performance of all emergency repairs to each ship



Figure 4.1 shows NAPETCO shore and shipboard mauagement structure

- · Purchase and supply of materials, fuel, lubricating and spare parts
- · Recruiting and assigning crew members to ship.

The shipboard engineering organisation is composed of the master (captain) who in the capacity of master is the head of the shipboard management and also the head of deck machinery and equipment maintenance. The engineering department is headed by the chief engineer who is slightly below the captain. He is in-charge of all ship machinery space and heavy deck machinery. (B. Butman 1998).

4.2 Skills and Current Maintenance Methods

The maintenance team at the Sierra Leone National Petroleum Company is composed of shore and onboard. The shore team is mainly contractors. All the vessels owned by the company are more than 20 years of age and there are constant breakdowns from main propulsion systems to auxiliary plants. Most small and large scale maintenance is corrective. Parts are replaced as and when they fail. There is no defined routine servicing, or maintenance procedures. Maintenance methods do not embrace routine services, such as the addition of lubricants and coolants and cleaning, etc. These are performed only when problems occur.

Planned maintenance procedures, (as mentioned in chapter 3) that are based on the manufacturer's recommendations regarding required services, time intervals (running hours, elapse time, etc.), and operational parameters such as pressure, temperature, vibration, knocking materials loss, etc. are not considered. Normally before the commencement of maintenance the manuals are not consulted to understand how the work should be performed. The lack of planned maintenance or maintenance procedures is due to the following reasons:

- Knowledge of the field: Almost all maintenance teams have little or no marine background
- Lack of training and experience. All training is internal, and informal There are no training procedures
- Lack of motivation
- Lack of spares and equipment
- No equipped shore or shipboard workshop for fabrication and other maintenance activities
- · No formal or established planning procedures exist

The shipboard team does minor maintenance and repairs. All major overhauling, repairs and maintenance are done by shore-based mechanical and electrical experts. None has a marine background. Due to the low number of experienced crew onboard major maintenance and repairs are subcontracted to shore staff, who have no experience with marine propulsion systems. Contracts are offered to them based on their experience and performance on shore mechanical and electrical equipment. No on-the-job training is provided to the crew.

As was stated previously individual chief engineers conduct maintenance to meet operational requirements using their own technical knowledge and judgement in terms of immediate needs. In NAPETCO there is no continuity in approach and maintenance priorities differ from one chief engineer to another. The net result is a wide variation of machinery condition and reliability (ie less reliable) within the vessels and across the fleet as a whole. Due to the over-maintenance of some equipment and lack of adequate maintenance of others there is no consistency. The inexperienced staff and lack of co-ordinated management effort in maintenance activities inevitably lead to frequent operational delays and breakdowns.

4.3 Effective Management

For an effective management organisation the present management structures should be modified as shown in figure 4.2. The functions need to be decentralised and each responsibility has to be defined.



Figure 4.2 Structure of Shore-Based Maintenance and Management

Figure 4.2 is drawn in two dimensions, the Managing Director is the overall boss. Below him are the Managers and below the Managers are the Administration and Personnel, Engineering Operations, etc.

The shore staff is composed of the following structure as shown in figure 4.2. Below the engineering operations responsibility is decentralised for the maintenance staff.

Diesel engineers are responsible for everything that has to do with the maintenance of diesel engines and related equipment.

Electrical engineers deal with all electrical installation, maintenance, repair and upgrading.

The Safety and Environment supervisors are responsible for the implementation and monitoring of safety procedures and equipment in ship operation and maintenance and repairs in order to prevent pollution and other hazardous accidents.

Crew manning personnel take care of selecting crew, training crew, medical care, office licensing, crew documents, etc.

Others include welders, technicians, etc.

The Operations Engineer Department takes the full responsibility for all maintenance and repairs for each voyage completed and whenever else necessary. During this period of work on machinery the onboard crew takes a short rest until the completion of all maintenance and repair. At the end of the voyage the onboard crew report all trouble shooting and abnormal performance of machinery to the shore maintenance team. The shore maintenance crew is trained not only on shore but also has experience at sea. The shore staff are qualified and experienced in accordance with Regulation III of STCW 95.

The shipboard management structure remains as shown in figure 4.1 but the level of responsibility is defined in accordance with the international standards.

4.3.1 Shore Maintenance Team

The shore maintenance team should be set up because of the constant changes within the marine industry, especially shipboard restructuring. If the option of low crew number is selected, the use of shore-based personnel cannot be avoided. The use of outside contractors should be inversely proportional to the number of crew.

In recent year's appliances and equipment on ships have been modernised, resulting in a decrease in the number of crew members. At the same time the fuel used in marine engines has become lower in quality for economic reasons. As a result, the structure of engines and auxiliaries have become more complex and the maintenance work more involved. (Field studies 1998).

Even in such circumstances, it is still important to maintain the reliability of machinery and improve the work ratio of engines. For this reason, although part of maintenance work has been shifted to land, work on ships is still important and a high level of technical judgement is necessary. Furthermore, maintenance work on machinery has been shifted from conventional corrective maintenance to preventive maintenance, and the necessity of foreknowledge has been recognised. Engineers now use computers with various kinds of software for failure diagnosis. These expert systems are highly valued. In land plants such systems have been put to practical use as a failure diagnosis device. The introduction of an expert system in ships is only a question of time. At present the installation of such system in ships is viewed as being rather difficult, however, especially in developing countries. The difficulties for developing counties in installing such a system are mainly financial.

4.3.2 Maintenance Preparation

Maintenance preparation may include the following:

- Work schedule
- Safety equipment
- Equipment for repairs
- Procedures
- Inventory of spare parts

Inventory is one of the major duties performed by shore based staff in maintenance preparation. It is a system used to organise and access the spare part's information associated with vessel machinery equipment, such as availability, quantity, recommended inventory levels, storage location, and pricing information. It identifies each piece of equipment, and is used to maintain inventory levels, record delivery receipts, and print bar code levels.

Information in the inventory management system is set-up in the following ways:

- Spare Parts Master Record screen shows detailed spare parts records and allows up-to-date revisions
- · Spare Part Status screen shows basic inventory information
- Parts Inventory adjustment option shows adjustments to inventory levels and allows up-to-date revisions
- · Print Part Levels option allows labels for the parts to be generated

The Spare Parts Status option displays a list of all spare parts belonging to a particular piece of equipment, along with the current inventory levels of those parts. This screen indicates the manufacturer part number, where the part is, how many you have and how many are on order.

The Parts Inventory Adjustments option is used to record spare parts inventory level changes. This screen allows the user to update easily the current inventory levels resulting from receipt of requisitioned inventory, inventory used, lost, damaged, or other miscellaneous inventory fluctuations.

4.4 Level of Authority

First and foremost shore management need to define the responsibly limits of shore maintenance teams and onboard maintenance teams. The following should be considered when doing this:

Budgeting: This is the total decided by the head office rather than by the sea staff.
 Focusing on ship machinery maintenance shipboard budgeting covers work done by shipboard personnel and the shore-based personnel. Confidence must be built between the head office and the maintenance team both onboard and ashore, to facilitate decisions about the amount of money to be used without consulting the head office. Above a certain limit the head office has to be informed on the purchase of spares and the amount spent related to maintenance.

It is necessary for shore based management to allocate a budget to be at the discretion of onboard managers. For shipboard budgeting to work it must be realistic. It must be big enough to cover the ship's needs and sufficiently flexible.

 Communication: In the broad sense, this is an important aspect of maintenance management. This is particularly true of shipboard maintenance management, because of the degree of isolation of the ships, job specification, reporting, etc. There can be confusion between the Master and the Chief Engineer/Mechanic about making certain reports to the head office, each one thinking that it is the responsibility of the other. Top management has the responsibility of clearly delineating authority and seniority. (Dr.B. Butman1998).

Decision making: Decisions about maintenance of ship machinery should be made by shore or shipboard engineers. Within his capacity as a senior engineer ashore or onboard the engineer must be given certain authority by which he can make decisions without consulting the head office, such as decisions about his subordinates, execution of duties, etc. Reports must be sent to the head office on the action taken. The key to any successful management plan is to allocate the decision-making authority and responsibility correctly within the organisation. (Dr. B. Butman).

4.5 Maintenance Record

Maintenance records have been one of the major factors affecting maintenance not only in shipping but in all sectors of the Maritime world. The Sierra Leone National Petroleum Company has no proper record keeping by either the shipboard or the shore-based maintenance staff. Maintenance and repair work carried out on an item or unit of equipment or machinery has not been compiled and kept for future reference. It is on the basis of asset history that senior maintenance staff are able to make decisions on the timing of equipment replacement, and on the suitability of machinery maintenance policies and strategies. Since no proper maintenance histories have been kept records are never available for engineers to carry out detailed analysis of component failure. Due to the poor maintenance history, analysis to reveal possible weaknesses in the plan or equipment is impossible.

4.6 Present Maintenance Policy

During this six year period, due to political instability, the Sierra Leone National Petroleum company has suffered a dramatic set back. The company has, therefore, been trying to reduce maintenance costs. The cut back was not based upon investment into improved equipment or improved operation and maintenance processes, but simply by reduced maintenance budgets. This was a relatively short term situation, however. Reducing maintenance in this way often leads to reduced reliability and increases out-of-service time. This effect then only leads to a reversal in maintenance policy and an increase in ship maintenance costs to reverse the situation. It also causes a sudden peak in on-board work requirements and a decrease in morale both on board and with the shore management involved. There were also sustainable risks involved because the ships had become less reliable.

CHAPTER 5

IMPROVEMENT OF MAINTENANCE METHODS

5.1 Traditional Compared to Modern Methods

The traditional method of maintenance is predominately used in both small and large scale industries (marine, wet and dry mining, manufacturing factories etc.) in Sierra Leone. Maintenance in Sierra Leone is still performed by looking at the individual equipment manufacturer's recommendations and building up an overall maintenance program from them. Some times the program and schedule are not followed. The human senses are usefully employed (sight, hearing, smell and touch) to determine whether a machine's condition is satisfactory or not in the broadest sense. Individual chief engineers conduct maintenance to meet operational requirements using their own technical judgement in terms of priorities. There is no continuity of approach in a long term sense, as maintenance of some equipment and lack of adequate maintenance of others. The net result is a wide variation in machinery condition and reliability within vessels and across the fleet as a whole. (Author's knowledge)

Machinery maintenance is gradually changing in developed countries into a more reliable and safe maintenance scheme. The maintenance routines for individual machinery and equipment are now in the process of modification through operational experience. The levels of unscheduled maintenance are presently falling. (Centenary Year Conference on Marine Engineering Now and the Future 17 - 18 July 1989) From the results of the investigation by British Petroleum Engineering Division, (shown in figure 5.1) 50% of condition and performance methods are in use in most developed shipping companies. The traditional methods (running hours, life, breakdown, calendar) are disappearing in the industry. The overall maintenance

effort has remained high and the cost of spares has risen. This method has made the reduction of maintenance crew onboard shins become a success. A high degree of continuity in machinery maintenance is achieved in spite of the reduction of crew The change from the traditional to the modern type of maintenance methods has been better realised by well established shipping companies like BP, MARSK LINE etc. and not yet realised in National Petroleum Company or in Sierra Leone overall. The application of this philosophy by Sierra Leone would enable the engineer to conduct maintenance only when it is necessary, i.e. when the condition of the machine deteriorates to a level where its performance drops off or it becomes unreliable in oneration. All machines wear naturally with time, due to friction, looseness, imbalance mis-alignment and so on. If the level of deterioration could be monitored at regular intervals, and a trend established, the engineer could reliably predict when the machine or equipment required corrective maintenance and plan the maintenance schedule in advance. This technique is known logically as predictive maintenance (as described in Chapter 3) through condition monitoring or condition based maintenance (BP Shipping Limited Division).

In recent years instruments and tools have been devised to supplement the natural attributes of the engineer pressure gauges, thermometers, ammeters and flow meters. They enhance his ability to establish that a machine is operating satisfactorily. Modern maintenance has an advantage over the traditional type. It saves time, reduces maintenance costs, and it makes it possible to reduce crew on ship and within the shore-based team. Research was carried out by BP Shipping Company proving that 37% (percent) of the total maintenance time was saved by using condition monitoring as shown in table 5.1. Four machines were used to compare the traditional (calendar system) and the modern methods (condition system) to find the best applicable system for each piece of machinery. There was a reduction in maintenance time when modern maintenance methods were used as shown in table 5.1. There was time reduction only when using the modern (condition monitoring)

maintenance system. Whilst such instruments largely fulfilled a performance monitoring role rather than a condition, if a machine appeared to be performing correctly within its design parameters, it was reasonable to assume that its condition was acceptable.

The introduction of the rotating machinery vibration measurement and analysis techniques have given the engineer the vital tool he has needed to firmly establish what the (performance) monitoring equipment had until this time indicated. In addition, it allows detection of early condition deterioration that may not have affected the machine's performance and which would not be evident from conventional instruments.

CALENDA R			37%		CA
CONDITION AND PE	RFORMAN	CE	50%		00
LIFE			3%		
RUNNING HOURS			5%		RU
BREAKDOWN			5%		BR
	RU 11 5% 3%	BR 5%		CA 17%	
	50%	\sim	-		-



Source: BP Shipping Limited Engineering Division

Condition monitoring is a more recent phenomenon and is still comparatively rare. It involves vibration measurement for rotating machinery and the comparison of recorded results with a theoretical "vibration signature" thus identifying potential equipment failure fairly precisely. Such techniques have the added advantage of leaving machinery alone whenever possible, rather than dismantling them, which can often, in and of itself, cause problems in the future. For ball and roller joints, shock nulse measurement is required.

It can be seen from Table 5.1 that using condition monitoring saves more than 20% of the time spent in maintenance.

Experimental data for condition monitoring systems in four plants in Norway has been analysed also. The economic cost/benefit evaluation shows a high return on investment. (ICMES 1990).

	Calendar system	Condition system	Percentage (%)
ITEM	(Traditional method)	(Modern method)	reduction
	Hours	Hours	
Inert gas fan	568	256	55
Cargo pumps	541	424	21
Feed water pumps	569	423	26
Alternators	186	69	63
TOTAL	1864	1172	37

Table 5:1 Maintenance man-bours reduction using condition Based system compared to Calendar system

Source: BP Shipping Limited, Engineering Division

The benefits of condition monitoring as seen in figure 5.1, and table 5.1 and the cost/benefit evaluation of the four plants in Norway, compared to corrective and predictive maintenance, are reduced downtime, reduced maintenance costs and fuel costs. These are achieved through:

- · Less unforeseen breakdown by early detection of incipient failures
- Substitution of preventive maintenance (PM) routines by condition-based maintenance achieving increased service intervals and simplified periodic processes
- Reduced fuel cost due to monitoring of thermal efficiency parameters and better time spent washing compressors, replacing seals, etc.

Hence to improve machinery maintenance the modern method (condition monitoring) needs to be gradually replacing the traditional method.

5.2 The Role of Shipboard and Shore-Based Staff

The area of refitting and maintenance management in the fishing industry and National Petroleum Company can best be separated into (a) shipboard activities and (b) contracted repairs ashore. In each of these companies the guidelines for established shipboard maintenance standards and procedures are provided by the shore superintendent/chief mechanical engineer. He should provide vital engineering support including troubleshooting, analysis of shipboard technical data, development of manufacturing procedures and requirements for maintenance and repair, etc. The lead role in managing the established ship board maintenance programme rests with the chief engineer. The planned maintenance and material management portion of the management of software packages can assist the chief engineer with his duties. It is slightly different in Sierra Leone as no software package is available in oil tankers nor in the fishing vessels.

Management of contracted maintenance is handled by shore staff, for the simple reason that the engineers are in a position to supervise or arrange for the supervision of the repairs, as well as deal with pre-and post-contract matters. Furthermore, they are usually the most experienced in project management. The chief engineer has two extremely important functions to perform: drawing up defect lists and providing onboard inspections on behalf of the owner.

Other functions of shore based personnel include:

- · Purchasing and procurement of materials, fuel, lubricants, and spare parts
- Analysis of shipboard technical data

The safety and environmental protection division are responsible for the implementation and monitoring of safety procedures and requirements in ship operations and maintenance and repairs in order to prevent pollution and other hazardous accidents.

Shore-based and onboard maintenance teams have been fully successful in Japan because of the high wages paid to crew. The onboard maintenance staff basically perform minor maintenance work. Their major activities are to monitor the performance of the machinery. In another words, they are operational engineers. All major maintenance and repair are done by the shore staff. This includes overhauling and major replacement. At the end of a voyage the onboard engineers submit their observations and report faults detected to the shore-based team.

5.3 Computer and Maintenance

Within the framework of growing maintenance complexity the advent of relatively inexpensive, lightweight and portable microcomputers was an obvious tool to add to maintenance systems. The first user friendly (at the time) computerised maintenance systems onboard and ashore appeared at the beginning of the 1980's. However, the computer technology of that time was behind the maintenance demands of the ship operator (as any system to organise maintenance requires more memory than the 16bite computer provided). The efficiency of computerised maintenance was limited by the capabilities of the computer, specifically its memory allocation and speed. Hence the various software modules for maintenance (assets, maintenance schedule, crew and stock control) were slow to use.





Source: Drewry shipping consultant

Computers can assist in planning, starting with the initial stage through to the organisation of individual maintenance tasks, the organisation of personnel and the snare parts inventory.

The computer analysis of machinery is made by (automatic) sensing parameters such as vibration, shock pulse, temperature and power. The parameter measures are then compared with an ideal model and adjustments made to the machinery's operation and maintenance schedule as necessary. Figure 5.2 shows the function of the computer in machinery maintenance, in monitoring, storing data, analysing data, and interpreting information, all of which have been of great help in maintenance.

5.3.1 Network Between Ship and Shore-based

Even under the circumstaice discussed in Chapter 4 section 3.1 paragraph 2 (crew reduction and fuel used in the marine engines has become lower in quality) it is still important to maintain the reliability of machinery and to improve the work ratio of engines. For this reason, though part of the maintenance work has been shifted to land, work on ships is still important and a high level of technical judgement is necessary. Furthermore, maintenance work on machinery has been shifted from conventional corrective maintenance to preventive maintenance, and the necessity of foreknowledge has been recognised. Various kinds of software for computers have been developed and failure diagnosis expert systems are highly valued. In land plants such systems have been put to practical use as failure diagnosis devices.

The introduction of an expert system in ships is only a question of time, but the technique has not yet been established. Installing such a system in every ship would be rather difficult especially for developing nations because of equipment costs. However, monitoring systems for machinery do exist from the monitors to the control department on land. The centralised remote monitoring system can be

monitored in control departments on land. Telephone lines provide the communication link allowing shore based experts to provide input into onboard maintenance problems. Maintenance control and failure diagnosis of machinery and related equipment also can be handled by expert shore personnel using this system. This system can function for a considerable number of ships.

Maintenance Management Information System (MMIS) plays a key role in the implementation of modern maintenance methods. MMIS developed due to the complexity and demand for the variety of resources and operations involved in maintenance. The MMIS covers all the maintenance related operations onboard and ashore for the purpose of optimising the implementation of the maintenance policy. Figure 5.3 shows the operational structure of a maintenance management information system. Applying the MMIS, the following should be considered:

Ability to perform the operations

- 1. Internally:
- Handle quickly a significant volume of record maintenance data in an orderly manner
- Transmit maintenance information from shore to ship and vice-versa integrating the maintenance of the ship with that of others in the fleet
- Link the maintenance records with the performance and conditions monitoring system of the ship

2. Externally:

- Access important information from other useful data banks, such as those of suppliers, manufacturers, shipbuilders, etc.
- Link the ship office with other users, such as marine machinery manufacturers, shipbuilders, technical institutes, etc.

Software involvement in support of operations

- 1. Internally:
- · Provides inventory status module of all the ship's machinery components
- · Provides corrective and preventive maintenance module
- Provides maintenance analysis module
- 2. Externally:
- Provides performance and condition specifications on all machinery
- · Provides technical reports

Within the internal domain, the inventory module contains all the information relevant to the previous and current status of the ship machinery characteristics, its components installed and in stock, and the materials and consumable of maintenance. This record is updated continuously, with the changes in status of all elements of the inventory during the operation of the ship.

The preventive and corrective maintenance module contains the work order for the execution of specific maintenance jobs on specific components. The description of those components comes into the work order from the inventory modules, and the description of the schedule or corrective maintenance jobs (including the necessary spares) follows the maintenance specifications of the suppliers and the maintenance experience of the ship. On completion of the maintenance job, the spread sheet updates the information from the work order, as far as the latest conditions of the components and the status of the spares and maintenance consumable are concerned.

The maintenance analysis module improves the organisation, execution and control of maintenance jobs, and controls the level of preventive maintenance (PM) by processing and assessing the data of the inventory status module (i.e. grouping the information by frequency of faults or defects according to manufacturer, type of



MAINTENANCE ANALYSIS MODULE

Failure or Defect Sensitivity Analysis of Component i.a.w:
 I. Mode of Failure or Defect
 I.2 Ship's System
 I.3 etc.
 Adjust W.O.i.a.w.
 Z.1 Performance Monitoring
 Z.2 Condition Monitoring
 Z.3 Cost of Maintenance
 4 Failure of Defect Sensitivity Analysis

Figure: 5.3 Operational Structure of MMIS Source: Management and Operation of Ships (IMAS95)

maintenance action, etc.) and by utilising the information produced by the performance and condition monitoring system of the ship.

The module of the internal domain:

- Informs the inventory module of the description of the ship machinery and its components on the delivery of parts and continuously provides the necessary updates on component specifications
- Informs the maintenance module of the necessary methods and techniques of maintenance
- · Informs the maintenance modules of novel methods and techniques.

The hardware structure of the MMIS contains the computers and their peripherals onboard and ashore and the communication media (modems, telephones, facsimiles and satellite systems). Computer technology today offers the ability to cover the maintenance needs of any shipping company in a cost effective manner, by reliably and quickly processing a large quantity of maintenance information. Satellite links are very important for the efficient transmission of maintenance data.

5.4 Training for The Non-Experienced and Experienced

The high level of ship machinery technology has resulted in complex maintenance and repair of machinery equipment and other appliances. Technology is also providing some assistance in meeting new demands on crew reduction and safety.

For maintenance to cope with the continuous advancement of technology, continuous training is inevitable in the industry.

Training should not only be considered for top management levels but also middle and low level maintenance staff. The training should include experienced and nonexperienced sea persons. As technology of ship machinery changes, the technology of training will need to keep pace, or even move ahead of it to help the maintenance staff adapt to new ideas and changes.

The types of training management that should be set up are **On- the- Job Training** and **Off-the Job Training**. Network diagram (Figure 5.4) shows the areas to be considered and the links of net work.



Maintenance Staff

Source: Japan Seafarer's Management System 1997

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

Maintenance decision-support models have been the subject summarised in this dissertation. The presentation from this study and the experience gained in the industry, indicate that a potentially significant maintenance cost may not result in increased reliability and availability. Decision-making requires relevant experience data. The collection and the presentation of such data through operators, should be enough in the sector of maintenance. With computerised maintenance planning and information systems (Chapter 5)now introduced in most shipping companies, the quality of maintenance has improved. Data will be available in the future to benefit both the designer and the operator.

From the discussion in Chapter 2 and Chapter 3 it can be deduced that the maintenance engineering concept is based on the assumption that maintenance does not start with activities to keep an existing installation running but starts on the drawing board and ends after scraping the installation. To keep machinery in perfect running condition maintenance should not be based on corrective methods but planned and preventive maintenance. Corrective maintenance should be the last result that is be applied when a machinery fails unexpectedly.

Chapter 4 explains that maintenance work in Sierra Leone is still viewed as a low priority and as a result, little or no management effort is applied to it. As has already been shown in Chapter 2, expenditure on maintenance can constitute a significant proportion of vessel operating costs and maintenance. Therefore, it should be treated as part of the overall management task. From commercial and operational view points it is important that maintenance be fully integrated with all other aspects of ship management. Operationally, the maintenance function is to be effective. Factors such as safety, staff skills and levels, spare parts gear, stock levels, data acquisition and analysis and communication have to be considered.

Chapter 5 has drawn attention to the rapid rate of growth in the development of maintenance (Figure 5.1). Maintenance is moving rapidly from the principle of fixed intervals and planned overhaul or replacement towards a reliability-centred approach. In a reliability-centred approach maintenance is tailored to the specific requirements taking into account the specific piece of equipment's operating context.

Based on the author's study and five years as vessel machinery operator, maintenance and co-ordinator between management and crew the following conclusions are made. The vessel's ownership (company) philosophy is an important influence on maintenance and repair policy. The increasing trend towards the use of third party ship management companies operating under tight budgetary and commercial constraints on behalf of "asset playing owners" (owners, managers or operators) with limited knowledge of the operating and technical aspects of shipping has had an overall negative effect on short and long term preventive maintenance.

In Sierra Leone the performance of maintenance by the onboard crew and shore based maintenance team would have been better and more effective if on-the-job training had been provided to the crew.

From the discussion in Chapters 2 and 3 it can be concluded that maintenance objectives are not only to ensure the availability of equipment and machinery but also include:

- An adequate level of equipment efficiency
- Controlling the rate of equipment deterioration
- Maintaining a high level of safety (STCW, MARPOL, SOLAS)
- · Complying with rules and regulations
- · Maintaining the second-hand or scrap value of the vessel

Recommendations

In the present prevailing market conditions any level of vessel "down time" must be unacceptable, because it is extremely costly in terms of lost revenue. The following should be considered to maintain and minimise machinery breakdown and reduce maintenance cost:

- Training aiming at increasing technical knowledge and skills, and the introduce of new ideas and technology to cope with increasingly complex equipment
- High level of maintenance

If the low crew number option is to be selected, the use of shore-based company staff, subcontractors and riding crew should be an alternative.

- Number of crew and composition using planned maintenance i.e by using low crew
 number with skilled or high crew number unskilled. Unskilled crew although
 costing less in wages, costs more overall because of higher maintenance costs than
 does a high cost skilled crew. High professional, well trained, profit motivated,
 properly remunerated people who derived real job satisfaction, that is, success
 against lower cost competition could be made.
- Allocation by top level management of decision-making authority and responsibility correctly within the organisation
- Use of the latest developments in the fields of computer and communication technology to reduce ship maintenance cost and improve the quality of services, whenever funds are available.

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APPENDICES

Appendix 1

REPAIR SPECIFICATION

Outline: The pipe detailed below is to be renewed. Allow for the removal of the pipe from its site, renewal and subsequent replacement using new bolts, nuts and joints of repairs supply. Any disturbed lagging, pipe clips or flange muffs to be reinstated to the satisfaction of owners representative. Pipe to be selected.

Site: Port side engine room, lower deck above evaporator.

Job aids: Staging to a height of 2 metres

Tests: Pressure test to 4 bar to be witnessed by nominated member of ship's staff.

Materials: Mild steel wall.

Connections: Flanged. Each flange secured by 4 x 16 mm bolts and nuts. Bolts 60 mm long. Existing flanges to be re-used.
	Main	Pipe	
No.	Bore	Length	Bends
1	20cm	20cm	2X 90°
		Brancnes	
2	Bore	Length	Bends
	locm	30cm	Nil

Bosses Nil Reducers Nil Clips 2, each secured by 4 X 12mm bolts

Renew Pipeline



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REPAIRING AND MAINTENANCE COSTS EXPENDITURE CATEGORIES

DIRECT	INDIRECT
1 Main Event Repairs	1 Ship Staff Costs
Dry-docking Surveys/Repairs	Running Maintenance/Repairs
Hull Fabric Maintenance	Continuous Machinery Surveys
Owners Routine Requirements	Planned Maintenance
General Repairs/Maintenance	Data Collection/ Recording/Feedback
	Training
· · ·	
2 Voyage Repairs	2 H.O. Administration.
Specialist Services	Maintenance Systems.
"Turn Round" Surveys	Data Processing/Analysis
Essential Repairs	Budgeting/Control/Monitoring
	Main Event- Specifics
3. Spares Gear/Equipment	- Tender Analysis
Running Maintenance/Repairs/Surveys	- Supervision
Main Event Repairs.	- Accounts
Voyage Repairs/Servicing	Voyage Repairs - Accounts
Modifications	Spare Gear-Purchase/Accounts
	· · · · · · · · · · · · · · · · · · ·

PROJECT MANAGEMENT

TODIC	DI /	NNI	INC	OF	ON-F	IO A R	D F	FP	A 1 R S	OF	4	MA	CHI	NEDY	/ UNI	(T
IUPIC:	FL/			Or.	011-1	U AR	_ r		-u - w	· • •	~	14154				

ACTIVITIES DESCRIPTION	0.0	FC	-	1.0		
	00	ES	F	LS	LF	S
Prepare work schedule						
	1	0	1	0	11	0
Survey of machinery		1				
	6	1	7	1	7	0
Develop a list of maintenance						
procedures required	1	7	8	7	14	0
Г			1			
Carry out necessary design	3	7	10	7	16	6
				-		
Check inventory of spare parts	2	1/	9	/	9	0
Identify additional spares required						
	1	9	10	9	10	0
Fabricate replacement parts (not						
available in stock)	6	10	16	10	16	0
Identify and obtain work						
force	I	8	9	14	16	7
Provide equipment for repairs	2	8	16	14	16	0
Provide materials for repairs	2	8	10	14	16	6
Provide safety equipment	2	12	30	28	30	10
Cominal and an aim	1.	1.	20	1.0	20	
Carried out repairs	14	10	130	10	130	10
Performed test and trials	,	20	21	20	21	6
Deliver	1:	30	1 20	30	31	
	Prepare work schedule Survey of machinery Develop a list of maintenance procedures required Carry out necessary design Check inventory of spare parts Identify additional spares required Fabricate replacement parts (not available in stock) Identify and obtain work force Provide equipment for repairs Provide materials for repairs Provide safety equipment Carried out repairs Performed test and trials Deliver	OD OD Prepare work schedule 1 Survey of machinery 6 Develop a list of maintenance procedures required 1 Carry out necessary design 3 Check inventory of spare parts 2 Identify additional spares required 1 Fabricate replacement parts (not available in stock) 6 Identify and obtain work force 1 Provide equipment for repairs 2 Provide safety equipment 2 Carried out repairs 14 Performed test and trials 1	OD ES Prepare work schedule 1 0 Survey of machinery 6 1 Develop a list of maintenance procedures required 1 7 Carry out necessary design 3 7 Check inventory of spare parts 2 7 Identify additional spares required 1 9 Fabricate replacement parts (not available in stock) 6 10 Identify and obtain work force 1 8 Provide equipment for repairs 2 8 Provide safety equipment 2 12 Carried out repairs 14 16 Performed test and trials 1 31	OD ES F Prepare work schedule 1 0 1 Survey of machinery 6 1 7 Develop a list of maintenance procedures required 1 7 8 Carry out necessary design 3 7 10 Check inventory of spare parts 2 7 9 Identify additional spares required 1 9 10 Fabricate replacement parts (not available in stock) 6 10 16 Identify and obtain work force 1 8 9 Provide equipment for repairs 2 8 16 Provide safety equipment 2 12 30 Carried out repairs 14 16 30 Performed test and trials 1 30 31	ODESFLSPrepare work schedule1010Survey of machinery6171Develop a list of maintenance procedures required1787Carry out necessary design37107Check inventory of spare parts2797Identify additional spares required19109Fabricate replacement parts (not available in stock)6101610Identify and obtain work force18914Provide equipment for repairs281614Provide safety equipment2123028Carried out repairs14163016Performed test and trials130313031	ODESFLSLFPrepare work schedule101011Survey of machinery61717Develop a list of maintenance procedures required178714Carry out necessary design3710716Check inventory of spare parts27979Identify additional spares required1910910Fabricate replacement parts (not available in stock)610161016Identify and obtain work force1891416Provide equipment for repairs28161416Provide safety equipment212302830Carried out repairs141630163031Defuerer13130313031

OD = Original duration,

 $\mathbf{EF} = \mathbf{Early}$ time of finish = $\mathbf{T}_{\mathbf{EF}}$

ES = Early time of start T_{ES},

S = Starting time

 $LS = Late time of start = T_{LS}$

F = Finishing time

Standard Maintenance Verbs:

Reports maintenance and repair works require the use of a limited number of verbs.

- Activity
 Common used verbs

 Machinery Operation:
 Stand by, Start (up), Open on/off, Cut Out, Put in/on Supply, Operates, Run, Stop, Close, Shut off/down, Connect/Disconnect, Engage / Disengage, Take over, Change over, Turn on/off, Vent, Take a reading of, Take a sample of etc.
- Maintenance and Repair Tighten/untighten, Make tight, Secure, Slacken, Loosen, Mount/Dismount, Fit, Fix, Refit, Assemble/Disassemble, Reassemble, Remove, Withdraw, Insert, Change, Replace, Set, Adjust, Regulate, Clean, Sound, Drain, Empty, Dry, Fill, Refill, Hold down; Maintain, Renew, Restore, Lift, Host etc.
- Ascertaining Condition: Inspect, Examine, Check, Ascertain, Assess, Go and read, See that, Measure, Gauge, Control, Find, Observed carefully, Take a reading of, Take a sample of, etc.
- Safety: Make sure, Ensure, Be sure to, Be careful of, Avoid, Try to..... if, Watch carefully, Pay (close) attention to, Keep in mind, etc.

Source: Josip Luzer 1998.

TECHNICAL SYSTEM AND SUB-SYSTEM THAT COMPRISES A SHIP

MACHINER



Source: Drewry Shipping Consultants

AWSY

WORLD MARITIME UNIVERSITY Malmö, Sweden

COMPARATIVE ANALYSIS AND IMPROVEMENT OF ONBOARD AND SHORE-BASED MACHINERY MAINTENANCE IN SIERRA LEONE

By

IBRAHIM C. SESAY SIERRA LEONE

A dissertation submitted to the World Maritime University in partial fulfilment of the requirements for the award of the degree of

MASTER OF SCIENCE

in

MARITIME EDUCATION AND TRAINING (ENGINEERING)

1998

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Declaration

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

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



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Special thanks to my son, Michael Samuel Sesay, for taking the pain of my absence throughout the two year period.

ABSTRACT

Title of dissertation: Comparative Analysis and Improvement of Onboard and Shore-based Machinery Maintenance in Sierra Leone

MSc

Degree:

This study is based on the description of how machinery maintenance can be improved in Sierra Leone. The study explains the development that has taken in current years on machinery maintenance. It also analysis the previous methods dominating maintenance and the changes that are presently taking place in upgrading maintenance to meet crew reduction and technology advances.

The author also looks at the management system of the shore-based and shipboard segments of the shipping industry and describes how responsibility should be distributed for an effective maintenance process. Responsibility should not be centralised but decentralised and evenly distributed throughout the organisational pyramid. The use of computers in machinery maintenance assists in the following areas:

- Implementation of the modern maintenance methods (Reliability Centred Maintenance).
- · Communication to transmit maintenance information from onboard to shore.
- · Documentation of repair work and inventory of spare parts.

The objectives of IMO and other international organisations also are important components in a quality maintenance program.

The marine engineer not only keeps machinery effective and reliable but also plays a role in protecting the environment, keeping people safe and protecting property.

This dissertation is a guide for the onboard shipboard maintenance team, the top management team and people involved in port and shore machinery maintenance. **KEYWORDS:** Engineer, Machinery, Maintenance, Reliability, Repair, Shipboard.

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LIST OF ABBREVIATIONS

HFO	Heavy Fuel Oil
ICMES	International Co-operation on Marine Engineering Systems
IMarE	Institute of Marine Engineers
IMO	Internation Maritime Organisation
ISM	International Safety Management
MARPOL	Marine Pollution
MMIS	Maintenance Management Information System
MMS	Marine Management System
NAPETCO	National Petroleum Company
NO _X	Nitrogen Oxides
РМ	Preventive Maintenance
RCS	Reliability-Centred Stockholding
SOLAS	Safety of Life at Sea
so _x	Sulphur Oxides
STCW	International Convention on Standards of Training, Certification
	and Watchkeeping for seafarers

LIST OF DEFINITIONS

Condition-based maintenance: Performing maintenance tasks on the basis of equipment condition and performance.

Condition monitoring: Measurement intended to determine the condition of equipment, to asses its need of maintenance

Downtime: Period of time the ship or a system, or a piece of equipment is unusable while it awaits maintenance to be completed.

Maintenance: An action which is carried out to return or restore an item to an acceptable standard.

Reliability-centred maintenance: Process which considers the physical asset as a whole and the defines what needs to be done to ensure that it continuous to carry out it's required functions in its operational environment.

Reliability-centred stocl holding: Rational methodology for determining the stock of spare parts need to hold to support your maintenance and production operations.

Ship machinery: Main propulsive system and various auxiliary systems supplying the necessary marine machinery and hull services.

Chapter 1

INTRODUCTION

Maintenance is the key concept in the availability of ships, their efficiency and service and, infact, in the operation of all physical assets in the marine industry. Lack or negligence of maintenance will not only result in disruption of services, but also in disastrous results to the marine and port industries and to the economic degradation of a nation. The need to keep within a set scheme in an unpredictable ocean environment and to complete a safe voyage calls for an appropriate maintenance method.

The efficiency and continuity of the shipping industry and port operations basically depend upon the availability and reliability of the machines and equipment used. Therefore, these machines and equipment should always be ready and in running condition.

Maintenance is a service that has specific value to the production process. It is an organisation that provides an increase in productivity and profitability. Therefore, the materials arranged in this dissertation should not only be the concern of those who are directly involved (shore-based and onboard maintenance staff) but also to those indirectly involved such as top management and decision makers.

1.1 Purpose of the Study

In previous years, there were more than five fishing companies in Sierra Leone. Each operated a fleet of more than a hundred vessels. There were a few oil companies operating oil tankers, barges and tugs of varying sizes and ages as well. At present these companies have only approximately 30 to 50 ships in their fleets in operation due to a number of reasons, but the major ones are:

- Lack of training: Training that could advance the skill level of personnel and cope with advances in technology is normally not provided to maintenance crew.
- Spare parts availability: It is always a problem to procure spare parts due to the foreign exchange rate and transhipment.
- Political stability: Changes of Government or the Government not being recognised by international committees has a negative effect on ship machinery maintenance.
- Lack of commitment: Because of the low wages and motivation maintenance crew or staff offer less priority to their work.

Ranking the contributing factors in terms of damage or total loss to a vessel lack of training is the highest. This paper will assist decision makers, planners and those who actually do the maintenance in minimising accidents, breakdowns and sinkings of vessels. This document will highlight the new development that has taken place in ship machinery maintenance pointing out necessary action that can be taken to move gradually from the traditional to the modern maintenance system. This paper also will provide materials to sensitise decision makers, planners and those who execute ship machinery maintenance to understand and provide answers to questions of this type:

- · What is to be maintained?
- · How is to be maintained?
- When is it to be maintained?
- · What maintenance system is most effective?

Shipping and fishing companies need to understand that the concept of maintenance is based on the assumption that maintenance does not start with activities to keep an existing machinery running/operating, but starts with the negotiations to purchase a vessel and ends after scraping.

The materials discuss in this dissertation will help maritime authorities understand how important the introduction of computers to ship machinery machinery. For the shipboard system this means training mariners beyond their traditional maritime skills if they are to develop the proper confidence to operate such systems reliably and safely.

The author has encountered a series of obstacles during the collection of the necessary materials, data and information. One of them was poor feedback from correspondence with consultants, companies and shipping agencies. As a result, no information or data from shipping companies, fishing companies nor Sierra Leone was gotten directly. Therefore, all the materials on this dissertation were written from experience and from materials collected and written about in maritime news letters, publications and sources from different countries.

1.2 Methodology

This study has been prepared using descriptive methods obtained by reference to books, lecturer handouts, reports from conferences, publications on marine engineering reports and experience gained during the field trips and in the work place.

Chapter 1 is a general introduction to the subject, purpose of the study and a description of the difficulties encountered during the collecting of material.

Chapter 2 highlights the objectives and factors affecting maintenance and the functions of marine engineers. This chapter clearly explains that a marine engineer's function is not only to keep machinery running but also to meet international standards for safer shipping and cleaner oceans.

Chapter 3 gives an analysis of the different types of machinery maintenance in general. This chapter explains what is meant by "planned" and "unplanned" and explains the application of each on the job.

Chapter 4 describes the maintenance organisation of the National Petroleum Company and how it is structured. It explains the company policy and the maintenance problems encounted by the company.

Chapter 5 explains the difference between the traditional methods and the modern methods of maintenance and the role of shipboard and shore-based personnel. This chapter highlights the importance of using a network between shipboard and the shore-base in maintenance and also suggests ways maintenance can be improved in the industry.

Chapter 6 concludes the study and gives recommendations for an effective and efficient maintenance. The author gives his opinion on the use of low crew number and the composition of the crew.

Chapter 2

OBJECTIVES OF MAINTENANCE AND FUNCTIONS OF MARINE ENGINEERS

Why, after a machine is constructed and in use, is it left with no maintenance?. This chapter explains the need for maintenance every day at a given time or on the verge of failing or after failing. The basic objectives of maintenance are:

- To manage the maintenance department so as to minimise total operating costs
- · To keep facilities and equipment operating in good condition
- · To keep facilities and equipment operating the optimum percentage of the time

 To avoid ship component failure, which, if failed, would affect the safety of the ship or might cause delays, damage to the cargo, or other serious losses like fines for pollution, legal costs, etc.

2.1 Objective of Maintenance

2.1.1 Prolong the Life Span of Machinery

Ship and shore based machinery is initially designed to fulfil designated efficiency requirements by the manufacturers. No matter what the technology of the system, it is impossible for it to operate and perform near to this level without maintenance. In the absence of maintenance the design efficiency parameters will fall below their expected value. A machine, therefore, must be maintained continuously to prolong its life span. Maintenance of machinery starts in the design stage and needs to be continued until the vessel is scraped. Therefore, to prolong the life span of machinery, all sectors of operation and maintenance considerations in the design of equipment is an important factor to bear in mind. From design to operation the equipment must undergo stringent quality control procedures. This factor must also be incorporated in planning maintenance strategy as it can make the equipment run almost indefinitely without major maintenance costs. The design from raw materials to the finished product must undergo strict quality control procedures. Lack of design consideration will cause endless work load maintenance tasks due to persistent breakdowns during the operation process. This is because the design of the equipment may not be able to carry the designed load. This in turn will cause excessive maintenance. Hence design is a vital factor to be considered to prolong the life of a vessel.

2.1.2 Reliability and Effectiveness

Ship machinery reliability is fundamentally important to all departments of the industry, not just the maintenance team. The RCM (Reliability Centred Maintenance) philosophy suggests that the overall requirement for the ship and it's systems (including machinery) should primarily be reviewed by a small team of not more than five or six people representing all departments involved in operating the ship. The starting point includes deciding what the objectives of the necessary maintenance are and what standards need to be applied. The team's function is to concentrate on analysing the maintenance requirements of each individual item of equipment or machinery, after looking first at the ship as a whole, and secondly at its systems. It also needs to consider what could go wrong with the vessel and its components. The logic is that if the ship and its machinery have been designed accurately, any problem with them must result from improper maintenance or lack of knowledge of the system.

The next point is to consider what the effect would be for each failure mode, and what processes and resources might be necessary to improve reliability. The advantages of this approach include not only the value of looking at the ship from an overall reliability view point but also the benefit of the inter-dependent team work involved.

Failures' modes can also be caused by poor communication and co-ordination between sea staff and the head office. Therefore, improving communication between sea staff and the head office (commercial and technical) reduces failure modes and increases reliability. This can also facilitate a better understanding of the organisation's objectives. If well-implemented individual departmental and organisational strengths and weaknesses are also highlighted, an increase in respect and understanding will be the result. (Dr. B. Butman 1998).

Reliability and effectiveness at the Sierra Leone National Petroleum Company are continuously deteriorating because the maintenance team is not committed for the following reasons :

- Lack of communication between onboard staff and management ashore
- · Lack of motivation
- · No defined responsibility between shore-based and onboard maintenance teams
- · Shore based staff have little or no marine background (Author's knowledge).

2.1.3 Environmental Protection

Environmental protection is presently the key burden issued for the marine industry. The challenge is to minimise pollution so that the environment will be friendly and safe to all its inhabitants.

Approximately 4% of gross sulphur oxides (SO_x) , together with nitrogen oxides (NO_x) , are thought to be responsible for some deforestation and extermination of fishes in lakes due to acid rain and discharges from national and international sea

born trade. (Nippon Kaiji Kyokai, 1996, 15). Research has shown that the pH value of drainage downstream of the scavenging air cooler is approximately 4 - 5 and this is caused by the souring of atmospheric air with rust generated in parts surrounding the scavenging air chamber. (Nippon Kaiji Kyokai 1996 15).

To minimise environmental pollution the main propulsion and auxiliaries should be maintained for less production of the above gases. All machinery must be maintained to avoid oil, dangerous gases and cargo from spilling into the sea and air.

2.1.4 Commercial point of view

Well-maintained machinery can run at a reasonable cost of operation and maintenance can keep it in service for a longer period of time. This scenario generates more revenue. To achieve this goal of a high profit margin the level of maintenance must be maximised. To achieve this goal maintenance availability and reliability must be optimal and maintenance personnel must be well trained and skilled. Each item in the machinery space needs to be maintained in good condition at all times. The aim is to maintain the voyage passage at reduced power, to avoid delay and eventual operation costs that develop from lack of maintenance.

Shipping companies are aware that ship maintenance is comprised of the costs incurred in the organisation, execution and control of all relevant work and measures undertaken to ensure the "totally efficient" operation of the ship. These costs cover everything that is directly and indirectly attributed to maintenance. This includes the work-force and materials resources, (spare parts, tools, etc.). Maintenance costs usually are second only to crew cost. They vary according to the type of ship, its design and the characteristics of structures and machinery space components. From the statistical figures in table 2.1 and 2.2 it can be seen that maintenance cost is between twenty-percent (20%) to twenty five-percent (25%) of the total operational costs (crew, technical, management and miscellaneous) of a sixteen year old tanker.

Table 2.1 Average operating costs for 130,000 dwt of a 16 year old tanker

Manning	Maintenance	Insurance	Administration	Stores lubes	Spares gears
32%	20%	17%	15%	8%	8%

Source: BP Shipping Consultants

Table 2.2 Typical operating costs for a product tanker

Personnel	Maintenance Administration		Finance	Stores	Disbursement	
48%	20.4%	13.4%	10%	7%	1.2%	

Source: BP Shipping limited Engineering Division

Hence to minimise maintenance cost and optimise profit, routine maintenance is inevitable.

Maintenance reduces the capital cost of the ship. Capital cost of the ship per year equals the cost of the ship divided by its life span.

2.2 The Functions of Marine Engineers on Board Ship

Different people have different explanations about the functions of marine engineers. Some will say a person who works on board ship is a marine engineer. Others think that somebody whose job is only the maintenance on board the ship is a marine engineer. In fact, a marine engineer on board ship does not only concern himself with the maintenance of the machinery. His work extends further to the objectives of IMO and the shipping company. The IMO objectives are the safe operation of vessels and environmental protection and to the shipping company is objective are the safe and economical operation of its fleet.

2.2.1 Safety

Safety is watch-keeping, repairs and maintenance, inspections of the machinery system and the safety of equipment maintaining a clean ship to receive bunkers, etc. Safe equipment machinery must be paramount since too many lives are lost at sea and too many injuries are suffered. Technology is only one half of safety and competence of seafarers. The engineer on watch should maintain a proper watch inside the engine room and the deck staff also have to keep an eye on the deck machinery and make reports on any suspected malfunction or trouble shooting. The engineer has to make frequent checks on the instrumentation equipment to make sure that the readings are in accordance with the manufacturer test values. For readings that are above or below critical limits, the engineer on watch should trace the fault and rectify it. If dealing with the fault is beyond his expertise, such a fault needs to be reported to the second or chief engineer. Inspection of pipe lines net work, observation of any leakage that might occur on flanges, valves fitting and water hammer inside pipes, is also the duty of the engineer on duty.

Inspection for vibration on rotating shafts, reciprocating systems, or any stationary machinery is another important area that the engineer inspects (author's knowledge). Generally speaking, vibration phenomena on board ships affect:

- the endurance of various parts of the hull steel-work
- · the behaviour of different engines and apparatus installed on board
- · the comfort of the crew

There are a number of other tasks that the engineer carries out on board ship. Inspection for a drop in the level of lubricating oil, fuel oil, circulating fresh water, hydraulic oil, stern tub oil, etc. If necessary the engineer on watch fills up the fluid (oil, cooling water, hydraulic oil, etc.) to prevent trouble shooting. He also inspects safety equipment to ensure that it can be operated safely and easily when needed for use. Inspection of electrical equipment, cable networks, electrical panels, electronics apparatus and tools used for repairs and maintenance. It is his job, as well, to inspect the pneumatic system for any air leakage along pipe line, valves, cylinder bottles, air throttline process. (Athors knowledge).

In general the marine engineer is responsible for the safe operation of the ship, to maintain the main propulsion plant, electrical power generation and distribution, refrigeration, air-conditioning and cargo handling machinery. He performs maintenance and repairs, and operates and manages the ship's machinery.

For safe operations the fuel quality must also be considered. It is the responsibility of the engineer to do secondary analysis to know whether the fuel is suitable for his engine for the following under mentioned reasons. Figure 2.1 shows how the sulphur content varies with wear.

Serious failures of the machinery plant in many cases are compound failures, in which chains of component parts failures are triggered by the sudden and exclusive wear of piston rings and cylinder liners that have been operating under stable conditions.

A ship's safety and seaworthiness and its ability to make regular sailings greatly depend upon the reliability of its main propulsion machinery. Damage statistics of "Nippon K. Kyokai" on the failure of diesel engines that constitute the majority of main engines of ships, shows that serious machinery damage is caused by the poor and unstable properties of heavy fuel oil. Many reports from shipping companies point out that these machinery failures were caused by the following abnormalities, on the basis of the results of analysis of the fuel oil used:





Source: Nippon Kaiji Kyokai 1996

- Engine operating parameters specifically connected to combustion such as cylinder pressures and exhaust gas temperature change significantly towards impairing operating performance. As a result, engine output is forced to be reduced.
- The specific normal operation can be impaired by unexpected failures of combustion chamber-related components. (Nippon Kaiji Kyokai 1996).

2.2.2 Economical Operation

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Before the seventies the economic operation of machinery was not considered to be a priority in the industry. The fuel crisis of 1973 changed that attitude. It was a hard blow to the industry when the price of fuel was forced up by OPEC countries. Due to the increase in price of fuel in 1973 engine development has been expanded. Finding ways to reduce fuel consumption rates has become a priority. The specific fuel consumption rate has been decreased by about 20% in the last 20 years (field study Poland 1997). At present the specific fuel consumption (SFOC) is still a key point for engine manufacturers and operators to reduce. Fuel costs are related to the following factors:

- power/speed selection
- engine optimisation overload range
- · recoverable waste heat
- auxiliary power need

It has been the function of the ship engineer to perform at the maximum level and at international standards, in maintaining machinery operation in order to maintain the design speed. Due to economic consciousness speed is not as much of a priority in the industry as reliability. With a proper maintenance system for machinery by the engineer economic functions are also achieved. Crew number is also a factor of economic operation but it is greatly influence by the level of automation present in a vessel, but safety considerations naturally impose a lower limit below which it is less certainly prudent to go. In practice, there is trade-off between crewing costs and maintenance costs. The value of experienced personnel on a ship are difficult to quantify but nevertheless there can be little doubt that there is considerable financial benefit in the long term, if experienced personnel are used, in term of reduced maintenance costs and reduced time of hired.

2.2.3 Environment

Waste oil is generated in machinery spaces by a number of sources, such as crank and gear cases and lubricating oil and fuel oil purifiers which create oily sludge. Hence, the marine engineer must maintain machinery space in order to meet the principle of environmental protection (MARPOL ANNEXE 1), which states that ships must:

- · Minimise the generation of oil and water mixtures
- · Separate oil from water where mixtures cannot be avoided
- · Set limits to the quality of oil which may be discharged into the sea
- etc.

The marine engineer's tasks also include responsibility for taking care of the oil discharge monitoring and control system, the incinerator (used to burn oil and other unwanted materials onboard), the oil-water separator and the oil water equipment to prevent pollution of the sea. He maintains the amount of oil discharge from the bilge's so that it does not exceed 15 PPM (part per million), (MARPOL regulation 16).

2.3 Maintenance in "ISM CODE"

The ISM Code is the international management code for the safe operation of ships and pollution prevention.

The objectives of the Code are to ensure safety at sea, prevention of human injury or loss of life, and the avoidance of damage to the environment, in particular to the marine environment and to property.

Therefore, it is essential to understand the Code as it relates to ship maintenance. By its provisions, procedures and drafts must be provided to onboard and shore based personnel dealing with the operation and maintenance of the ship machinery system. For the most appropriate methods of implementing the Code, the shipping company should establish the procedures by which its ships are maintained in conformity with the provisions of the rules and regulations. Therefore, the personnel in charge of the implementation of the maintenance of the ships (Chief engineer or shore based staff) should report the results of implementation and record them based on the plans.

Chapter 3

TYPES OF MACHINERY MAINTENANCE

The aim of the maintenance department on board and at shore is to provide an efficient service in order to maximise machinery availability at the cheapest cost. To achieve the above, periodic servicing must take place and is categorised as follows:-

- planned maintenance
- preventive maintenance.
- corrective maintenance

3.1 Planned Maintenance

Major repairs overhaul, calibration (plan factor).

Planned maintenance systems, to a varying extent, have been in existence for many years in many properly organised shipping companies. In Sierra Leone National Petroleum Company there are no defined methods of implementation of the maintenance system (Author's knowledge). This failure is due to poor organisation and technical difficulties. In developed countries the availability of computer-based planned maintenance systems has, however, made their use both feasible and in many cases most advisable.

In theory optimum maintenance is achieved when the maintenance level is such that the cost of maintenance balances the costs arising from breakdown and delays. To be

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successful, and to avoid mistakes made in the past, a planed maintenance system must be fully integrated into the company. It must be flexible and the temptation to treat it as a prime target for cutting costs when times get hard must be avoided.

An effective machinery maintenance programme depends for its success upon:

- · A complete knowledge of all the machinery to be covered
- The extent of maintenance required and how long it will take in each case, together with the facilities, materials, man power, skills and spare part's replacement required
- The frequently with which maintenance must be undertaken. How long it takes and how the work can be combined and accomplished with minimal adverse effect on the ship's operation

A shipping company that correctly implements a maintenance plan will reap the following benefits:

- · The efficiency of the equipment will increase
- There will be greater availability of equipment, less expensive emergency repair, proper coverage of machinery, effective use of labour, etc.

If maintenance work is planned the work load can be evenly distributed avoiding periods of high and low activity levels. Constantly varying peaks and troughs of maintenance activities, as well as not being sound economically is also unsettling to the work force as shown in figure 3.1. In figure 3.1 the area under S_1 and S_2 represents the total man-hours over the periods taken. Based upon investigations from other shipping consultants (Drewry shipping consultants, BP Shipping Company) and from the graph, the total man-hours with preventive maintenance are less than the total man-hours without preventive maintenance. The total work load is reduced by adopting preventive maintenance. Since, among other reasons, the right numbers of persons are available when required and are working within normal hours, the work load can be completed more efficiently. By planning maintenance the peaks and troughs are reduced as shown in figure 3.1.



Period (weeks)

Figure 3.1 Smoothing the Maintenance Work

Source: Drewry shipping consultants

Computer programmes play an ever increasing role in planing, starting from the initial stages throughout the organisation to the individual maintenance tasks. Figure 3.2 shows how a maintenance plan is implemented. The machinery space is analysed by automation sensing shock, temperature, pressure, etc. and the information can be displayed on the pulse's computer screen.





Source. Drewry shipping consultants

There are three elements of planning. They are:

- Inventory identify the total assets that need to have maintenance and put them into the maintenance programme
- · Identify identify machines and their space in order to provide easy access
- Scheduling- scheduling for maintenance tasks, inspection, lubrication, repair parts and replacement indicating their frequency
- Others- registration of machinery working characteristics schedule for personnel, lubrications, quantity control and allocation.

Good maintenance planned systems must:

- Be comprehensive
- Be flexible
 - -To allow unscheduled repair
 - -To allow changes of periodicity
- · Be simple to operate
- · Include spares parts and necessary stores management
- Have a reporting system that provides a continuous picture of the condition of all equipment
- · Provide information on costs to all concerned.

3.2 Preventive Maintenance

Preventive maintenance is a branch of planned maintenance tasks that is executed to prevent machinery failures and excessive running cost. Preventive maintenance includes:

- · Lubrication and minor adjustments
- Schedule and checking
- · Repairs and overhauls
The main objective of preventive maintenance is to stop functional delays, reduce maintenance costs, increase the life time and also the operational safety and reliability of machinery.



Figure 3.3 Organising a Maintenance Task

Source: David Mottram Lecture on RCM, 1998, WMU.

Figure 3.3 shows how maintenance tasks are organised, the planned and unplanned maintenance and the types of preventive maintenance.

An example of preventive maintenance is the lubricating schedule. Failure to lubricate a space machinery part at the right interval of time will result in plant breakdowns. Oil and greases are specified by manufacturers after careful consideration of plant duties and ratings, and the way to use the specific and equivalent lubricate is outlined by them. Over greasing of all balls and roller bearings can cause serious problems and it is therefore important that oil and grease levels are strictly maintained. In most developing countries, or companies, lubrication is a function of the maintenance department. In other companies it is the responsibility of the operating staff.

Using a preventive maintenance form, the following items will be included:

- Plant item
- Plant number
- Location
- Point of lubrication
- · Methods of lubrication
- Recommended lubrication
- Frequency of lubrication
- · Frequency of sample of oil change, etc.,

3.2.1 Periodic

Periodic maintenance is done on fixed calendar intervals or after achieving certain accumulated running hours specified by the maker. Maintenance and repair are carried out when the condition reaches a certain level. The period method is applied to those machinery components whose actual operational condition cannot be determined at any given moment by visual inspection or by non-destructive methods. Examples of preventive maintenance are routine checks and inspections of the machinery space.

The inspection relies mainly on the use of eyes, nose and hands, paying special attention to odour, abnormal sound, heat emission and instrumentation readings. Retightening loose bolts and nuts and checking of valves for abnormal sounds when the piece of machinery is in operation also is part of the inspection. Other specifics of a maintenance inspection include:

- · Checking for signs of rust
- · Checking for machinery overheating
- · Inspecting for cracked moulding
- · Checking the external terminals, of the electrical system
- · Checking for heating and abnormal sounds
- · Checking for leakage or damaged pipes

Using specially designed wall charts and documentation of regular planning meetings (weekly) a record of work to be done can be kept. The chart is controlled by the chief engineer. Regular communication is important to the process of providing quality period maintenance. Documentation is required for present and future analysis of the system and for meeting international regulations. The wall chart may contain the following:

 A planning board that displays the maintenance routines for three months, one month, one week and one hour-runs. Work not completed in the period and work to be carried out onboard also can be shown here

- Documentation cards with details of items of equipment, work to be carried out, tools and spare parts required, the necessary safety precautions, records showing that the work has been done and notes for future reference
- · Work allocation board showing all operating staff on board and ashore
- Defect documents (defects recorded on the planning board that are outside the work schedule)

3.2.2 Condition Maintenance

Condition maintenance is designed to detect trends in the operating characteristics of equipment that indicate that deterioration has developed and therefore that maintenance is required. The equipment is monitored with periodic measurement of vibration and deterioration, slack nuts, the speed of the engine flywheel, gauge measurement of temperature and pressure, insulation testing to detect electrical insulation deterioration, and visual checks to detect wear, leakage, corrosion, etc.

An effective system of preventive maintenance will provide:

- Effective use of capital funds through tight budgetary control, with subsequent savings in maintenance and spare gear costs
- Greater availability of machinery and equipment with an eventual reduction in maintenance levels
- · Less expensive emergency repair and, where problems arise, quick diagnosis
- Proper maintenance coverage of the ships structures, accommodation, machinery and equipment
- · Effective use of plant, labour, time and maintenance of equipment.
- Increase in forecasting and plant planning ability and the highlighting of weaknesses or potential problems

- High staff morale, arising from increasing professional involvement and an increase in efficiency
- Effective and comprehensive monitoring and maintenance records with proof of effective operation
- A complete record of repairs and maintenance carried out onboard ship and ashore and a means of planning for the coming main event and voyage repairs with parts and service requirements, (Drewry: shipping consultancy)

3.3 Corrective Maintenance

Corrective maintenance is performed when the whole or part of the equipment fails. Figure 3.4 shows a technique for detailing the information stored for a corrective maintenance action. Before an equipment fails there will be a signal or notice of breakdown through information obtained by means of an electronic monitoring system. Corrective maintenance can best be implemented by using monitors to determine the performance of the machine. An example of this is the use of a vibrating monitoring instrument to determine the rate of vibration. Following the installation or overhaul of a machine, the overall vibration levels are recorded for selected points on the bearing caps. Points in the orientation vertical horizontal, and axial directions are recorded so that identical location readings are taken on a regular basis, for example bi-weekly. The vibration levels are compared to general data to provide an indication of sudden or gradual change in identically recorded vibration levels. If there is a change in the internal condition of the machine, it indicates a need to investigate it and correct the cause before damage occurs.



Figure 3.4 Corrective Maintenance Action

Source: ICMES 96, Safe and Efficient Ships.

3.4 Short Term Maintenance

Short term maintenance consists of general and detailed planned maintenance to achieve high availability and preparedness in a machinery plant for normal operation. It is also done in the case of disturbances as a result of a major overhaul or as major preventive maintenance. It is a safety maintenance system executed with the company's available resources. The company decides upon resource utilisation. Thus a maintenance policy is needed to ensure a high availability of equipment despite daily changes in plant output capacity. One major factor that can negatively influence short term maintenance is the mismanagement of the maintenance activities in the various sections of the maintenance department.

Delay in the procurement of materials is one of the main reasons maintenance tasks get slowed down. This problem affects most developing countries because most of the spares have to be purchased from foreign countries with foreign currency, causing delays. Meanwhile the plant suffers downtime and loss of service availability. The benefit of the short term maintenance policy is the continuity of plant operation with only minor interruptions. (Author's experienced.

3.5 Long Term Maintenance

Long term maintenance is a set of economic maintenance procedures and affects the operation costs in the long term. The benefit of a long term maintenance system is that it provides for a longer life of equipment. Therefore investment in new equipment will be unnecessary for a long time. The equipment will have a low depreciation value and a high second value when it becomes necessary to sell it.

3.6 Fauit diagnosing

Fault-tracing constitutes an important part in the rationalisation of maintenance work. If repair has to be carried out quickly and efficiently, it is important that the fault is located and correctly diagnosed. Fault tracing time should be as short as possible. A fault tracer must work logically and methodically if time-consuming and expensive mistakes are to be avoided. A good fault tracer should have elementary knowledge in a wide area outside his area of competence. Figure 3.5 shows a typical fault-tracing flow chart for a hydraulic machinery system.



Figure 3.5 Typical fault-tracing flow for a hydraulic machinery system

Source: Maintenance and reliability Södertälje, February 1996.

Proper and successful maintenance programmes can provide excellent results in saving time, money, materials and effective utilisation of workmanship for the shipping industry. Below is a set of benefits and improvements that can be obtained from a properly implemented maintenance program:

Improvement of overall service quality

- Increase in machinery availability
- Improvement of safety and reliability of machines and equipment
- · Reduction in the number of down-times of machinery equipment
- · Minimisation of un-predicted machinery failure and unnecessary repairs
- · Decrease in maintenance and operational costs
- Increase in the life span of machinery space and improvement in machinery space utilisation
- · Increase in the total production of the organisation
- Increase in labour productivity
- Improvement in the working environment, human safety, etc. (David Mortram 1998)

CHAPTER. 4

MANAGEMENT AND MAINTENANCE STRUCTURE OF SHORE AND SHIPBOARD ORGANISATION

4.1 Management Organisation

The Sierra Leone National Petroleum company, the Sierra Leone Port Authority and the fishing companies are the largest companies in Sierra Leone with tankers, bergs, fishing vessels' tugs and ferries. The National Petroleum Company Marine Division (NAPETCO Sierra Leone Limited) is engaged in shipping and offshore bunkering. The organisation and administration are divided into shore management at the top level of management and shipboard management at the lower level of management. The top, or shore, management is headed by the Managing Director who is also the general manager of NAPETCO. He oversees all the activities of managers and administrators. Therefore both shore and ship engineering operations fall under his supervision. The functional divisions of the shore engineering operations are:

- Marketing Manager: takes care of finding cargo, arranging voyages, leasing and chartering of the four vessels owned by the company
- Operations Manager: deals with the ship's operations, maintenance and repair, plans ship yard repairs and also recruits, and arranges for contractors, etc
- Accountant: handles' allocations of funds, the budget, payments and financial controls including maintenance of separate accounts for every ship
- Others: include those who are responsible for the safe keeping of spare parts, the ship chandler, etc.

The ship management organisation includes direct engineering supervision by the Operations Manager and his team, comprised of mechanical and electrical engineers. The Operations Manager responsibilities also include:

- · Safe operation of the entire ship and machinery equipment
- Safe guarding normal operational conditions of every repaired maintenance at minimum cost and the lowest loss of the ship's operation time
- Co-ordination of the preparation and supervision of the performance of all emergency repairs to each ship



Figure 4.1 shows NAPETCO shore and shipboard management structure

- · Purchase and supply of materials, fuel, lubricating and spare parts
- · Recruiting and assigning crew members to ship.

The shipboard engineering organisation is composed of the master (captain) who in the capacity of master is the head of the shipboard management and also the head of deck machinery and equipment maintenance. The engineering department is headed by the chief engineer who is slightly below the captain. He is in-charge of all ship machinery space and heavy deck machinery. (B. Butman 1998).

4.2 Skills and Current Maintenance Methods

The maintenance team at the Sierra Leone National Petroleum Company is composed of shore and onboard. The shore team is mainly contractors. All the vessels owned by the company are more than 20 years of age and there are constant breakdowns from main propulsion systems to auxiliary plants. Most small and large scale maintenance is corrective. Parts are replaced as and when they fail. There is no defined routine servicing, or maintenance procedures. Maintenance methods do not embrace routine services, such as the addition of lubricants and coolants and cleaning, etc. These are performed only when problems occur.

Planned maintenance procedures, (as mentioned in chapter 3) that are based on the manufacturer's recommendations regarding required services, time intervals (running hours, elapse time, etc.), and operational parameters such as pressure, temperature, vibration, knocking materials loss, etc. are not considered. Normally before the commencement of maintenance the manuals are not consulted to understand how the work should be performed. The lack of planned maintenance or maintenance procedures is due to the following reasons:

- Knowledge of the field: Almost all maintenance teams have little or no marine background
- Lack of training and experience. All training is internal, and informal There are no training procedures
- Lack of motivation
- Lack of spares and equipment
- No equipped shore or shipboard workshop for fabrication and other maintenance activities
- No formal or established planning procedures exist

The shipboard team does minor maintenance and repairs. All major overhauling, repairs and maintenance are done by shore-based mechanical and electrical experts. None has a marine background. Due to the low number of experienced crew onboard major maintenance and repairs are subcontracted to shore staff, who have no experience with marine propulsion systems. Contracts are offered to them based on their experience and performance on shore mechanical and electrical equipment. No on-the-job training is provided to the crew.

As was stated previously individual chief engineers conduct maintenance to meet operational requirements using their own technical knowledge and judgement in terms of immediate needs. In NAPETCO there is no continuity in approach and maintenance priorities differ from one chief engineer to another. The net result is a wide variation of machinery condition and reliability (ie less reliable) within the vessels and across the fleet as a whole. Due to the over-maintenance of some equipment and lack of adequate maintenance of others there is no consistency. The inexperienced staff and lack of co-ordinated management effort in maintenance activities inevitably lead to frequent operational delays and breakdowns.

4.3 Effective Management

For an effective management organisation the present management structures should be modified as shown in figure 4.2. The functions need to be decentralised and each responsibility has to be defined.



Figure 4.2 Structure of Shore-Based Maintenance and Management

Figure 4.2 is drawn in two dimensions, the Managing Director is the overall boss. Below him are the Managers and below the Managers are the Administration and Personnel. Engineering Operations, etc.

The shore staff is composed of the following structure as shown in figure 4.2. Below the engineering operations responsibility is decentralised for the maintenance staff.

Diesel engineers are responsible for everything that has to do with the maintenance of diesel engines and related equipment.

Electrical engineers deal with all electrical installation, maintenance, repair and upgrading.

The Safety and Environment supervisors are responsible for the implementation and monitoring of safety procedures and equipment in ship operation and maintenance and repairs in order to prevent pollution and other hazardous accidents.

Crew manning personnel take care of selecting crew, training crew, medical care, office licensing, crew documents, etc.

Others include welders, technicians, etc.

The Operations Engineer Department takes the full responsibility for all maintenance and repairs for each voyage completed and whenever else necessary. During this period of work on machinery the onboard crew takes a short rest until the completion of all maintenance and repair. At the end of the voyage the onboard crew report all trouble shooting and abnormal performance of machinery to the shore maintenance team. The shore maintenance crew is trained not only on shore but also has experience at sea. The shore staff are qualified and experienced in accordance with Regulation III of STCW 95.

The shipboard management structure remains as shown in figure 4.1 but the level of responsibility is defined in accordance with the international standards.

4.3.1 Shore Maintenance Team

The shore maintenance team should be set up because of the constant changes within the marine industry, especially shipboard restructuring. If the option of low crew number is selected, the use of shore-based personnel cannot be avoided. The use of outside contractors should be inversely proportional to the number of crew.

In recent year's appliances and equipment on ships have been modernised, resulting in a decrease in the number of crew members. At the same time the fuel used in marine engines has become lower in quality for economic reasons. As a result, the structure of engines and auxiliaries have become more complex and the maintenance work more involved. (Field studies 1998).

Even in such circumstances, it is still important to maintain the reliability of machinery and improve the work ratio of engines. For this reason, although part of maintenance work has been shifted to land, work on ships is still important and a high level of technical judgement is necessary. Furthermore, maintenance work on machinery has been shifted from conventional corrective maintenance to preventive maintenance, and the necessity of foreknowledge has been recognised. Engineers now use computers with various kinds of software for failure diagnosis. These expert systems are highly valued. In land plants such systems have been put to practical use as a failure diagnosis device. The introduction of an expert system in ships is only a question of time. At present the installation of such system in ships is viewed as being rather difficult, however, especially in developing countries. The difficulties for developing counties in installing such a system are mainly financial.

4.3.2 Maintenance Preparation

Maintenance preparation may include the following:

- Work schedule
- Safety equipment
- Equipment for repairs
- Procedures
- Inventory of spare parts

Inventory is one of the major duties performed by shore based staff in maintenance preparation. It is a system used to organise and access the spare part's information associated with vessel machinery equipment, such as availability, quantity, recommended inventory levels, storage location, and pricing information. It identifies each piece of equipment, and is used to maintain inventory levels, record delivery receipts, and print bar code levels.

Information in the inventory management system is set-up in the following ways:

- Spare Parts Master Record screen shows detailed spare parts records and allows up-to-date revisions
- · Spare Part Status screen shows basic inventory information
- Parts Inventory adjustment option shows adjustments to inventory levels and allows up-to-date revisions
- · Print Part Levels option allows labels for the parts to be generated

The Spare Parts Status option displays a list of all spare parts belonging to a particular piece of equipment, along with the current inventory levels of those parts. This screen indicates the manufacturer part number, where the part is, how many you have and how many are on order.

The Parts Inventory Adjustments option is used to record spare parts inventory level changes. This screen allows the user to update easily the current inventory levels resulting from receipt of requisitioned inventory, inventory used, lost, damaged, or other miscellaneous inventory fluctuations.

4.4 Level of Authority

First and foremost shore management need to define the responsibly limits of shore maintenance teams and onboard maintenance teams. The following should be considered when doing this:

 Budgeting: This is the total decided by the head office rather than by the sea staff.
Focusing on ship machinery maintenance shipboard budgeting covers work done by shipboard personnel and the shore-based personnel. Confidence must be built between the head office and the maintenance team both onboard and ashore, to facilitate decisions about the amount of money to be used without consulting the head office. Above a certain limit the head office has to be informed on the purchase of spares and the amount spent related to maintenance.

It is necessary for shore based management to allocate a budget to be at the discretion of onboard managers. For shipboard budgeting to work it must be realistic. It must be big enough to cover the ship's needs and sufficiently flexible.

 Communication: In the broad sense, this is an important aspect of maintenance management. This is particularly true of shipboard maintenance management, because of the degree of isolation of the ships, job specification, reporting, etc. There can be confusion between the Master and the Chief Engineer/Mechanic about making certain reports to the head office, each one thinking that it is the responsibility of the other. Top management has the responsibility of clearly delineating authority and seniority. (Dr.B. Butman1998).

Decision making: Decisions about maintenance of ship machinery should be made by shore or shipboard engineers. Within his capacity as a senior engineer ashore or onboard the engineer must be given certain authority by which he can make decisions without consulting the head office, such as decisions about his subordinates, execution of duties, etc. Reports must be sent to the head office on the action taken. The key to any successful management plan is to allocate the decision-making authority and responsibility correctly within the organisation. (Dr. B. Butman).

4.5 Maintenance Record

Maintenance records have been one of the major factors affecting maintenance not only in shipping but in all sectors of the Maritime world. The Sierra Leone National Petroleum Company has no proper record keeping by either the shipboard or the shore-based maintenance staff. Maintenance and repair work carried out on an item or unit of equipment or machinery has not been compiled and kept for future reference. It is on the basis of asset history that senior maintenance staff are able to make decisions on the timing of equipment replacement, and on the suitability of machinery maintenance policies and strategies. Since no proper maintenance histories have been kept records are never available for engineers to carry out detailed analysis of component failure. Due to the poor maintenance history, analysis to reveal possible weaknesses in the plan or equipment is impossible.

4.6 Present Maintenance Policy

During this six year period, due to political instability, the Sierra Leone National Petroleum company has suffered a dramatic set back. The company has, therefore, been trying to reduce maintenance costs. The cut back was not based upon investment into improved equipment or improved operation and maintenance processes, but simply by reduced maintenance budgets. This was a relatively short term situation, however. Reducing maintenance in this way often leads to reduced reliability and increases out-of-service time. This effect then only leads to a reversal in maintenance policy and an increase in ship maintenance costs to reverse the situation. It also causes a sudden peak in on-board work requirements and a decrease in morale both on board and with the shore management involved. There were also sustainable risks involved because the ships had become less reliable.

CHAPTER 5

IMPROVEMENT OF MAINTENANCE METHODS

5.1 Traditional Compared to Modern Methods

The traditional method of maintenance is predominately used in both small and large scale industries (marine, wet and dry mining, manufacturing factories etc.) in Sierra Leone. Maintenance in Sierra Leone is still performed by looking at the individual equipment manufacturer's recommendations and building up an overall maintenance program from them. Some times the program and schedule are not followed. The human senses are usefully employed (sight, hearing, smell and touch) to determine whether a machine's condition is satisfactory or not in the broadest sense. Individual chief engineers conduct maintenance to meet operational requirements using their own technical judgement in terms of priorities. There is no continuity of approach in a long term sense, as maintenance of some equipment and lack of adequate maintenance of others. The net result is a wide variation in machinery condition and reliability within vessels and across the fleet as a whole. (Author's knowledge)

Machinery maintenance is gradually changing in developed countries into a more reliable and safe maintenance scheme. The maintenance routines for individual machinery and equipment are now in the process of modification through operational experience. The levels of unscheduled maintenance are presently falling. (Centenary Year Conference on Marine Engineering Now and the Future 17 - 18 July 1989) From the results of the investigation by British Petroleum Engineering Division, (shown in figure 5.1) 50% of condition and performance methods are in use in most developed shipping companies. The traditional methods (running hours, life, breakdown, calendar) are disappearing in the industry. The overall maintenance

effort has remained high and the cost of spares has risen. This method has made the reduction of maintenance crew onboard shins become a success. A high degree of continuity in machinery maintenance is achieved in spite of the reduction of crew The change from the traditional to the modern type of maintenance methods has been better realised by well established shipping companies like BP. MARSK LINE etc. and not yet realised in National Petroleum Company or in Sierra Leone overall. The application of this philosophy by Sierra Leone would enable the engineer to conduct maintenance only when it is necessary, i.e. when the condition of the machine deteriorates to a level where its performance drops off or it becomes unreliable in operation. All machines wear naturally with time, due to friction, looseness imbalance, mis-aligment and so on. If the level of deterioration could be monitored at regular intervals, and a trend established, the engineer could reliably predict when the machine or equipment required corrective maintenance and plan the maintenance schedule in advance. This technique is known logically as predictive maintenance (as described in Chapter 3) through condition monitoring or condition based maintenance (BP Shipping Limited Division).

In recent years instruments and tools have been devised to supplement the natural attributes of the engineer pressure gauges, thermometers, ammeters and flow meters. They enhance his ability to establish that a machine is operating satisfactorily. Modern maintenance has an advantage over the traditional type. It saves time, reduces maintenance costs, and it makes it possible to reduce crew on ship and within the shore-based team. Research was carried out by BP Shipping Company proving that 37% (percent) of the total maintenance time was saved by using condition monitoring as shown in table 5.1. Four machines were used to compare the traditional (calendar system) and the modern methods (condition system) to find the best applicable system for each piece of machinery. There was a reduction in maintenance time when modern maintenance methods were used as shown in table 5.1. There was time reduction only when using the modern (condition monitoring)

maintenance system. Whilst such instruments largely fulfilled a performance monitoring role rather than a condition, if a machine appeared to be performing correctly within its design parameters, it was reasonable to assume that its condition was acceptable.

The introduction of the rotating machinery vibration measurement and analysis techniques have given the engineer the vital tool he has needed to firmly establish what the (performance) monitoring equipment had until this time indicated. In addition, it allows detection of early condition deterioration that may not have affected the machine's performance and which would not be evident from conventional instruments.



Figure 5.1 Implementation of condition monitoring techniques Source: BP Shipping Limited Engineering Division

Condition monitoring is a more recent phenomenon and is still comparatively rare. It involves vibration measurement for rotating machinery and the comparison of recorded results with a theoretical "vibration signature" thus identifying potential equipment failure fairly precisely. Such techniques have the added advantage of leaving machinery alone whenever possible, rather than dismantling them, which can often, in and of itself, cause problems in the future. For ball and roller joints, shock nulse measurement is required.

It can be seen from Table 5.1 that using condition monitoring saves more than 20% of the time spent in maintenance.

Experimental data for condition monitoring systems in four plants in Norway has been analysed also. The economic cost/benefit evaluation shows a high return on investment. (ICMES 1990).

	Calendar system	Condition system	Percentage (%)
ITEM	(Traditional method)	(Modern method)	reduction
	Hours	Hours	
Inert gas fan	568	256	55
Cargo pumps	541	424	21
Feed water pumps	569	423	26
Alternators	186	69	63
TOTAL	1864	1172	37

Table 5:1 Maintenance man-hours reduction using condition Based system compared to Calendar system

Source: BP Shipping Limited, Engineering Division

The benefits of condition monitoring as seen in figure 5.1, and table 5.1 and the cost/benefit evaluation of the four plants in Norway, compared to corrective and predictive maintenance, are reduced downtime, reduced maintenance costs and fuel costs. These are achieved through:

- · Less unforeseen breakdown by early detection of incipient failures
- Substitution of preventive maintenance (PM) routines by condition-based maintenance achieving increased service intervals and simplified periodic processes
- Reduced fuel cost due to monitoring of thermal efficiency parameters and better time spent washing compressors, replacing seals, etc.

Hence to improve machinery maintenance the modern method (condition monitoring) needs to be gradually replacing the traditional method.

5.2 The Role of Shipboard and Shore-Based Staff

The area of refitting and maintenance management in the fishing industry and National Petroleum Company can best be separated into (a) shipboard activities and (b) contracted repairs ashore. In each of these companies the guidelines for established shipboard maintenance standards and procedures are provided by the shore superintendent/chief mechanical engineer. He should provide vital engineering support including troubleshooting, analysis of shipboard technical data, development of manufacturing procedures and requirements for maintenance and repair, etc. The lead role in managing the established ship board maintenance programme rests with the chief engineer. The planned maintenance and material management portion of the management of software packages can assist the chief engineer with his duties. It is slightly different in Sierra Leone as no software package is available in oil tankers nor in the fishing vessels.

Management of contracted maintenance is handled by shore staff, for the simple reason that the engineers are in a position to supervise or arrange for the supervision of the repairs, as well as deal with pre-and post-contract matters. Furthermore, they are usually the most experienced in project management. The chief engineer has two extremely important functions to perform: drawing up defect lists and providing onhoard inspections on behalf of the owner.

Other functions of shore based personnel include:

- · Purchasing and procurement of materials, fuel, lubricants, and spare parts
- Analysis of shipboard technical data

The safety and environmental protection division are responsible for the implementation and monitoring of safety procedures and requirements in ship operations and maintenance and repairs in order to prevent pollution and other hazardous accidents.

Shore-based and onboard maintenance teams have been fully successful in Japan because of the high wages paid to crew. The onboard maintenance staff basically perform minor maintenance work. Their major activities are to monitor the performance of the machinery. In another words, they are operational engineers. All major maintenance and repair are done by the shore staff. This includes overhauling and major replacement. At the end of a voyage the onboard engineers submit their observations and report faults detected to the shore-based team.

5.3 Computer and Maintenance

Within the framework of growing maintenance complexity the advent of relatively inexpensive, lightweight and portable microcomputers was an obvious tool to add to maintenance systems. The first user friendly (at the time) computerised maintenance systems onboard and ashore appeared at the beginning of the 1980's. However, the computer technology of that time was behind the maintenance demands of the ship operator (as any system to organise maintenance requires more memory than the 16bite computer provided). The efficiency of computerised maintenance was limited by the capabilities of the computer, specifically its memory allocation and speed. Hence the various software modules for maintenance (assets, maintenance schedule, crew and stock control) were slow to use.





Source: Drewry shipping consultant

Computers can assist in planning, starting with the initial stage through to the organisation of individual maintenance tasks, the organisation of personnel and the snare parts inventory.

The computer analysis of machinery is made by (automatic) sensing parameters such as vibration, shock pulse, temperature and power. The parameter measures are then compared with an ideal model and adjustments made to the machinery's operation and maintenance schedule as necessary. Figure 5.2 shows the function of the computer in machinery maintenance, in monitoring, storing data, analysing data, and interpreting information, all of which have been of great help in maintenance.

5.3.1 Network Between Ship and Shore-based

Even under the circumstairce discussed in Chapter 4 section 3.1 paragraph 2 (crew reduction and fuel used in the marine engines has become lower in quality) it is still important to maintain the reliability of machinery and to improve the work ratio of engines. For this reason, though part of the maintenance work has been shifted to land, work on ships is still important and a high level of technical judgement is necessary. Furthermore, maintenance work on machinery has been shifted from conventional corrective maintenance to preventive maintenance, and the necessity of foreknowledge has been recognised. Various kinds of software for computers have been developed and failure diagnosis expert systems are highly valued. In land plants such systems have been put to practical use as failure diagnosis devices.

The introduction of an expert system in ships is only a question of time, but the technique has not yet been established. Installing such a system in every ship would be rather difficult especially for developing nations because of equipment costs. However, monitoring systems for machinery do exist from the monitors to the control department on land. The centralised remote monitoring system can be

monitored in control departments on land. Telephone lines provide the communication link allowing shore based experts to provide input into onboard maintenance problems. Maintenance control and failure diagnosis of machinery and related equipment also can be handled by expert shore personnel using this system. This system can function for a considerable number of ships.

Maintenance Management Information System (MMIS) plays a key role in the implementation of modern maintenance methods. MMIS developed due to the complexity and demand for the variety of resources and operations involved in maintenance. The MMIS covers all the maintenance related operations onboard and ashore for the purpose of optimising the implementation of the maintenance policy. Figure 5.3 shows the operational structure of a maintenance management information system. Apolying the MMIS, the following should be considered:

Ability to perform the operations

1. Internally:

- Handle quickly a significant volume of record maintenance data in an orderly manner
- Transmit maintenance information from shore to ship and vice-versa integrating the maintenance of the ship with that of others in the fleet
- Link the maintenance records with the performance and conditions monitoring system of the ship

2. Externally:

- Access important information from other useful data banks, such as those of suppliers, manufacturers, shipbuilders, etc.
- Link the ship office with other users, such as marine machinery manufacturers, shipbuilders, technical institutes, etc.

Software involvement in support of operations

- 1. Internally:
- · Provides inventory status module of all the ship's machinery components
- Provides corrective and preventive maintenance module
- Provides maintenance analysis module
- 2. Externally:
- Provides performance and condition specifications on all machinery
- Provides technical reports

Within the internal domain, the inventory module contains all the information relevant to the previous and current status of the ship machinery characteristics, its components installed and in stock, and the materials and consumable of maintenance. This record is updated continuously, with the changes in status of all elements of the inventory during the operation of the ship.

The preventive and corrective maintenance module contains the work order for the execution of specific maintenance jobs on specific components. The description of those components comes into the work order from the inventory modules, and the description of the schedule or corrective maintenance jobs (including the necessary spares) follows the maintenance specifications of the suppliers and the maintenance experience of the ship. On completion of the maintenance job, the spread sheet updates the information from the work order, as far as the latest conditions of the components and the status of the spares and maintenance consumable are concerned.

The maintenance analysis module improves the organisation, execution and control of maintenance jobs, and controls the level of preventive maintenance (PM) by processing and assessing the data of the inventory status module (i.e. grouping the information by frequency of faults or defects according to manufacturer, type of



MAINTENANCE ANALYSIS MODULE

Failure or Defect Sensitivity Analysis of Component i.a.w:
I. Mode of Failure or Defect
1.2 Ship's System
1.3 etc.
2. Adjust W.O.i.a.w.
2.1 Performance Monitoring
2.2 Condition Monitoring
2.3 Cost of Maintenance
2.4 Failure of Defect Sensitivity Analysis

Figure: 5.3 Operational Structure of MMIS Source: Management and Operation of Ships (IMAS95)

maintenance action, etc.) and by utilising the information produced by the performance and condition monitoring system of the ship.

The module of the internal domain:

- Informs the inventory module of the description of the ship machinery and its components on the delivery of parts and continuously provides the necessary updates on component specifications
- Informs the maintenance module of the necessary methods and techniques of maintenance
- · Informs the maintenance modules of novel methods and techniques.

The hardware structure of the MMIS contains the computers and their peripherals onboard and ashore and the communication media (modems, telephones, facsimiles and satellite systems). Computer technology today offers the ability to cover the maintenance needs of any shipping company in a cost effective manner, by reliably and quickly processing a large quantity of maintenance information. Satellite links are very important for the efficient transmission of maintenance data.

5.4 Training for The Non-Experienced and Experienced

The high level of ship machinery technology has resulted in complex maintenance and repair of machinery equipment and other appliances. Technology is also providing some assistance in meeting new demands on crew reduction and safety.

For maintenance to cope with the continuous advancement of technology, continuous training is inevitable in the industry.

Training should not only be considered for top management levels but also middle and low level maintenarice staff. The training should include experienced and nonexperienced sea persons. As technology of ship machinery changes, the technology of training will need to keep pace, or even move ahead of it to help the maintenance staff adapt to new ideas and changes.

The types of training management that should be set up are **On- the- Job Training** and **Off-the Job Training**. Network diagram (Figure 5.4) shows the areas to be considered and the links of net work.



Maintenance Staff

Source: Japan Seafarer's Management System 1997

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

Maintenance decision-support models have been the subject summarised in this dissertation. The presentation from this study and the experience gained in the industry, indicate that a potentially significant maintenance cost may not result in increased reliability and availability. Decision-making requires relevant experience data. The collection and the presentation of such data through operators, should be enough in the sector of maintenance. With computerised maintenance planning and information systems (Chapter 5)now introduced in most shipping companies, the quality of maintenance has improved. Data will be available in the future to benefit both the designer and the operator.

From the discussion in Chapter 2 and Chapter 3 it can be deduced that the maintenance engineering concept is based on the assumption that maintenance does not start with activities to keep an existing installation running but starts on the drawing board and ends after scraping the installation. To keep machinery in perfect running condition maintenance should not be based on corrective methods but planned and preventive maintenance. Corrective maintenance should be the last result that is be applied when a machinery fails unexpectedly.

Chapter 4 explains that maintenance work in Sierra Leone is still viewed as a low priority and as a result, little or no management effort is applied to it. As has already been shown in Chapter 2, expenditure on maintenance can constitute a significant proportion of vessel operating costs and maintenance. Therefore, it should be treated as part of the overall management task. From commercial and operational view points it is important that maintenance be fully integrated with all other aspects of ship management. Operationally, the maintenance function is to be effective. Factors such as safety, staff skills and levels, spare parts gear, stock levels, data acquisition and analysis and communication have to be considered.

Chapter 5 has drawn attention to the rapid rate of growth in the development of maintenance (Figure 5.1). Maintenance is moving rapidly from the principle of fixed intervals and planned overhaul or replacement towards a reliability-centred approach. In a reliability-centred approach maintenance is tailored to the specific requirements taking into account the specific piece of equipment's operating context.

Based on the author's study and five years as vessel machinery operator, maintenance and co-ordinator between management and crew the following conclusions are made. The vessel's ownership (company) philosophy is an important influence on maintenance and repair policy. The increasing trend towards the use of third party ship management companies operating under tight budgetary and commercial constraints on behalf of "asset playing owners" (owners, managers or operators) with limited knowledge of the operating and technical aspects of shipping has had an overall negative effect on short and long term preventive maintenance.

In Sierra Leone the performance of maintenance by the onboard crew and shore based maintenance team would have been better and more effective if on-the-job training had been provided to the crew.

From the discussion in Chapters 2 and 3 it can be concluded that maintenance objectives are not only to ensure the availability of equipment and machinery but also include:

- An adequate level of equipment efficiency
- · Controlling the rate of equipment deterioration
- Maintaining a high level of safety (STCW, MARPOL, SOLAS)
- · Complying with rules and regulations
- · Maintaining the second-hand or scrap value of the vessel