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General maintenance of marine vessels and related equipment

Abdalia Fadhil Adam
WMU

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GENERAL MAINTENANCE OF MARINE VESSELS AND RELATED EQUIPMENT

BY

Abdalla Fadhil Adam.

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

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

Signature..............

Date..20th Oct, 1992

Supervised by: M. Kimura,
Course Professor,
World Maritime University,

....

Assessed by:
S. Ohnstad,
Course Lecturer,

S. Ohnstad

Co-assessed by:
Y. Metge,
Former Engineer Supperintendant and
Visiting Professor,
World Maritime University.

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PREFACE.

Maintenance in marine industry has a variety of sectors which makes one wonders what area or aspect the writer intends to follow in his write up to convey his message adequately. It may be commercial shipping, sea transport of cargo, marine services, port operation, cargo handling, or shipyard repair works. The main object of the writer is to convey the message that the role of maintenance in all these sectors plays a crucial part in the development of national and international sea borne trade.

The development of global maritime technical structure, safety requirement on board the ships, and environmental concerns have made maintenance of ships and related equipment and facility to have become all the more important to prolong the industry. There is need therefore to address this subject well. In this way nations will avail themselves of the benefits resulting from good maintenance practices on the marine assets and facility which will ensure availability, reliability, and continuity of efficient services in the marine field for economic development of the nations.

The attitude of maintenance in developing nations however has been a lax one. The result of this has shown most developing nations have a declining number of fleet in their shipping lines. This attitude is reflected in these nations by countless number of state projects which end up in failure due to lack of maintenance follow up. In the marine sector unless there is a change of attitude shipping activities and related industry will be bound to stagnate for a long time to come. Recovery of these essential services for the nations will be too late or never, simply because of negligence of maintenance.

INTRODUCTION

Maintenance is the key concept in availability, efficiency and of services, and operation of physical assets in any institution. Lack or negligence of maintenance has not only resulted in disruption of services, but also in disastrous results in the marine industry and economic degradation of a nation. The marine industry is a dynamic one. The need to keep within a set schedule in an unpredictable ocean environment and ending with a safe voyage calls for strict observance of planned maintenance programme.

The subject will be explored in many areas of maintenance and other department which have relation with the activities of maritime maintenance of vessels, facility and equipment in order to establish the fundamental elements of maintenance procedures. The idea is to understand clearly the behavior and process of the equipment over their working cycles. In this way the basic causes of problems in maintenance can be related to specific maintenance strategy in order to optimize the industry's operation. It is observed that ashore and marine maintenance have a lot in common. However maintenance at sea is more prudent than ashore because of he intensity of machinery installation in the later case and adverse sea environment.

The format detailed in the table of contents will cover many ares of concern to maintenance procedures and tasks for both ashore and at sea to explain the essence of maintenance in the General Maintenance of Vessels and Related Equipment.

GENERAL MAINTENANCE OF VESSELS AND RELATED EQUIPMENT.

List of Figures and Tables.

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The dissertation is dedicated to my wife and children.

1.00 CHAPTER ONE. BASIC REQUIREMENT IN MAINTENANCE SYSTEM.

1.01 CONCEPT OF MAINTENANCE.

Maintenance is the routine upkeep work on natural or artificial assets and facility to prolong the useful life cycles of these resources. The concept of maintenance is important acumen for survival, availability, and sustainability of the resources. It is therefore of paramount importance to view maintenances as means to be sustainable and the need to assure future generation of the available resources and operational services for peaceful economic development of nations. Maintenance of assets however is such a common activity that it is surprising how often it is taken for granted and so neglected. The emphasis is placed on productivity and operation of the plant. It is hardly surprising that in the developing nations no sooner has a plant been commissioned and after a couple of years or so a minor breakdown will create chaos and confusion because no one has anticipated a failure so soon. This type of situation is referred to as crisis maintenance procedure. The plant may have to be shut down for a while to fetch a craftsman or mechanic merely to clean or renew a choked filter unit. The reason is general lack of maintenance consciousness. Every time a new project is undertaken there are no maintenance support arrangements to support the running of the plant so that the benefits of the projects can be realized for a prolong period of time to come. Negligence, complacency and lack of awareness for the essence of planned maintenance will render these plants vulnerable to early failure. The plant will not be able to sustain the duty it is expected to perform for a prolonged period with less problems. This also is one of the fundamental causes of problems in maintenance. It must be realized that whenever a plant or facility is required to perform well within the available resources the concept of maintenance must be taken as an integral part of the operation of a plant. Consideration of a maintenance section is established even before the commissioning of the project.

The tendency in the developing nations is however to attend to maintenance tasks as and when a breakdown has occurred. This attitude can lead to costly, and sometimes tragic, consequences for the economic development of nations. The answer to this problem is to institute education on planned maintenance concepts within all the sectors of any profession, technical, social, commercial to improve the economic development of the nations. The concepts of maintenance must incorporate design, installation, operation with all the related elements such as management and administration of the of the infrastructure of the environment.

In order to view this concept properly it is necessary to consider some of the basic factors that influence maintenance activities for an asset, vessel, or facility in general, as related to the maritime industry.

1.02 PREDICTABILITY AND PROBABILITY OF FAILURES.

The problem of predicting the failure rates of equipment is a universal one. This is an empirical problem which has challenged man to come up with a failure free equipment or system. This is the fundamental cause of problems in maintainability of any assets.

Despite high development in technology, manufacturers have not become as perfect as God the Creater. That is the reason interruption, breakdowns, and failures still are a common occurrence in the operation of plant processes. Unlike human beings, machinery and equipment do not have the ability to take care of their own processes without human interference.

Even with the advanced state of automation so far, the chances of failure in the equipment or process are still known to take place.

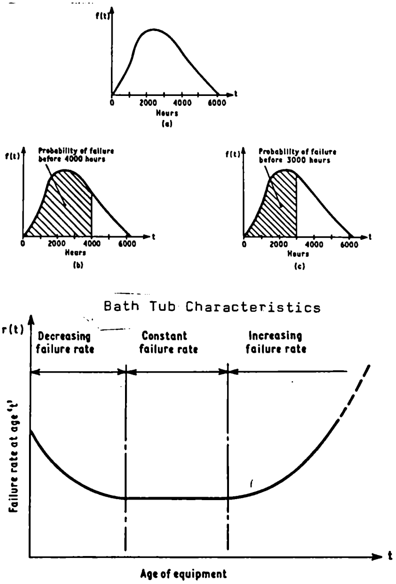
Assets and equipment have a life cycle right from design, manufacture through to commission and operation. Failure occurrence is possible at any of these life phases. This is due mainly to inability to predict the occurrence of failure in time and so prevent it. This difficulty has led many scientists and research workers in the quest to come up with failure-free components of machinery. The success of the quest resulted only on the establishment of the rate of failure patterns or trends in the life cycle of equipment. The predictability of failures in equipment and even the analysis of the failures rely on the science of the statistics. Thus the probability of failure rate, the chance of completion of the maintenance tasks, reliability and availability are obtained from the Weiubull characteristics as shown in the figure 1.02 The curves for the behavior pattern in the life cycle of the equipment have been determined by examining the data on the distribution of failure frequency over a specified period by statistical basis. It can be seen in figure 1.02 (d) that the chances of failure are predominant at the initial or infant phase and a prolonged maturity phase of less chances of failure is possible. The final phase of the equipment life cycle shows the wear out phase. This is definitely an indication of the need for major overhaul and replacement of items in the plant. Figure 1.02 illustrates this phenomenon very well. It is then appropriate for good planned maintenance programme to bear this behavior in mind so that corresponding maintenance actions can be carried out in these distinct life phases to prolong the time and improve the mean time between failures.

Monitoring and recording performance of the equipment life cycle, will realize some good measure of:

(a) Predictability from the analysis of data and information collected. This documentation will be like memory bank to

retrieve valuable information for planned maintenance tasks.
(b) Scheduling of appropriate maintenance tasks can then be organized accordingly and at minimum costs.
(c) Equipment availability and operation at optimum time.
(d) Good working conditions of maintenance facility and equipment most of the time.

Figure 1.02 (a, b, c, and d)
Weibull Curve and Probability of Failure



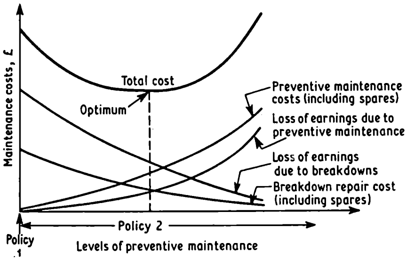
Source: Ship Maintenance, A Quantitative Approach.
By S. Shields, 1975.

1.03 OBJECTIVES OF MAINTENANCE

The main objectives of maintenance are to take care of the equipment of a plant at minimum cost. In this way the plant can run at a reasonable costs of operation and maintenance to generate revenue from its services for a long time. In order to achieve these goals, the level of maintainability, availability and reliability must be optimized to realize a high profit margin. The facility and the equipment will be maintained in good condition most of the time. Figure 1.03 illustrates optimization of the maintenance expenses. It is evident that a compromise between the costs of amongst the maintenance policies provides the minimum expenditure.

Figure 1.03

Total Costs of Breakdown and Preventive Maintenance Policies.



Source: Ships Maintenance, A Quantitative Approach.
By S Shields, 1975.

In marine transport, evaluation of the causes of failures is taken seriously and counter measures are taken in good time in order to keep up with the objectives of the trade, which is transfer of a commodity from one destination to another safely, with cost benefit to both the ship operator and the shipper. For a ship operator the objectives will be smooth passage, availability, reliability and productivity of sea transport, at the least cost of maintenance. Hence in the maritime industry critical equipment is normally installed in duplex or twin fashion especially those performing essential services like the auxiliary machinery, (generators), steering systems, lubricating pumps and others. The idea is to maintain the voyage passage even at reduced power to avoid delay and eventual operational costs due to lack of maintenance. (It is also for the safety of the vessel, cargo and the crew to avoid loss of the equipment in the event of major failure, during the voyage.)

Another reason for such duplex installation is to keep to the classification society requirement of mandatory spares on board vessel. This requirement facilitates implementation of standard requirement for marine transport and provides for observation of the International Convention for safer and cleaner seas as stipulated in the Convention on Life at Sea, (commonly known as Solas), and The Convention on Marine Pollution (Marpol), of 1974/1978 and 1973/1978, respectively.

The objectives the marine sector will realize among other benefits:

(a) Safe and uninterrupted sea passage between destinations, due to problems resulting from equipment failures or international requirements.

(b) Availability, reliability, and productivity of sea transport.

(c) Low depreciation value and higher second hand market value when it becomes necessary for the equipment to be disposed of, at the end of the useful life.

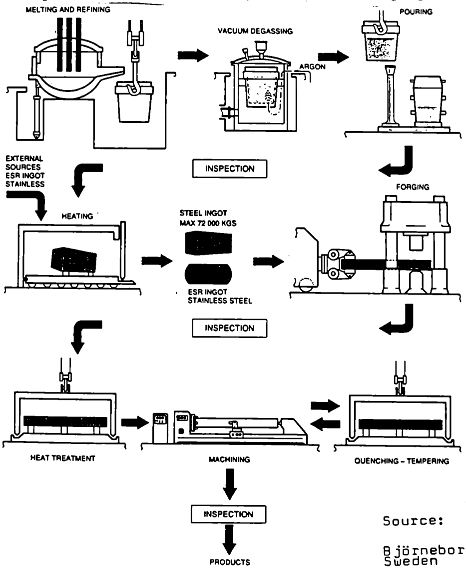
(d) Reduction of operational and maintenance costs will realize higher profitability due to cost benefit accruing from long time operation with minimum.

(e) Development and expansion of the fleet and low depreciation value and higher second hand market value when it becomes necessary for the equipment to be disposed off, at the end of the useful life.

1.04 EFFECT OF EQUIPMENT DESIGN.

In all sectors of operation and maintenance, consideration of the design of the equipment is an important factor to bear in mind. From design to operation the equipment must undergo stringent quality control procedures. This factor must always be incorporated in the planning of maintenance strategy as it will make the equipment run almost indefinitely without major maintenance costs. The design, from raw material to the finished product, must undergo strict quality control procedures. Examples of this is shown in the figure 1.04 (a) and (b)

Figure 1.04 (a and b) Propeller Shaft Forging.

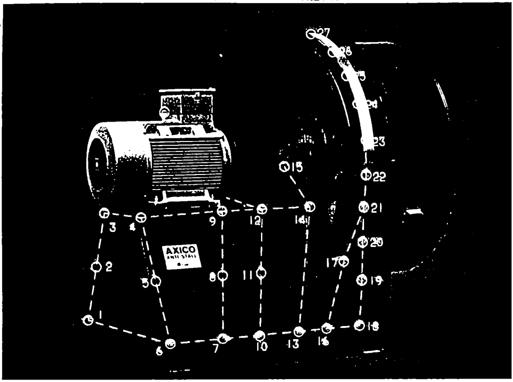


Source:

Björneborgs Jerverk AB, Sweden

Stress Relief of Fan Motor Structure.

(b)



Modal analysis is used to study resonance conditions and fatigue stress when a fan is being developed or adapted to specific requirements.

Source: Fläkt Industri AB, Växö , Sweden

The quality control is incorporated in every step of inspection of the manufacture of the propeller shafts for vessels. Lack of design consideration will have endless workload of maintenance tasks due to persistent breakdowns during the operation process. This is because with bad design the equipment may not be able to carry the designed load. It will then definitely cause excessive maintenance work due to insufficient and subsequent use. When minor repair needs to be done it will cause extensive unavailability of equipment. For-thought in this respect will provide:

(a) Maintainability at low time frame for repair works.

(b) Economical services and operation.

(c) Reliability of equipment.

1.05 DESIGN FACTORS.

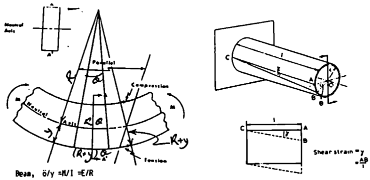
Assets and equipment of a plant or facility are made up of physical objects of simple or composite materials. The strength, chemistry and the constituents of the materials, as well as the construction of the components of the equipment, general properties, and the mode of design play empirical role in the subsequent maintenance behavioral patterns of the component manufactured. The sizes and strengths vary with the nature of loading on these materials. Understanding the design process from science of the strength of the materials and behavior under load has an important bearing on the operation and maintenance of the equipment. In this way the physical as well as chemical properties and characteristic will aid the design phase for any projects in which these items are intended to be used. Thus the science of strength of materials is a crucial factor in design and maintainability of parts, and components of machinery.

1.06 CONCEPTS OF BEAM EQUATION THEORY IN BASIC DESIGN.

Figure 1.06 shows the basics of the effect of applied forces on to a beam. The theory of beam and torque is a good illustration of the relationship of the physical effects of the application of forces on components of machinery. These effects can depict the initial data and information to enable and view the failure modes of parts of machinery or equipment. This is an important concept for a designer to take into account besides his or her intuition and judgment of other factors in equipment design. After manufacture the components are installed in machinery and will be subjected to forces of various nature. These forces will be concentrated or distributed, steady or oscillating in nature. They will induce stresses in the component and only the material macro structure and its resisting strength will be responsible for counteracting the disturbing stress.

Figure 1.06. Beam and Torque Equation.

(a) (b)



Beam, ö/y =M/I =E/R

ö = Stress at position y, in N/m squared.

y = Distance to outer of the beam, meters.

M = Applied bending moment, in Nm.

I = Secound moment of area, in m.

E = Modulus of Elasticity of the material, in N/m

R = Radius of the curveture, in meters.

Shaft, t/r = G0/L = T/J

t = Shear stress in the shaft, in N/m

r = Radius of the shaft, in meters.

G = Modulus of rigidity, N/m

0 = Angular deflection, in radians.

L = length of the shaft, in meters.

T = Torque applied on the shaft, in Nm.

J = Polar secound moment, in m

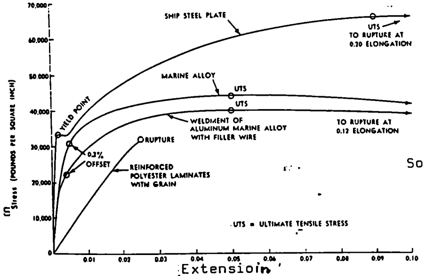
Source: Class Notes.

Compressive, direct forces, or torsional forces will be disturbing forces which must be neutralized by counter reactive forces within the material molecules for stability of the component. Otherwise the component will be deformed permanently and failure of machinery will result. From the evaluation of the physical strength factors in relation to ultimate strength, extension, maximum stress, moment of inertia, and the component can be designed. In this way the appropriate material strength also can be evaluated. A measure of the safety factor can then be determined taking into account other factors influencing it such as corrosion, wear, and environment.

1.07 FACTOR OF SAFETY.

The effect of subjecting machinery parts to compressive or tensile stress under normal condition will tend to deform the part, by extension or reduction in size. The stiffness of the material will however retain its original size. This is the principle of Hookes Law, which stipulates the extension or reduction in size is proportional to the applied stress. Figure 1.07 explains this principle clearly. On the other hand, if the applied stress exceeds the limit of elasticity of the material it will yield, and eventually break as the ultimate strength of the material is reached.

Figure 1.07 Stress and Extension Characteristics.



Extension

Source: Class Notes

It is observed that the breakage occurs at a lower stress than the yield stress. Also before breakage the material passes through a plastic stage. Some other materials do not exhibit this characteristics very clearly. Therefore in research work, a straight line parallel to characteristic curve from 2% strain gives an arbitrary stress proof curve. Where it meets the curvature of the characteristics it is considered as the yield point of the material under test.

Hence forces applied on a part have a definite relation to the deformity upto the elastic limit. Machinery parts need to be designed within the safety limit to ensure some measure of safety. This is known as a factor of safety. It must be established first before final design approval.

Nonetheless the factor of safety also depends on the nature of the load application. With steady load, its value can be low. Otherwise with dynamic alternating load of various maximum values higher safety factor values will have to be considered. Low working stresses have been known to cause failure due fatigue fracture under repeated loading of the part. Design of major engine components like pistons and piston rods have shown defects that result in crack propagations. This is a result of low safety factor in such a highly dynamic loading condition. Other factors such as bad workmanship, corrosion, and wear affect the safety factor drastically. These will accelerate the deterioration process which can lead to early failure of machinery components. A higher factor of safety is required by the modern trend of highly rated engines, in order to ensure a higher reliability along with high engine efficiency.

1.08 BASIC REQUIREMENTS OF MAINTENANCE SECTION.

Having considered the fundamentals of materials, it is only proper to review the basic requirements of maintenance systems. An effective planned maintenance programme will only be possible with the availability of dedicated maintenance resources. These will be in the form of:

(I) A maintenance section or department office which will execute the programme.

(II) Capital investment in the facility and equipment.

(III) Labour force in the manpower.

(IV) Facility, tools and equipment.

(V) Data and documentation.

1.08 (I) Maintenance Section.

A designated maintenance section or department must first be established with the sole responsibility of maintaining all assets of an institution, vessels or port facility. This section is allocated to a technical division of the institute. In the maritime sector this responsibility will usually be held by the marine superintendent and the chief engineer of a vessel. Where marine related equipment and facilities are concerned, the port authority will ensure that its technical department has a section to take care of the assets and equipment for cargo work, and port operation.

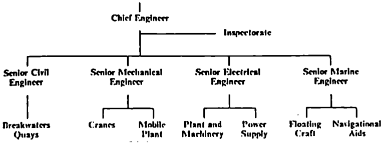
Maintenance policy of the port operation and port floating crafts will be formulated by the heads of these sections to streamline the activities and perform maintenance tasks of all the port and vessels which support port operation.

For sea going maintenance work this responsibility is borne by the chief engineer, and the captain through the second engineer, and chief officer. They will initiate the day to day maintenance work. Sub-contractors for major maintenance work for the vessel are arranged by ships office, ships staff and ship repair yard. The organizational chart is shown in

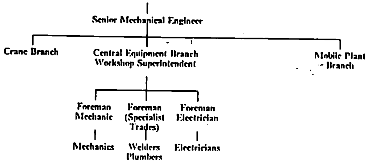
1,08'
figure 1.09 as a model.

Figure 1.08 Organization charts.

Example of organisational structure of Engineering Department



Traditional organisation of a Mechanical Engineering section



Source: Port Equipment: Policy Management and Maintenance, I.P.P. 3, Series. (Seminar), (Untactd) 1990.

1.08 (II) Capital.

A fiscal budget must be prepared for maintenance purposes. However the maintenance section will determine the capital allocation because the analysis of the capital expenditure in maintenance work is influenced by the policy advocated by the institution. An example of this is that a normal wearout failure may be dealt with one of three policy decisions.

(a) Immediate replacement of the defective item.

(b) Replacement after total failure.

(c) Replacement of the item at the next overhaul.

Any one of the above policy decisions will involve expenditure from the maintenance budget. However the policy with the least costs to maximize the profit and minimize the losses at acceptable level of the availability will be the ideal policy. This will be explained farther later on because all the financial avenues related to the specific maintenance tasks must be explored to ensure cost efficiency of the maintenance policy. There is no straight forward solution, considering the complexity of modern plants.

In marine and related industry, capital outlay will be set aside and budgeted for the purpose of taking care of the assets and equipment on vessels and port facilities. The money is not only for the wages of labour force but also for the purchase of statutory or essential spares, stores, and material for the smooth running of the maintenance program. Allocation of the capital outlay will depend on the maintenance policy advocated and maintenance tasks involved. Generally, the cost of the labour force and purchase of the statutory spares and material will form the major expenditures in this sector. Consideration must be given to other eventualities of expenditure as indirect costs of hire of outside labour force, energy costs, down time loss, as a result of unavailability of equipment. Therefore records of the costs of maintenance tasks will be necessary so that the unit cost of maintenance expenditure per unit time be established. This will enable costing of non-availability or stoppage in operation. These maintenance activities are cost intensive. They can be justified by keeping up the productivity at a high level. In order to do that it must also be insured a hhigh level of availability and sustainability of the operation and related maintenance in the port and marine industry. Hence acceptable budget allocation in this sector is foreseen to ensure continuity of operation and keeping in the best standard of availability of services and equipment.

With proper management of maintenance system investment in the system will gradually but surely realize the benefits of the system.

1.08 (III) Labour Force

The labour force is the human resource of maintenance sector. It is the manpower required to run the maintenance system effectively and efficiently. It represents a huge financial commitment in terms of costs of manhours for the performance and time taken to carry out the maintenance work.

The labour force will consist of mainly technical personnel like engineers, craftsman and non technical personnel as the administration staff. The organization of the labour force follows the normal hierarchy of most companies. As far as sea going vessels are concerned, crew members led by the chief and the second engineer both operate and maintain the equipment and machinery onboard the ship. The Chief Mate takes care of deck requirements while at sea. Ship repair yards are hired for major shipboard maintenance. In this respect the arrangement are made by the ship and the marine office. The labour force is crucial maintenance resource for any industry. For both marine and other related industries, the labour force is required to take care of the assets and port facility to improve the national economy of their states. The labour force will then be deployed to perform the maintenance on a shift or day work basis. At sea, the situation is different as the crew will be permanently onboard the ship. This situation makes the labour force at sea feel bored and will affect the work perform. There is a need, therefore to foster good labour relationships, in order to optimize the labour force and efficient performance of maintenance work can be realized, for the good of the industry. For any institution, whether production, commercial, or transport labour force is a delicate issue and must be treated with caution. Labour disputes and labour unrests are not conducive to national or international trade. Hence this resource needs to be treated with caution to maintain interest and for the labour force to offer their best in the enhancement of high productivity. The quality of labour in marine vessels is of different category to normal shore labour force in that all members of ship are regarded as either crew or passengers. The crew therefore consists of the working members of the ship. Each crew member has a specific duty to perform, with minimum qualification required by the international regulation. Hence the labour force on board the vessel is either skilled and qualified worker or semiskilled and of multidiscipline nature. Available recent surveys indicate that sea going labour force is very costly affair. The table 1.08 shows random number of ships with operating expenses to highlight the explanation. As for the developing nations skilled and qualified labour are scarcely available which necessitates expatriate personnel for the running and improving the port facility operation.

Table 1.08 Operation and Maintenance Costs.

Ship:	A	B	C	D	E
Age:	15	11	7	6	4
Type:	Ore Carrier	General Cargo	Bulk Carrier	Bulk Carrier	O.B.O.
Deadweight:	9000	6800	36000	7500	113000
PERSONNEL:					
Wages and leave	90,000	99,900	86,500	86,000	94,000
Overtime	17,800	16,750	12,600	11,400	14,100
Pensions	4,750	4,900	4,750	4,300	4,500
Crew Travel	1,600	5,500	8,700	7,600	12,100
Manning expenses	2,400	2,200	2,150	2,400	2,750
Miscellaneous	7,500	7,500	8,900	9,600	9,500
	124,050	136,750	123,600	121,300	136,950
STORING:					
Provisions	9,570	10,400	11,800	11,000	12,400
G.P. Stores	{ 3,000 2,500	{ 5,300 2,600	8,800	9,450	13,000
Cabin Store	2,500	1,650	1,550	1,500	1,750
Lub. Oils	2,850	4,000	8,250	10,500	21,200
	21,220	23,950	30,100	32,450	48,350
MAINTENANCE:					
D/D Repairs	23,000	36,500	38,500	60,000	74,000
Other Maintenance and Repairs	16,500	10,750	15,500	12,700	15,000
Spare Gear	8,300	13,250	15,400	13,750	14,250
Damage Irrecoverable	2,200	3,000	11,000	5,500	15,250
	50,000	63,500	80,400	91,950	118,500
INSURANCE:					
Marine Insurance	10,750	16,450	26,500	66,000	123,000
P. & I.	6,000	5,370	10,100	12,000	20,000
	16,750	21,820	36,600	78,000	143,000
GENERAL:	5,500	7,750	8,750	8,600	10,500
TOTAL:	£217,520	£253,770	£279,450	£332,300	£446,800

Source: Ship Maintenance, A Quantitative Approach.
By S. Shields, 1975.

1.08 (IV) Facility, Tools, Spares and Stores.

The availability of the physical resources like workshop facilities, tools, equipment spares and stores provides for quick and effective maintenance work to be done. These resources will also include special equipment for heavy duty work.

Investment in the equipment represents a large capital expenditure for the port facility. It is however convinient and reasonably cheaper to own the facility than to hire from an outside company.

The spares requirement is a major problem to control as a means of the physical resources. The quantity of spare parts for each item of the machinery is impossible to exactly determine. This problem depends on the demand of the spare parts per specified period. It also depends on the following criteria:

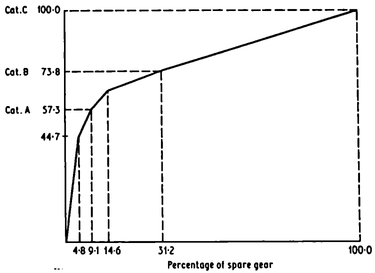
(a) The frequency of failure in the equipment.

(b) The frequency of the maintenance tasks.

(c) The expected life cycle of the equipment.

As a means of determining the level of spare gear and the level of stock control, it will rely on the application of the Pareto Curve in this regard, Figure 1.08 indicates how the characteristics curve is used.

Figure 1.08 Pareto Curve.



Cat. A = category A

Category A : High capital cost, low level of stock.
Category B : Relatively low cost, regular renewal, 1/3 stock.
Category C : Low cost, frequent renewal, High level of stock

Source: Ship Maintenance, A quantitative Approach.
By S. Shields. 1975.

The resources consist of special tools, work shops, of various discipline and technical requirement in marine and related industry.

Dock yard facilities are for essential for the maintenance of floating craft such as berthing tugs, labour, pilot, mooring boats. These are essential for movement of shipping at the port. Both mechanical and electrical work shops would care for the cargo transfer machinery such as forklifts, mobile cranes, and tractors used at the port. With high availability of the equipment, maintenance tasks can be easily accomplished even at high tonnage output. Shipping will have no reason for delays at the port.

Spares as a maintenance resource is very important matter in the overall maintenance programme. Equipment breakdowns can easily be managed when spare parts are available. The major cause of un-availability of equipment and machinery turns out to be lack of spares. This can be very costly in the operation of a port facility. Delays and work stoppages are then inevitable. The costs to hire equipment will drain revenue. Ship delays will cause shipowners to raise claims against the port. Cargo work will have a low tonnage output. Even more serious is the case for maintenance work at sea. Continuity of voyages may be impaired as there is no service depot at sea to obtain the spares. Apart from the statutory requirement of essential items on board ships adequate spares must be kept on board. It is difficult to quantify the spares stock requirement for port facilities or vessels. However for port facilities spare kits, seals, electrical pares must be made available for quick replacement. In marine vessels essential systems of machinery are duplicated. Other simple or complex items like propellers, shafts, because of their sizes and complexity pose large capital investments. Hence decision to install spares will rely on the probability of failure of the items. So discretion needs to be exercised in order to arrive at a proper decision. Nevertheless, the inventory of spares and their proper storage on board serves well for a reliable voyage. It is hardly imaginable to conduct maintenance work at sea without spares and stores material.

1.08 (V) Documentation and Data collection in Maintenance.

Documentation, data collection and recording of accurate information is an important procedure in any maintenance system. These give essential information regarding maintenance and equipment management. There are two main types of information categories; descriptive and prescriptive. The first one provides a list of figures and information of a particular item or system, with no relation to other system. The second gives information and how other systems are affected.

The objectives of documentation and data collection are the following:

(I) To create an inventory or asset register of all the items machinery for identification and record of the maintenance information in a plant.

(II) Systematic information in terms of the types of machinery, systems, or components for easy management of the spares.

(III) To organize maintenance procedures and scheduling maintenance work effectively, e.g. A system of job or work cards. This will enable costs evaluation of the labour, materials, time in which maintenance is performed and any overheads in the maintenance tasks.

(IV) Recording all maintenance work will reveal the behavior of the machinery components. The frequency of breakdowns in the operational life of equipment will enable management decision for replacement after economic life.

(VI) Management of the maintenance by analysis of the data and feed back information can organize effective scheduling.

The data and documentation in the maintenance must have the following quality:

(a) Accurate and relevant information on the behavior of maintenance tasks and the equipment. This will enable the right decision to be made.

(b) Easily accessible and simple coding systems, relevant to the maintenance equipment.

It is therefore important to keep up a document on the asset, equipment, tools, maintenance work orders, and costing procedures. This is an important procedure to enable efficient management of maintenance systems.

The assets must be entered into an asset register so that the quantity and evaluation of maintenance work can be easily organized.

All the functions of maintenance activities, purchase, and operations, evaluation of maintenance workload after completion is part of the documentation to be recorded.

Disposal of equipment is another crucial issue. It is essential to ensure proper papers are kept for eventual disposal of scrapped equipment, once it has reached its full life expectancy. For machinery and other equipment technical information is also needed. Other than the normal entry of technical information, suppliers name, manufacture address capacity, type, tools and spares list, both instructional and operational manual for the equipment must be available. These will be useful during the maintenance of the equipment. Maintenance work cards and records on equipment must be kept in the process maintenance system, so that allocation of costs can be done accordingly. Documentation of maintenance can benefit the system a great deal. Recording performance and other functions related to the system will provide a useful feed back for maintenance purpose.

Most data is in the form a list or table of figures. Graphical representation however provides a pictorial image which gives the trend of maintenance behavior immediately.

The information is related to the maintenance work on the equipment, time, labour force which performs the maintenance tasks and spares and materials used. Hence the ideal representation of the data and documentation is based on the information which can be translated into monetary form. This will give the cost effectiveness of the maintenance work. With accurate and unique data available it is possible to interpolate the figures to:

(a) Forsee causes of failures in the maintenance.

(b) Utilize available information on the resources to meet the operational changes, and so avoid unnecessary expenses for spares, e.g. ship board spares may be adequate for a change in trade route, or extra spares need to be purchased.

(c) Provide quick response to maintenance task requirement.

The summary of the analysis of documentation and data collected in the performance and actions to rectify faults will make the causes of failure and the condition to reduce. Data and evaluation of tasks can enable optimum management of the planned maintenance.

Considering the factors above mentioned maintenance scheduling and execution will realize most of the objectives set for it in the maintenance department.

2.00 CHAPTER TWO. CAUSES OF THE MAINTENANCE TASKS.

2.01 FAILURE IN EQUIPMENT.

In the previous chapter the concepts and basis of maintenance requirements were highlighted in the design and operation of a plant and equipment. It was seen that the purpose of a maintenance programme was to utilize the available resources namely, man, spares, and tools to ensure a high level of the availability of the equipment. This is done by ensuring that the condition of the equipment is at a high order for the plant to operate at a specified availability and performance over a specified life time. In this chapter failures of equipment in general and a review of the failure mechanism will be the subject matter. These constitute the causes of the maintenance tasks.

A failure is said to have occurred in equipment when the equipment is not capable of performing a function as designed by the manufacturer. The equipment is expected to perform a full workload before it can be said it is available for work.

2.02 FAILURE MECHANISM.

A variety of processes may be attributed to a failure mechanism. The cause may be inherent to the equipment, related to external sources or due to human element error. Whatever the root cause of failure, it is critical for maintenance purposes, to observe and determine the mode and the parameters of the source or cause of failure in order to formulate an effective maintenance strategy to ensure availability of the equipment.

Common failure mechanism are as follows;

(a) Over loading the machinery component.

(b) Environmental effects e.g. corrosion, erosion and abrasion which weakens the machinery items.

(c) Misloperation due to ignorance or intentional damage.
(d) Human error in design or during operation or in production.
(e) Overriding or bypassing the safety limits for machinery protection.
(f) Materials defects.

One or a combination of two of the above causes may be attributable to a failure. In trouble shooting, the reasons for need be identified so that recurrences are avoided.

2.03 REASONS FOR ANALYSIS AND DIAGNOSIS OF FAILURE.

Evaluation of the accurate data and information will reveal service history trends of the equipment. This information is statistically based but has a valuable influence on the management of maintenance tasks. Therefore analysis of all the data collected over a period will form a data bank for the planning maintenance strategies for a plant or vessel.

The information and data is available in machinery performance logs and maintenance documentation for the plant. These will be in the form of work orders, analysis of critical equipment problems correspondence files and in the operation and maintenance instruction manuals of the equipment.

Maintenance engineers can also provide valuable information in this regard because of their experience and knowledge of machinery failures of. Classification of all the equipment in the plant according to their functional system and criticallity should be conducted. It will then be necessary to codify and rank-order the various failure modes so that the maintenance workload can be apportioned appropriately. This indeed is important because different equipment has different possibilities of failure rates. Thus maintenance tasks can be concentrated first on the equipment which are highly critical. This will reduce the maintenance expense due to indiscriminate maintenance over all the equipment; with no due regard on the maintenance labour and material costs.

2.04 SPECIFIC ADVANTAGES.

The advantages of analyzing maintenance requirements of a plant are numerous. A few will be discussed in order to show maintenance tasks can be conducted with cost benefits in a plant.

(a) The result of analysis will bring to surface the criterion of time reference for components so that the mean time between failure and the mean time to replace a component will be established.

(b) A criterion of failure mode will also be known (i.e. age, operational design etc.) as will the frequency of failure. Necessary adjustments can therefore be done in time.

(c) Establishment of primary or secondary causes of failure will lead to preventive, or corrective action to be planned in time.

(d) Criticallity and priority of maintenance workload by economic impact on the plant will give a good guideline for initiation of appropriate maintenance workload to suit the prevailing condition.

(e) Investigation of major failures is of paramount importance in order to institute procedures of accountability Whenever a major maintenance problem occurs, it is normal practice, especially where critical failure has caused disruption or stoppage in production, to institute an investigation.

Different companies have their own different formats for carrying out this procedure. However as soon as a critical problem has taken place, it is necessary to conduct an official investigation. The report of the investigation will be retained for future reference.

These forms have common characteristics when filling them for any accident. Typical entries will comprise the date of the accident, place, time and if the environmental condition so that the location can be easily identified and the environmental situation was conducive to the cause of the accident. If the equipment is afloat, the tidal position will be required as part of the entries.

The personnel involved in the accident, their names and job descriptions at work, the equipment in the plant that was involved in the accident, and the cause or causes are very important items of the entries. So in depth investigation into the cause is critical so that the cause of the accident or major failure can be established if it is due to maintenance or operational error, or the act of God.

The extent of casualty or damage to the equipment incurred and the action which is taken to restore production as a temporary or permanent measure are also entries required in the report. Recommendations to prevent recurrence must be made in the report. The investigation report form is normally in several copies, some of which are sent to the company's insurance office, personnel office, others are retained in the section where the accident took place. The people involved get their copies. This procedure is exceedingly important especially when claims are raised due to personnel injuries.

The purpose of this investigation is to find out the cause or causes that precipitated the accident. Then corrective or preventive measures can be instituted with the aim of ensuring that recurrence will not take place. The procedure for investigation should always be done. Otherwise no amount of excuse will satisfy the authority with recurrence of critical problem or major accident.

2.05. ADVANTAGES OF ANALYSIS

The importance of failure analysis is to enable the maintenance staff to achieve the following benefits:

(a) Formulate appropriate maintenance policy to match the items, equipment and the modes of failure pattern in a plant.

(b) Awareness of the causation of failures will assist the management to make correct maintenance decisions for the plant to operate effectively.

(c) Discriminate between critical and noncritical items for appropriate attention of maintenance tasks.

A plant or facility may consist of a number of equipment or items. These may be simple or complex, and may not have the same possibility of failure rates. Establishing the factors of priority, maintenance workload can be created for a few number of equipment which need major maintenance work. Hence there is no conflicts between maintenance and operation of the plant. The overall operational cost will also be reduced. Some of the common failures will now be reviewed.

2.06 FAILURE PATTERNS.

The mechanical properties of materials under applied load, may exhibit elastic, inelastic, or plastic behavior. Any of these is an indication of the load bearing capability of a piece of material and the ability of a component to retain its shape and size in operation, within its load limits. In the course of time and depending upon the selection of material and design, the load bearing capability will degrade due to defects, or deterioration. The component then becomes weak. Hence reliability is lowered. Failure onset is then inevitable. Table 2.06 illustrates much more simply the general failure division.

Table 2.06

Fracture mode identification chart

Instantaneous failure mode(a)		Progressive failure mode(b)			
Ductile overload	Brittle overload	Fatigue	Corrosion	Wear	Creep
• Necking or distortion in direction consistent with applied loads • Dull, fibrous fracture • Shear lips	• Little or no distortion • Flat fracture • Bright or coarse texture, crystalline, grainy • Rays or chevrons point to origin	• Flat progressive zone with beach marks • Overload zone consistent with applied loading direction • Ratchet marks where origins join	• General wastage, roughening, pitting, or trenching • Stress-corrosion and hydrogen damage may create multiple cracks that appear brittle	• Gouging, abrasion, polishing, or erosion • Galling or storing in direction of motion • Roughened areas with compacted powdered debris (fretting) • Smooth gradual transitions in wastage	• Multiple brittle appearing fissures • External surface and internal fissures contain reaction scale coatings • Fracture after limited dimensional change

CONTRIBUTING FACTORS.

• Load exceeded the strength of the part • Check for proper alloy and processing by hardness check or destructive testing, chemical analysis • Loading direction may show failure was secondary • Short-term, high-temperature, high-stress rupture has ductile appearance (see creep)	• Load exceeded the dynamic strength of the part • Check for proper alloy and processing as well as proper toughness, grain size • Loading direction may show failure was secondary or impact induced • Low temperatures	• Cyclic stress exceeded the endurance limit of the material • Check for proper strength, surface finish, assembly, and operation • Prior damage by mechanical or corrosion modes may have initiated cracking • Alignment, vibration, balance • High cycle low stress: large fatigue zone; low cycle high stress: small fatigue zone	• Attack morphology and alloy type must be evaluated • Severity of exposure conditions may be excessive; check: pH, temperature, flow rate, dissolved oxidants, electrical current, metal coupling, aggressive agents • Check bulk composition and contaminants	• For gouging or abrasive wear: check source of abrasives • Evaluate effectiveness of lubricants • Seals or filters may have failed • Fretting induced by slight looseness in clamped joints subject to vibration • Bearing or materials engineering design may reduce or eliminate problem • Water contamination • High velocities or uneven flow distribution, cavitation	• Mild overheating and/or mild overstressing at elevated temperature • Unstable microstructures and small grain size increase creep rates • Ruptures occur after long exposure times • Verify proper alloy

Source:

Metal Hand Book: Failure Analysis and Prevention (Vol.11) 9th ed. Metal Park, Ohio: American Society for metal 1986.

There are a variety of ways to classify failure patterns, but primarily wear out or chance failures. Two major sub-divisions are as follows:

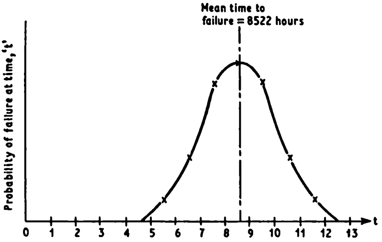
(a) Progressive Failure: This type of failure is caused by one or a combination of causes which precipitate a propagation of a minor defect which ends in total failure.

Progressive failures can be investigated and preventive measure instituted before occurrence of break down.

Wear, corrosion or incipient crack can be inspected in a component. These mechanism can fail a piece of machinery due to residual stress in the weakened component, as in fatigue failure. The progressive failures show a normal probability of frequency distribution curve with a mean time at the maximum

probability. In this respect the mean time between failure occurrence can be calculated. Figure 2.05 shows the uniform distribution.

Figure 2.05 Uniform distribution of Failures.



Distribution of bearing failure times

Source: Ship Maintenance, A quantitative Approach.
By S. Shields, et al. 1975.

(b) Instantaneous Failure: This type of failure occurs randomly by external causes to the equipment. It is a chance failure. e.g. brittle fracture, caused by over loading or an external course to the equipment and it is difficult to predict.

It is observed that failures are also designated by the mechanism that causes the failure, for example wear, corrosion, distortion, creep. Others failures may be caused by bad design or misoperation. These are caused by human element because of negligence or complacency in performance of work due to lack of motivation or other physiological reasons. All the above failure patterns have a behavioral characteristics and process mechanism specific to the name of the failure. A few will be explained in due course after a review of failure analysis so that the relation to maintenance can be established.

2.07 LINEAR CRACK MECHANISM.

Cracks are fractures or cleavage in a material due to elastic-plastic behavior of a material when subjected to load. The cracks account for major causes of failures in a component. Where indication of crack formation and propagation is evident, it must be viewed seriously to combat failures because these cracks are the basis of component failures.

The sketch on figure 2.07 below shows how the mechanism of crack formation and propagation in a material is started. The loading in a material imposes stress. Where crack is present the area at the tip of the crack is very small. Therefore the stress intensity will be exceedingly high. If the load increases beyond the yield limit micro fracture may result. Depending on the thickness of the material gradual crack propagation will proceed until failure due to unstable crack propagation occurs. Fracture toughness varies with the thickness. So thin material has little resistance to cracking, where as thick material can withstand minor cracks, as shown in the figure 2.07 (b)

Figure 2.07 Crack Formation.

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Fig. 11 Schematic illustrating displacement of atoms at the crack tip
The bond A-A_0 constitutes the crack tip, and B is the liquid-metal atom.

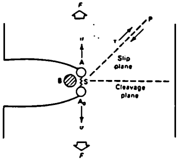
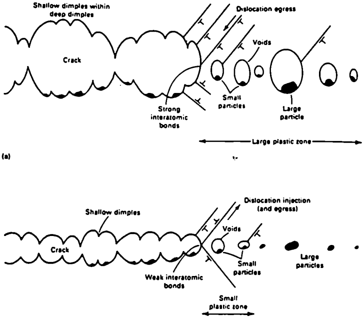


Fig. 12 Schematic illustrating the mechanisms of crack growth by microvoid coalescence
(a) Inert environment. (b) Embrittling liquid-metal environment



Source: Metals Hand book: Failure Analysis and Prevention (Vol.11)) 9th ed. Metal Park, Ohio: American Society for Metals 1986.

cracks must be detected so that remedial measures can be taken soon. Many ways are available to test for crack presence in a component. Some of these are as follows:

(a) Ultrasonic devices, magnetic, dye penetrant and any incipient cracks can be inspected. These devices are referred to as non destructive testing methods.

(b) Other ways consists of visual inspection, with magnifying glass at times. Any incipient cracks can be discovered when regular inspections are normally done. Ways of combating crack propagation are to ensure that there is no stress concentration, if a crack has been started a hole can be made at the tip of the crack to stop propagation.

Metal lock repair technique can be instituted. This is a way of stitching the crack by means of special metal keys. It is applicable to large items mainly and has a high reliability with major components of high capital value. The main advantages of this type of repair are:

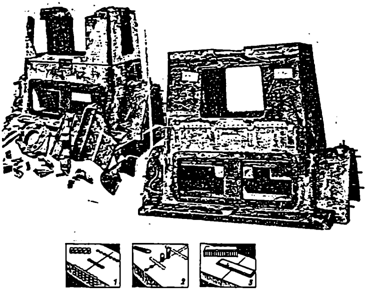
(a) The repair costs are always less than half the costs replacement of the component.

(b) No need of dismantling the machinery for the metal lock repair work.

(c) On site repair work is possible

Figure 2.07 (c) shows some of the main works by the metal lock type of repair work.

Figure 2.07 (c) Metal Lock Repair Work



Source: Marine Maintenance Manual vol. 2. Saltech.

2.08 WEAR OUT FAILURE

Wear is a progressive removal of material of a solid surface by moving parts, or by gas, liquid, or chemical corrosion on the surface of the component. The mechanism it uses are abrasion, corrosion, erosion by solids, gas, liquid, on the component. It is a gradual deterioration of the solid surface characterized by a reduction in size and eventual malfunction of the component, for example in the internal combustion engine worn out bearing shell, piston rings allow blow by of hot gases into the scavenge spaces. If the stuffing box sealing is also worn out these gases will foul the lubricating oil in the crank case with devastating effect on the lubrication system. Unless wear effects adversely influence the ability of a component to function wear may not constitute a failure on its own. The wear out failure is age related and can be manageable. During preventive maintenance tasks, a comparison of worn out components with a standard size enables a decision for replacement to be made before failure occurrence. It is normal practice to discard excessively worn out items in order to prevent pending failure in the system. Examples are piston rings, in internal combustion engines, or wearing ring in centrifugal pumps.

Investigation and analysis of wear failures almost invariably brings the question of lubrication to mind. Lubrication of working parts are factors which will be detailed later on. Meanwhile it is of paramount importance to bear in mind the fact that loss of optimum lubrication in the working system will lead to a rapid wear mechanism and sudden wear out failure.

The action to reduce wear out failures will involve the following strategies:

(a) Maintenance of lubrication system at the highest perfect condition to minimize wear effects.

(b) Selection of best materials for component be made, so that the material chosen may have self lubricating properties

(c) Records of wear rates should be kept in order to assist in maintenance plan.

(d) Condition monitoring of the oil by debris in filters fitted with pieces of magnets, and periodic laboratory tests to analyze the used oil.

(e) Maintenance of the static and rotary filters regularly will ensure adequate pressure in the lubricating system.

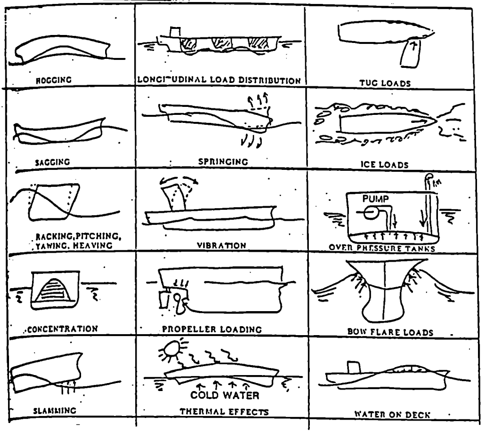
the above procedure will ensure prolonged useful life of the running items. Timely replacement will then be possible and the obvious benefit will be availability and reliability of the equipment at a high level.

2.09 DISTORTION FAILURE.

Deformation in size and shape of a component that renders the component no longer able to support its intended load is known as distortion failure. The deformity is caused by loading which exceeds the yield strength of the material. When the load is removed the component does not retain the original dimension. The component is then said to have suffered a permanent set or off set. It will not have the same strength properties as original. The reason for this is most engineering materials exhibit elastic perfectly plastic properties. When the loading is within elastic limit the component will retain its dimension. As soon as the loading exceeds the plastic regime, the material will be distorted and with strain or work hardening it will fail prematurely.

This is an important factor in design of engineering components because loss of elasticity cause the component to buckle. The loading that just causes bow or buckle in a component is referred to as critical force . This force varies directly with the distance from the point of application to the neutral axis of the component. The stiffness of the material is less when the force is applied nearest to the neutral axis of the component, and will increase with the distance from the neutral axis. This effect can be seen when a side force applied on a flat bar flexure will easily result. Otherwise a much higher force will be required when applied at the edge of the flat bar. This applies in the same way for plates, frames, shells and columns. When the critical force is large the force and the stress will cause plastic flow and permanent damage will result. This phenomena is very important design property for the structural strength of materials as ca be seen in the beam equation. Figure 2.09 shows the sketches of a vessel under varying loads. The section modulus will resist the loads.

Figure 2.09 Load on ship structure.



Source: Lecture Notes on Strength of Material

2.10 BRITTLE FAILURE.

The breakage of a component caused by impact loading on a structure is referred to as brittle failure. This failure is characterized by a rapid crack propagation with little or no plastic deformation on the structure with sudden unexpected failure.

It is the impact energy which causes the fracture because the strain energy within the structure is not adequate to resist the impact. Normally brittle failures occur in flat plane surface with tiny notch. Figure 2.10 shows the brittle failure mechanism. Other foams of loading, tensile force and high strain rates can cause a brittle failure in a ductile material at low temperature with corrosive environment.

Figure 2.10 Brittle Failure

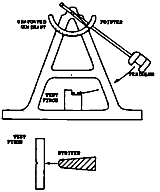


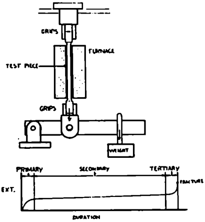
Fig. 60 Impact Test (Charpy)

Source: General Engineering Knowledge, Marine Engineering Series. By H.D. McGeorge.

2.11 CREEP FAILURE

This is a progressive stress occurring on a component under sustained stress at temperatures high in relation to the melting point. It exhibits visco-elastic behavior in the material under constant load as a function of time. Deformation of the component by reduction in bulk density and thinning of material is then detectable in the component, for example lead or wax creeps at room temperature under load, while exhaust turbine blades also show creep failure due to sustained high temperature. Creep failure undergoes three stages before final failure. Figure 2.11 (a, b, and c) shows the stages of the creep failures.

Figure 2.11 Creep Failure



Source: General Engineering Knowledge. Marine Engineering Series. By H. D. Mcgeorge.

(a) Primary Creep. In this stage strain rate decreases with time due to strain hardening effects.

(b) Secondary Creep. In this stage the strain rate is constant because as strain hardening effects increases so is the reduction of cross sectional area of the component. The effect of the true stress magnitude will balance out the creep rate.

(c) Failure Phase. At this stage the decreasing cross sectional area becomes the controlling feature the creep rate rises rapidly until failure occurs.

The right selection of materials, or alloys is important in combating creep failures. Otherwise replacement of parts may be inevitable for maintenance tasks.

2.12 FATIGUE FAILURE

This is a progressive failure pattern which shows brittle or ductile fracture after a prolonged period. It is often caused by a combination of residual stress presently in the component and external cyclic or alternating stress over a along time. It is age related failure with sudden unexpected failure.

The residual stresses consists of stress within the component due to workmanship on the equipment, stress concentration at cross sectional areas where sectional changes occur, or strain and work hardening in a material after manufacture.

Cyclic stress may be vibration, alternating stresses overload. In course of time these stresses may be higher than the stress designed for the material and fatigue fracture failure will result.

The mechanism of the fatigue failure takes three stages:

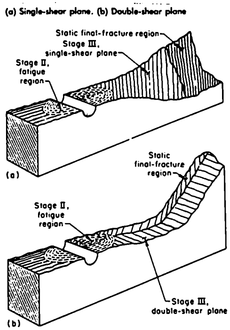
(a) Initial fatigue damage like a crack.

(b) Crack propagation.

(c) Final sudden fracture of the component.

Figure 2.12 illustrates the failure mechanism.

Figure 2.12 Crack Propagation.



Source: Metal Hand Book: Vol. 11, 9th. ed.

2.13 CORROSION FATIGUE FAILURE.

Corrosion is the process in which an oxide film is deposited on the metal surfaces; or the ionization of the hydrogen atoms from the parent material. The metal tends to return to its natural status of mineral ore by oxidation in an environment. The other way that gives the same effect is by the action of the hydrogen ions which causes electrochemical reaction to weaken and reduce the size of the parent metal.

Other factors in operation which influence corrosion are:

(a) Time of exposure in the wet environment.

(b) The pH value of the electrolyte.

(c) Bad workmanship.

Exposure of the material in open atmosphere for ordinary steel will form a type of corrosion referred to as mill scale. Farther exposure to damp environment rust formation will result. This will not protect the material any more so after a prolong period corrosion fatigue failure will result. The process of corrosion is shown in the figure 2.13.

With either source of corrosion the effect is reduction in the size of the structure or component with eventual failure due to corrosion. The mechanism by which corrosion develops is the release of locked up energy sometimes called free energy within the metal granular macro structure. The energy causes the atoms of the metal to combine with oxygen in atmosphere or surrounding environment and form a oxide film on the surface of the metal. This oxide is desirable because it inhibits farther formation of corrosion process. Nonetheless if the film is destroyed the process will resume with reduction in size and multi crack formation on the surfaces of the metal. The rate at which the process develops relies on many factors depending on the electro-chemical characteristics of the metal and its engineering applications.

Thus corrosion can be in the form of:

(I) General corrosion, in the environment of atmosphere or electrolyte by oxidation or passivation process.

(II) Galvanic corrosion, as a result of electro-chemical action.

(III) Stress corrosion, as a result of workmanship on the material. Figure 2.13 shows the process.

The maintenance requirement will be:

(a) To protect the component from moisture and oxygen by means of coating the material surface with paint.

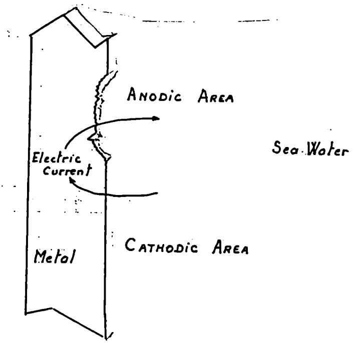
(b) Choice of appropriate material for system installation.

(c) Cathodic protection in the sea environment; and impressed current cathodic protection.

(d) Avoidance of disimilar metal as far as possible in the sea water.

(e) Drainage of entrapped sea water on the vessels.

figure 2.13 corrosion Process



Source: Lecture notes, by the visiting professor, Y. Metge.

2.14 ACTION TO REDUCE FAILURES.

Now that the awareness of different common features of failures and their causation mechanisms have been established comprehensive maintenance actions need to be identified so that failures can be reduced to a minimum or eliminated.

The strategy of the action will involve consideration of the following:

(a) Equipment design and manufacture.

(b) Procurement of the equipment with maintenance support options, like spares, operational and maintenance manuals.

(c) Proper selection, installation and commission of the equipment.

(d) Stand by or reserve equipment depending on load requirement and necessity.

The above items will be assumed to have been considered carefully bearing in mind the maintenance requirement and cost effectiveness. The actions pertaining to operation of the plant and its equipment is presently discussed and involves,

(e) Inspection of equipment.

(f) Running in procedures.

(g) Regular monitoring and record of the condition of the equipment

(h) Cleanliness of machinery and environment.

2.15 INSPECTION OF EQUIPMENT.

In order to reduce initial failures of equipment, by maintenance tasks the initial procedure is to read and study the manufacturers operation and maintenance manuals provided for the appropriate equipment. There is no one recommended way to care for all equipment in all working circumstances. Discussion of the procedures below will merely form some of the essential prerequisites for equipment especially the internal combustion engines because of its vast applications in the marine and related industry. Hence initial general inspection of the equipment followed by specific system inspections is crucial before operation. The process comprises a close check on the various components of the unit including the moving parts to ensure no part suffers any apparent defects. More specifically the inspection will involve the following systems.

(a) Lubrication System.

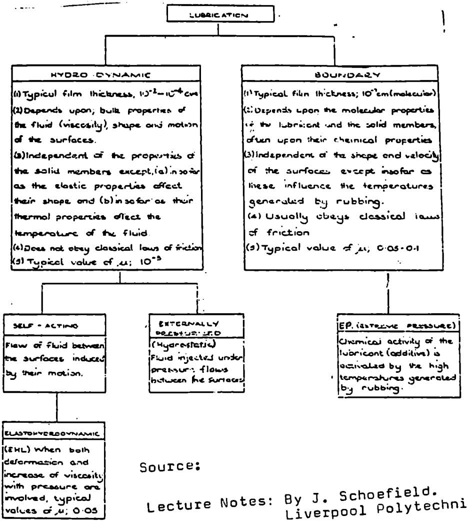
The oil level and quality are as specified in the operational manual. The system is adequately primed and all drains or cocks are shut off before running. There is no impediment in the system to restrict the oil flow. System parameters are maintained at the required levels. It can not be over emphasized that lubrication is a crucial prerequisite for among other reasons to ensure indefinite operation of equipment with minimum maintenance work. It is required to maintain perfect preservation of lubrication system to prevent serious failures.

The system comprises, among other things a pressure pump which takes suction from the machinery sump and supplies to a pipe gallery connected to various critical machinery components, like crankshaft bearings, piston rods, valve push rods, and rocker arms for the valve operation; cam shafts which operates fuel pumps. The oil then is passed through coolers to remove excessive heat before it drains into the sump and the cycle continues through filtering element for removal of any solid particles that may cause damage to the moving parts. These filtering elements are regularly inspected to ensure efficient performance. They are mainly of two types, static and dynamic filtration which will be discussed in greater detail later on in sub chapter 4.07, where the main component of the system will be examined closely.

The maintenance action is to ensure efficient lubrication system all the time. Figure 2.15 (a) illustrates classification system.

The purpose of lubrication is to reduce the frictional resistance between moving parts which are in contact and moving relative to each other by an oil film between them. In this way wear of the parts can be minimized. The failure in maintaining this can result in maintenance work.

Figure 2.15 (a) Classification forms of Lubrication.



Source:

Lecture Notes: By J. Schoefield.
Liverpool Polytechnic.

(b) Fuel Injection System.

The fuel oil injection system is the heart of the internal combustion engine. The equipment in the system consists of all the items from the daily service tank to the injector The items comprises suction filter just after the tank, flow meter, auxiliary booster pump, main booster pump, injection pump and the injectors. Other ancillary items are installed for control and monitoring purposes. The major items are as follows:

The injection pump is precision equipment and has the task of metering, and delivering fuel at a high pressure to the injector.

The fuel injector frequently develops faults and requires closer observation and rectification for engine operating for a long time at highest load.

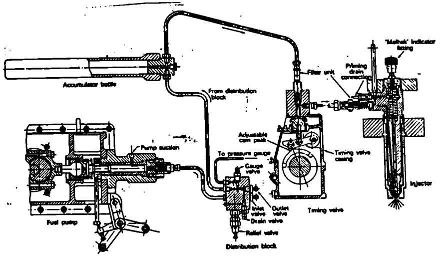
Clean fuel oil is also important for minimizing engine problems. Where power development is by means of fuel combustion as is the case with internal combustion engines injection systems will give less trouble with good, clean fuel oil.

The process comprises injection, ignition, and combustion in a controlled manner with highly precision equipment like the injection pumps, fuel valves, and filtering elements.

The function of the process is to provide a timed fuel injection in the form of atomization at the certain instant of the cycle of operation into the engine so that spontaneous ignition and combustion will take place with a rise in pressure and temperature. A proportionate mass of air will have been compressed into the combustion chamber to facilitate this process. Air intake is another prerequisite for the combustion and scavenge process. This will be given a detailed explanation in later chapters.

Maintenance requirement will involve maintaining the injectors in highly efficient condition. All the injection equipment must be maintained as specified in the instruction manual. In this respect it is advisable to carry out testing and evaluation of performance so that direct overhauling of the injection equipment will consist of replacement of parts. The precision nature of these equipment with fine tolerances makes it necessary for factory maintenance by experts with proper facility work Both static and dynamic filtering devices will be installed in the system these will require frequent inspection to ensure not only the cleanliness of fuel but also there is no water contamination in the fuel oil system. Figure 2.15 (b)

Figure 2.15 (b). Fuel Oil Injection System.



Source: The Running and Maintenance of marine machinery.
By G.T. Brayan, 1967.

(c) Cooling System

In order to operate a machinery at or within the required limitation of the material, cooling system must be maintained at high level of efficiency. Periodic attention is required so that excessive heat is removed effectively. Heat removal in the heat exchangers or through the engine will be by convection, radiation, and conduction. It is important however to ensure the purity of the cooling medium. Water purity is very crucial in this respect. Conglomeration of muddy deposit within cooling spaces and scale formation will impair cooling effectiveness. Thus periodical inspection through the inspection doors and scrapping the mud deposit or flushing the system with higher pressure flow of water than the normal pressure will keep the system in good shape. During and after flushing it must be ensured that no ingress of water into the combustion chamber or oil sump.

The hard scale formation caused by lime water will present difficult removal from the jacket system. So dilute water treatment additive can be added at low cost to avoid this scale formation. The addition of this anti-scale agent can control this effect at low costs and improve the cooling system.

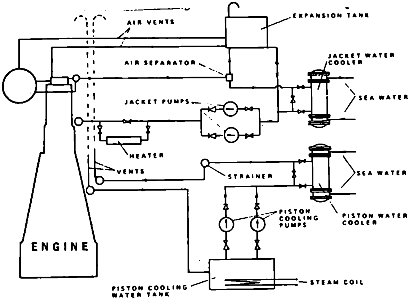
Cooling for the internal combustion engine is of different types. Depending on the part of engine being cooled then the type of cooling gives the name of the cooling system. Some of the cooling systems will be explained later on but these are just mentioned her as jacket, piston, nozzle, sea water cooling and lubricating oil systems.

The purpose of these cooling systems is to remove the heat developed at the engine as soon as it develops and hence allow the engine performance to increase.

The maintenance requirement in this respect is to ensure that heat transfer between the engine and the cooling media does not take place with a high temperature gradient to cause thermal stress on the component.

The system equipment in all comprises two major items, the pressure pump and the heat exchanger. Both of these items will be discussed more later in chapter 4.00, for now it should be appropriate to say that efficient performance of these two items will go a long way to improve the cooling systems. Ideal cooling system is shown in figure 2.15(c).

Figure 2.15(c) Ideal Cooling System



Source: Marine Engineering Series, Diesel Engines, 2nd Ed. By A.J. Wharton.

2.16 START AND STOP SYSTEM.

The main thing in the starting and stopping systems of any machinery is the ability to control the equipment safely during start, normal and emergency stops. The starting arrangement will depend on the rating and frequency of starting the machinery. The duty of the starters is to be able to overcome the initial torque due to the inertia and frictional forces of the masses of the moving parts of the machinery from stand still. It is a good practice to start machinery at no load and gradually build the speed till the machinery responds on its own power. Other machinery where the load is directly coupled to it have to be started on load. The starting system must be appropriately designed to cater for this duty. In this case the starter will be highly rated to enable efficient performance. It is normal to find that the control of the starting system at a local or remote positions from the engines. At the same time the system is arranged to start automatically. These conditions are important to recognize because if any maintenance work on the machinery the remote start control must be prevented to operate for safety reasons. However once started and running the machinery can be stopped by shutting off the fuel oil. An emergency may arise the compressor can stop immediately.

There are three types of starting arrangements in common use. These are explained below with their maintenance requirements highlighted.

(a) Air Starting System.

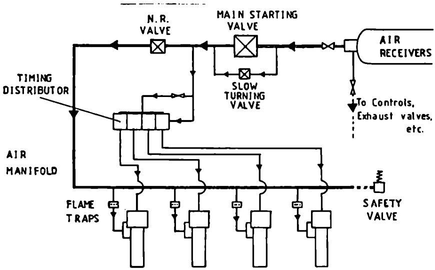
This system comprises an air compressor usually a reciprocating types because of the high pressure requirement or a hybrid type of rotary and reciprocating type. Other ancillary items consist of an air bottle (air receiver), coolers to improve the efficiency of the air compressor. Both of these will be fitted with safety fittings to protect the system in the event of excessive pressure e.g. relief valve or bursting discs.

The compressor can be driven by an electric motor. or diesel engine. Apart from the normal crankshaft lubrication of the compressor the cylinders have their own wick lubrication. This will invariably introduce oil mist into the system. The oil traps and automatic oil drains must be maintained in efficient operation to prevent risks of explosion.

Two modes of operations can achieve the starting arrangement objectives. The compressed air is released into the cylinder unit at the high pressure to turn the engine for starting. The other way is by having a pneumatic motor with gear arrangement which engages a fly wheel and turning the engine to start. As soon as the engine has started the gear disengages. The later mode is used mainly with small or medium speed engines, while the former has the sole application in slow speed engines. The disadvantage with this is air release into the cylinder unit may introduce water vapour. This process will create corrosion. Figure 2.16 (a) shows air starting systems of a large and medium speed engines.

Figure 2.16 (a)

Starting air system.



Source: Marine Engineering Series, Diesel Engines, 2nd. Ed. By A. J. Wharton.

The maintenance required with the compressor will be to ensure the following:

(a) All the stages develop the required pressures.

(b) The safety fittings for example the safety valves, drain cocks, oil traps are working normally.

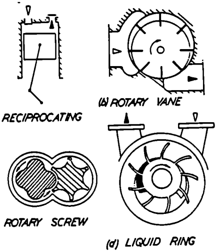
(c) Both water and oil must be prevented from entering the system as this can result in a serious accident.

(d) All the pressure gauges on the compressor and the air bottle must be in working condition.

The demand of compressed air for starting the main and auxiliary engines on board ships is such that in most cases two air compressors with an emergency one are installed on board ships. Hence if one compressor is on operation schedule the other one will then be on standby.

The maintenance tasks must be done according to the requirement of classification society regarding the ability of the starting arrangement to cater for certain number of starts before the air bottle becomes empty. Figure 2.16 (b) shows the selection of basic construction o6 air compressors

Figure 2.16 (b) Types of Air Compressors.



Source: Marine Engineering Practice, Vol.1,part 1 Selection, Installation and Maint nance of Marine Compressors.

(b) Electric Starter

The electric starting system requires careful maintenance because the system is vulnerable and susceptible to a variety of causes for failure. These causes are obscure and difficult to diagnose even for experienced operator.

The system comprises of an electric motor. Usually a direct current driven motor; batteries of voltage level compatible to the voltage required to drive the motor of a high starting torque characteristics. The batteries in this case will have to be highly rated in terms of ampere-hours so that they are capable of several starts while the voltage level is maintained normal. Installation of a battery charging unit will then be part of the system. The unit will either be installed externally or attached to the machinery. The function of the unit will be to replenish the battery voltage automatically.

The principle of operation is same as for the pneumatic motor.

The starter motor engages to flywheel of the engine and turns the engine for the initial torque. Once the engine has fired it accelerates faster and starter motor disengages automatically.

The maintenance requirements will be concentrated mainly on the batteries and the brush gear at the motor. These are the areas where problems will be prone. The charging unit being a static machine normally will offer little or no problems for a long time.

Hence the batteries are maintained and charged at a required voltage level. The electrolyte is of proper specific density. There should be also ventilation means at the storage space of the batteries. The starter and generator must not be neglected during the inspection. The brush gear in this respect will need special care because starting problems with D. C. motors hibernate at this area. So regular inspection and clean up of the carbon brush dust and ensuring the correct contact resistance between the brush and the commutator will have ensure efficient operation of the starting system.

Another area is to ensure the mechanical parts are in good order. The air gap between the armature and the stator is according to the instruction manual, bearings and or bushes are not worn out. Deviation of the air gap gives an indication of wear on the bearings or bushings that support the armature. Inspection of the air gap and comparison to the given size in the instructional manual will assist in deciding for the replacement in time. This will prevent damage of the rotating armature and stator field windings in operation. Water ingress into the motor must be prevented as this will faul the starter.

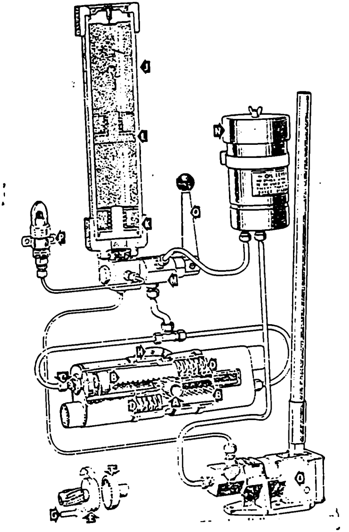
(c) Hydraulic Starting System.

Two types of system, one is of manually operated by hydraulic pump, cylinder, with an accumulator. This is used mainly with small diesel engines. The other one a hydraulic motor is installed near the flywheel. In both cases the oil pressure provides a force which creates a torque to turn the engine.

The main thing to watch in this respect is to make sure that the system is well purged up and that there are no undue leakages. The operating level should be well secured when the engine is in operation. Figure 2.16 (c) illustrates hydraulic system.

Once the operator is satisfied with the initial inspection hand cranking of the machine is done to see if the machine has free movement and no loose items in the way. Now the engine is prepared for running in procedure.

Figure 2.16 (c) Hydraulic Starter.



A. Pinion with helical teeth
B. Piston racks driving pinion A
C. Hydraulic fluid inlets
D. Piston-rack return springs
E. Driving dog integral with pinion A
F. Driven dog on crankshaft
G. Axial thrust due to helical teeth of piston rack and pinion
H. Starter mounting flange

J. Hydraulic accumulator
K. Piston lowered under compressed air
L. Piston raised by hydraulic pressure
M. Relay starting valve
N. Hydraulic fluid feed tank
O. Hand pump for charging accumulator
P. Plunger pressure gauge
Q. Starting lever

Source: Diesel Engines, Question and answers, By, J.N. Seal.

2.17 RUNNING-IN PROCEDURE.

All equipment before commissioning in service must undergo a running-in procedure. This is an important procedure because the chances of early failure are high at this stage, as depicted from the bath tub curve diagram which was discussed in the first chapter. This will avoid any infant mortality, the chances of which are very high at this early age. This process enables the working surfaces to bed-in gently without undue wear. A long life skin of matching surface is formed on the rubbing surfaces. This is a desirable condition before final commissioning of the equipment into service. Utmost care needs to be taken because failure at this stage can have a serious impact on the replacement and maintenance costs.

The lubrication medium in this process will be enriched with colloid graphite to improve lubricating oil quality to have more adhesive film spread on the new smooth surfaces. The microscopic graphite interpose themselves between high spots of opposed rubbing surfaces providing adequate lubrication to reduce wear and allow the working faces to bed-in accurately.

The procedure will involve starting and running the machine at no load for a short period of time. Then the engine is loaded to 25% load for a short period. Then 50% for over a day and then gradually loaded with observation of all the parameters. After the running-in period, a suitable lubricant must be maintained according to the makers recommendation. This is applicable to every individual piece of machinery. Table 2.17 shows the test procedure for the medium speed engines.

Table 2.17

Running and Testing Procedure.

Times and conditions

First run	minimum r.p.m.	no load	2 min.
Second run	minimum to 300 r.p.m.	no load	5 min.
Third run	300 r.p.m.	no load	10 min.
Fourth run	minimum to 500 r.p.m.	no load	30 min.

After each run feel around the engine, e.g., on the crankcase doors, for signs of overheating or unequal heating of similar parts. A complete internal inspection is required after each preliminary run to ensure that the engine has been running correctly. On shutting down after each of these runs, feel all bearings and pistons for signs of overheating and for unequal heating.

NOTE:- When examining the internal parts, keep all naked lights away from the engine.

Fifth run	500 r.p.m.	no load	30 min.
* Sixth run	500 r.p.m. to rated speed	no load	30 min.
* Seventh run	rated speed	no load	30 min.

* Check the operation of the overspeed trip and adjust if necessary.

Eighth run	rated speed	25% load	45 min.
Ninth run	rated speed	50% load	45 min.
Tenth run	rated speed	75% load	45 min.
Eleventh run	rated speed	50% load	30 min.
Twelfth run	rated speed	100% load	30 min.
Thirteenth run	rated speed	110% load	30 min.
Fourteenth run	rated speed	100% load	30 min.

Source: Ruston Diesel, Maintenance Manual 6.R.K.M,

2.18 REGULAR MONITORING AND RECORD OF PERFORMANCE.

Regular monitoring of equipment performance is another factor which influences the reduction of failures. This process consists of monitoring of all the parameters of various systems and recording them. Besides the parameters it is important to record the following features.

(a) Load developed every time equipment is in operation.

(b) Running hours and any replenishment of lubricating and fuel oils.

(c) Maintenance work carried out, time taken and any materials used. The advantages of this procedure is more than just reduction of failures. It is a creation of an interface between the machines and operators. This relationship goes a long way to prolong efficient performance of the equipment and the data collected over time will form the basis for future maintenance strategies.

It is also important initially to adhere to the manufacturers operation manual for initial running of equipment. Modification and adjustment can be considered after creating confidence of the behavior of performance later on.

In the absence of an instruction manual an old adage can be followed: "Clean fuel, clean engine, clean engine room, cleaner driver."

Routine inspections at time intervals should be established. This will depend on various factors of engine performance, load patterns and the environment. Another factor is vibration, and noises in the machinery spaces. Discussion of this will be more detailed later on. For now the effect of vibration and noise level gives a good indication of pending problems.

2.19 CLEANLINESS.

Another important factor during inspection is cleanliness of external and internal of equipment. This applies a great deal to diesel engines. Unclean engines mean neglect on the plant. This demoralizes the maintenance staff and operators. Failures and threat to safety of operation will be imminent. As regards the internals of the machinery it depends upon the followings:

(a) Load and load consistency, at low load more fouling of engine parts will take place.

(b) Atmospheric cleanliness, and ambient temperature and humidity can affect the cleanliness.

(c) Quality of fuel and lubricants have a great part to play in this respect. The fuel oil must in clean condition.

(d) The operators regular attention to work and regard the working place as his home.

2.20 CONCLUSION.

It is possible to reduce failures and maintain the primary factors in perfection so that reliability, availability, and maintainability be ensured for a prolong time. These condition are related to each other and depend on the type of equipment, observation, and operating personnel. Therefore appropriate maintenance work carried out effectively will ensure durability compatible to profitability and economy of the plant.

3.00 CHAPTER THREE.

3.01 SELECTION OF THE MAINTENANCE SYSTEM

Selection of a maintenance system is an art of evaluating performance of equipment in a plant over a period. Maintenance procedures should maximize profit an minimize maintenance costs. Then maintenance can be conducted at a scheduled routine to keep the equipment, vessel, or facility in the best condition most of time.

The purpose of selection is therefore to match intelligently, appropriate maintenance procedures to forestall and prevent unexpected, breakdowns or repairs. These will cause downtime, unavailability of equipment and raise the production costs of the plant. The costs of these can be so high as to offset the profit margin of running the plant. So maintenance must be seen to be working within the constraints of reducing these costs while the at same time maintain operation to generate revenue at reasonable costs on maintenance tasks.

It seems hard to comprehend that a well selected maintenance policy will realize a great deal of benefits. What is needed is to consider the enormous expenses which will be incurred due to direct and indirect costs as a result of costly repair, costs of the component for replacement of parts, energy costs, cost of hire and downtime costs. These costs are certain to prevail with inadequate or no maintenance procedures in a plant.

The complexity of the equipment in a modern plant has made it imperative to plan out an effective maintenance system. The reason is a stoppage in production or operation at a facility will result in irretrievable losses and possible payment of claims where a contractual agreement is involved between client and suppliers.

Selection, however, will depend on the workload requirement and the company's philosophy on maintenance level and type of a plant. The workload on a plant may be of a continuous nature, essential service demand, statutory requirement by classification society over a period of time. It is important in the selection of a maintenance system to consider, as well, short and long term maintenance plans in a broad sense for all the equipment and decide to apportion a major workload of maintenance tasks on equipment of high priority. This will give a flexible and comprehensive approach to maintenance and realize profitability with safe and prolonged working life of the equipment.

3.02 CRITICALLITY AND OBJECTIVES OF MAINTENANCE.

Analysis of the performance of the items, equipment, and machinery of the plant over a specified period will reveal the behavioral pattern of the various equipment and their functions in the plant. It will indicate that all the equipment have different modes of failure patterns. Failure in some equipment can be rectified while production of the plant continues. Other failures will cause stoppage in production or can be damaging to the equipment and also a safety risk. The same thing applies on board a vessel. The latter type of equipment can put the plant at a high vulnerability. Examples of this are failures in power generation, steering or mooring equipment in a vessel or cargo handling equipment. The result can be a catastrophe. All equipment and items are in a plant important for the operation and achievement of goals in a ship or port facility The criticallity of these equipment will form a basis or criterion which will determine the maintenance tasks.

Some failures are more critical than others in a plant. The consequence of failure of equipment with a high criticallity affects the production process or continuity of movement in sea transport Maintenance tasks in this respect will be concentrated upon the equipment of high criticallity to prevent major break-downs which can cause stoppage in operation. Take for instance, a plant with 1,000 pieces of equipment. Ten of these items have a failure characteristic as explained above; the efforts of maintenance tasks must be concentrated on these ten. The other equipment failures have no adverse effects on the plant. So they will be planned in-line maintenance tasks. The whole point is to maintain operation at a reduced cost of design and implementation of maintenance tasks. These costs soar initially and the benefits take some time to be realized. Indiscriminate implementation of maintenance tasks on all equipment will not realize the objectives and costs will be enormous. These are the constraints a maintenance designer will have to face and he will have to suggest steps of action to be taken to identify the level of criticallity of the equipment in a plant and give equitable priority.

Maintenance tasks, as opposed to repair work after a breakdown, are a means of maintaining the equipment in safe and healthy condition most of the time. The objective of maintenance therefore is to plan out the available resources and know-how in order to prevent and correct maloperation and failures in good time. This practice will create a continuity in operation so as to reduce the operational expenses in a plant in the long run.

3.03 TYPES OF MAINTENANCE SYSTEMS.

There are many types of maintenance systems in existence that form the policies of a company or institution. It has been observed that the difference in their reference is derived from the nature and purpose of the maintenance tasks performed at the time. Examples are the short and long term maintenance policies. These form the major branches of all maintenance policies for a plant. Others are preventive, corrective, breakdown maintenance systems and these are the offspring of the above systems. There are also others like routine, service, urgent, and emergency maintenance systems. It is however intended to discuss some types of the common maintenance systems. The purpose and benefits of them will be reviewed with regard to attainment of the goals of the company's maintenance policies.

3.04 SHORT TERM MAINTENANCE.

Short term maintenance consists of general and detailed planned maintenance to achieve high availability and preparedness in a plant for normal operation and in case of disturbances as a result of major overhaul or major preventive maintenance. It is achieved by daily allocation of the labour force to various sections of the plant for inspections and scheduled works. The idea is to ensure the availability of labour force, manpower, equipment and material with little down time.

This is a safety maintenance system and executed within the company's available resources and the company's decision on the resource utilization. It is considered that this maintenance policy is needed to ensure a high availability of the equipment and reliability of the equipment despite daily changes in the plant output capacity. One major factor that influences short term maintenance is the mismanagement of maintenance activities in the various sections of the maintenance department.

Delays in the procurement of materials is one of the main reasons which can hold down progress in maintenance tasks. This problem affects the developing countries a great deal because most of the spares have to be purchased from foreign countries with foreign currency which have to undergo delaying protocol procedures; meanwhile the plant suffers downtime losses and services availability.

The benefit of the short term maintenance policy is the continuity of the plant operation with minor interruptions.

3.05 LONG TERM MAINTENANCE.

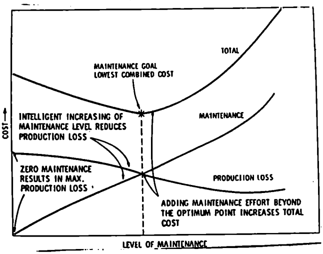
This is an economical maintenance procedure and affects the operation costs in the long term.

Factors which influence this maintenance are indicative of pending equipment failures with no cause for alarm because preventive and corrective procedures of a long term nature have been planned for.

The benefits of this long term maintenance system is that it provides for long life of equipment. So investment on new equipment will then be unnecessary for a long time. It is a suitable procedure for classification society or authority requirements. The equipment will have a low depreciation value and therefore high second value when it becomes necessary for replacement.

The only snag with this system is the expenditure will affect the operation costs when it comes to major overhauls and repairs. Nonetheless balancing the cost with operation expenditures can achieve optimization of operational costs and profits. Figure 3.05 shows typical cost and maintenance level characteristics.

Figure 3.05 Optimum Maintenance Level



Source: Cost-Effective Maintenance Management, Production Improvement and Downtime Reduction, By F. Herbaty, 1983.

It can be seen that optimization of both corrective and preventive maintenance costs will have optimum value to operate on.

3.06 BREAKDOWN MAINTENANCE.

This type of maintenance is only carried out after the total failure of equipment. Then a report of failure is made to the maintenance personnel to attend to it. Only lubrications and normal services are carried out during the operation. Nothing is done in way of monitoring and inspections because the cost of the item is less expensive than the cost for the maintenance. Thus it is only suitable for items which have low criticallity and downtime is a negligible percentage of the maintenance costs. Otherwise, for equipment with high percentage costs and high criticallity, then the failure in this equipment will result in production loss and crises in operation.

The concept of no maintenance at all until a breakdown is reported is not economical because items and equipment can fail because of so many other reasons such as:

(a) The item in equipment will become obsolete and deteriorate with time in operation.

(b) It may be cheaper to use new and cheaper items for the plant, with greater useful life than the plant. These items can now be designed.

(c) Failure rates due to maloperation or design are still known to happen.

Having no maintenance tasks until breakdown can cause other breakdowns unexpectedly and possible equipment damage.

3.07 CORRECTIVE MAINTENANCE.

This is the type of corrective maintenance that is conducted to restore an item which has ceased to meet acceptable standards. This is normally conducted when the failure is deemed likely to happen; a criterion has shown that the performance of a plant is not meeting the required load due to design defect; leakage in the pipe connection; a gradual drop in the lubrication pressure. Other causes of design and maloperation may precipitate failures to make corrective measures necessary. With detection of weak points in design, recording and analysis of failure and criticallity of items it is possible to plan out for corrective action after a failure.

Maintenance philosophy does not regard corrective maintenance as purely a maintenance process. The reason is the purpose of maintenance is to reduce as much as possible the occurrence of the failures, especially failures of critical equipment in a plant. Therefore corrective maintenance can be restricted to condition monitoring of those items and functions which tend to lower the normal standard performance of equipment. It is possible to measure expected wear rates and other parameters such as pressures and load characteristics of equipment with condition monitoring. So preventive action can be taken before failure occurrence.

3.08 PREVENTIVE MAINTENANCE.

"Maintenance is a combination of actions carried out to return an item to or restore it to an acceptable condition." And "preventive maintenance" is maintenance carried out at a predetermined interval or to other prescribed criteria, and intended to reduce the likelihood of an item not meeting an acceptable condition." These are British Standard definitions and will give a good guideline to approach maintenance processes properly. However a proportion of prevention and correction for maintenance procedures will result in more comprehensive and flexible action for the care of all equipment.

Preventive maintenance can be divided into minor and major preventive maintenances. At the same time minor preventive maintenance is also split into two approaches. The first approach is to implement no major maintenance tasks on equipment or systems initially for a specified period. The reason is quality assurance in modern technology, design, and manufacturing trends have produced machinery of high reliability and durability because of the best material selection and application in the production of equipment. In that time only necessary lubrication, and procedures for inspection, minor adjustments and cleanliness on a short time basis are carried out regularly. Not too much time is expended on these short services. However during inspections problems or troubles which are noticed must be recorded to form a criterion of the level of minor preventive procedures for the future.

The other approach is to institute condition monitoring so that the performance of all the parameter will be recorded and evaluated. This is a form of indirect repair. It is essential to formulate the basis of major maintenance work procedures for future requirements.

The major maintenance system is applicable to critical equipment in a plant because failure in this equipment will constitute serious production loss and stoppage due to unavailability of service. It comprises periodic overhaul and parts replacement. The workload in this maintenance procedure will involve conditioning monitoring, and knowledge the mean time to failure. A plan can be arranged or scheduled to carry overhaul before failure occurrence. With these factors in mind maintenance can be executed at a time suitable for production or operation conditions.

In major overhaul calibration, inspection of the components and comparison to the standard sizes will enable deviations to be known. Then the decision to replace the items can be made easily. This will create confidence in operation with little or no interruptions. Therefore fixed time period or other criterion must be established. Examples of these criterion can be any of the following:

(a) Running hours from the last overhaul.

(b) Traction mileage or number of voyages.

(c) Load bearing capability of the equipment or deterioration of the hull surface.

(d) Plant efficiency with standard inputs.

This will enable the appropriate maintenance tasks to be executed periodically without failure. Otherwise postponement of the maintenance for no good reason may weaken the equipment due to excessive wear on the moving part and failure will result. Example such as excessive wear in piston rings in the internal combustion engines or leaking propeller shaft will result in disastrous results to operation and safety.

The importance of major preventive maintenance cannot be over emphasized in all sectors of industry. It bears serious economic safety and environmental implications. Negligence of it imposes hazardous conditions in the working environment. The costs of unavailability and downtime may result in irretrievable losses of revenue

3.09 MAINTENANCE SYSTEM.

A system in which the performance of maintenance tasks should achieve an "Optimum balance between plant availability and maintenance resources utilization" (Kelly 1989). The maintenance system or organization will normally consist of the following elements:

(a) The Resources. (Personnel)

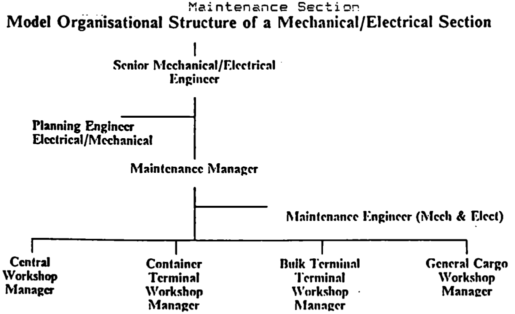
This will consist of the labour force which will be men and women who will be deployed in the various sections of the maintenance department. A majority of the labour force will be personnel with technical qualifications. Others will be either semi-technical or non-technical staff who will carry out non-technical work at the offices for minor administrative work and on site for manual work. The maintenance section is always a technically oriented due to the technical nature of the maintenance work.

Hence it is this section that will be charged with the duty of organizing, execution and control of the maintenance work for all the assets of a company or port facility.

A typical organization of the maintenance section will comprise a civil engineer or chief marine engineer. Either of these designations will normally form the head of the maintenance department.

The job description will include the execution of the company policies relating to maintenance and he is answerable to the managing director of the company. Principal engineers, both civil and marine, will be under the head of maintenance section. It is intended to discuss the labour force related to the marine and related industry. The illustration in the figure 3.09 will give better view of the organization of the maintenance section.

Figure 3.09 Organization Chart for the Maintenance Section



Source: Port equipment: Policy Management and Maintenance I. P. P. 3, Series. (seminar), (Unctad) 1990.

All the employees in an institution come under the umbrella of the labour force. It is a common practice to see that right below the foreman level a distinctive line exists. This line divides the labour force between administration or management in office work and employee who work in the field or yards. The success of a maintenance system will depend on the inputs and cooperation of these two divisions so that maintenance goals are achieved with cost efficiency.

In the developing nations the main drawback is the labour force with adequate know how to maintain the equipment properly.

(b) Administration and Training.

The administration is the top of the organization hierarchy as shown in the figure 3.09 (a). Normally it comprises the heads of the following sections or departments:

(a) The head of the administration department.

(b) The head of the maintenance section.

(c) The financial manager as the head of the accounts section.

(d) The head of the store and supply section.

(e) A representative of the personnel department.

The objective of the management is to authorize the maintenance budget and ensure that maintenance work is implemented according to the company standard policy.

The principle actor in the management sector of maintenance will be the maintenance sectional head. His role in the management is viewed as a necessary evil because most of the time he will have to convince the management to invest in the maintenance strategy; and this investment does not represent immediate pay back revenue. The only saviour in his role is the understanding the value of maintenance in relation to losses due to lack of it.

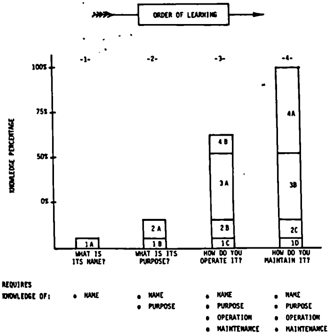
The personnel managers role will be in ensuaring the labour force is adequate and of the right skill. Hence the training and manpower development will also fall under the personnel section.

The labour force is expected to know the equipment, the operation, and maintenance of the equipment in order to work with it effectively. Lack of know how in operation will only abuse the functions of equipment and this will end in damage and costly repairs. Hence, this necessitates the need for training programme within the labour force.

Training is the need in a plant to be able to repair or rectify any breakdown that may arise. Thus in order for a plant to run efficiently it will be necessary to establish a training scheme for the workers for replacement, or for manpower development so that adequate staff will be available. The training can be of general skills or of special skills. The essence of training is for both the operators and maintenance personnel to be able to identify the various machinery and equipment under their care, to know the purpose of the equipment, the operators should have a slight knowledge of equipment maintenance so that minor troubles can not evolve into major problems. Both the operators and maintenance worker must be conversant with the operation and maintenance of the equipment while the maintenance workers must have overall knowledge of disassembly and overhaul of the equipment when it comes to major overhaul. The figure 3.09 (b) will show the respective level of the requirement for a maintenance worker.

Other areas of training will be in trouble shooting and diagnosis of faults. This will enable quick identification of faults and possible corrective actions to be taken in time. All these skills and know how are achieved by appropriate training programme that must also be maintained in a plant.

Figure 3.09(b) Learning Process for the Workers.



Operation and maintenance learning process.

Source: Cost Effective Maintenance Management, Productivity Improvement and Downtime Reduction. By F. Herbaty, 1983.

(c) Work Planning and Control.

In the maintenance system a mechanism of planning and control will be established. The purpose of this mechanism is analysis, plan, execution, and recording of the maintenance workload over the equipment in a plant. The reason is to ensure that all the maintenance effort is correctly directed to the objectives set by the company. This is achieved by establishing a record history of all the equipment with their frequency of breakdowns and their causes if it is parts or system functions which are not covered in the maintenance tasks. Rates of the cost of services and hire of equipment. The personnel involved in this function must be competent so that they can make right judgement of maintenance requirement and allocate jobs to competent workers. It may be necessary to have regular meetings to decide on the allocation of work, time the work is expected to end and the number of labour force necessary for various jobs. This procedure will enable standards of a job performance, work costing and analysis of labour productivity to enhance the maintenance system organization.

3.10 CLASSIFICATION SOCIETIES AND MAINTENANCE.

One of the objectives of maintenance in maritime vessels is to comply with the minimum requirements of the classification societies. In order for a ship owner to operate in sea borne trade he is obliged by the insurance underwriters or brokers to request one of the classification societies e.g. the Bureau Veritas, Lloyds, Det Norske Veritas Nippon Kaiji Kyokai, American Bureau of Shipping to conduct survey and inspection procedures according to the international requirements of the maritime industry. This procedure will establish the sea worthiness of the vessel before venturing into the sea borne trade.

The ship owner will insure the vessel against various other risks with different brokers for both hull and machinery in the event of damage or loss. In any case the classification society will be involved as an independent international association whose objectives are safety of life at sea and uniform standards of vessels. These associations work hand in hand with the highly recognized international body, the International Maritime Organization.

The I. M. O. is a specialized organ of the United Nations with responsibilities of maintaining uniform standards in economical and social development of the maritime industry. It has evolved international conventions over the years on ship construction, operation, pollution, safety, navigation and manning of the sea borne vessels. Some of the most important of these conventions are the conventions on the Safety of Life at Sea, the Load Line Convention, the Marpol Convention. All these conventions strongly emphasize the maintenance of equipment on board the whole vessel. The purpose is to ensure the safety of life, cargo and the ship at sea. Minimum affordable standards in the industry must be met by all the maritime nations in the areas of equipment design, construction, operation and maintenance.

All the classification societies have a common approach to perform these duties. They institute periodic, annual, and special surveys of ships machinery, hull and the safety equipment. The reason is within the deck and engine room departments all the equipment have been stripped and inspected within a five year period.

With a new-building, the inspection will commence right from the design and the steel work scantlings. This approach will ensure that high quality control of material is used and construction of the safety equipment.

The older the ship becomes the more stringent the inspection will be because the failure rate in the equipment or the vessel will be high due to aging of the vessel.

Drydocking is another survey inspection that will be a main maintenance item in the life cycle of the vessel. This topic will however be taken again in later chapter. The classification societies also ensure that the vessels have not omitted the drydocking survey inspections. In this inspection opportunity is made to inspect the bottom fittings of the vessels and checking of the propulsion shaft.

With a continuous machinery and hull survey the vessels are required to have at least 20% of items to be inspected each year respectively. So that in this way all the items will be covered by the fifth year. At the present classification societies have made computer print outs which are quarterly published for each vessel. This enhances the role of maintenance in the sea borne vessels a great deal. Recordings of major and minor maintenance works and registration of the vessels keep the maintenance of marine vessels reasonably safe position.

Classification societies also carry out quality control of manufacturers of ships equipment. This gives quality assurance of the major equipment on board the vessels, for which certificates are then awarded for each equipment. The method of conducting this type of survey to ensure that, from the commencement of the drawings of the equipment, that design and material, are up to the standards required. The manufacturers are later awarded quality assurance certificates to proceed with the manufacture of the equipment like propulsion engines, motors, and pumps for the engine department. Windlasses, capstans, and winches for cargo cranes are amongst the equipment on the deck side. This practice has an important impact on the maintenance of the equipment because once quality has been assured reliability of performance is then unquestionable. The ship owners will expect a maintenance free vessel initially to capitalize on the huge investment of the vessel.

Both the I. M. O. and the classification societies have a very strong impact on the maintenance of sea going crafts. The conventions on the maritime matters like the load line inspections are amongst the elements which necessitate the maintenance workload on board the vessels.

3.11 SAFETY AND SECURITY OF THE ENVIRONMENT IN MAINTENANCE.

The policy for maintenance must include safety and security procedures and arrangements in a plant. This will involve a variety of safety precautions and arrangements of warning notices to alert the maintenance staff of the dangers of the machinery, equipment and the environment around the working place.

Slippery and oily surroundings can pose a safety hazard to personnel and the facility. This situation should not be allowed to prevail. Where it can not be avoided notices must be displayed to warn staff of the pending dangers. Safety warnings must also be brought to the notice of the maintenance staff when using lifting equipment, high pressure vessels, and high voltage installations. Another important safety consideration is the wearing of protective gear when working in toxic environments or working with welding or grinding machines. Approaches to the port entrances form safety and security concern for the port facility. Thus maintenance of the navigational aids for ship traffic in and out of the port must reduce any risks of accidents at the entrance.

The above causes can create critical problems in the production and maintenance work in a plant if no provision for safety measures are taken.

The main purpose of safety arrangements is to remove the risks that cause accidents. In this way the vulnerability of the equipment, vessel, environment and personnel will be reduced.

A designated person must be appointed to take care of the safety items in the plant. The head of the maintenance section and the safety personnel will cooperate in this regard to achieve a safe working environment. Where safety items constitute threats to human life immediate maintenance action must be taken to prevent an occurrence even if it means a stoppage of the plant.

With regards to floating vessel at sea, the insurance industry has issued statistics of many cases of accidents which have resulted in total loss. Figure 3.00 illustrates loss trends in the period of 1985 to 1990.

Table 3. Loss at Sea

	1990 No.	1989 No.	1988 No.	1987 No.	1986 No.	1985 No.
Foundered	149	443	561	523	431	440
Missing	128	26	29	78	82	32
Fire/Explosion	40	57	83	29	29	94
Collision	72	76	63	3,156	448	14
Contact	0	42	0	0	7	3
Wrecked/Stranded	0	34	23	34	27	9
Lost, etc.	0	10	4	21	43	27
TOTAL LIVES	389	688	763	3,841	1,067	619

Source: Lloyd List 1980-1990

Various causes can be attributed to these tragic accidents. Some of these causes may be due to human error or acts of God, others may be due to lack of maintenance and safety requirements on the structural strength of the vessel. These accidents may pose a serious environmental threat of oil pollution.

Compliance to safety requirements will go a long way to prevent accidents that will also be an environmental hazard.

Safety policy, however, is a costly investment because the policy lends itself to be the reaction to accidents that may have occurred. Therefore, it is a probability factor that comes to consideration when safety matters have to be discussed. Hence deference and postponement of performing safety work on the equipment are major reasons for the nonavailability of the equipment despite a great deal of investment in the safety equipment. This appears to be an idle capital which gives no revenue. There is a tendency then to postpone periodic inspections and maintenance on safety equipment merely because of good trade prevailing. This is a practice that should be discouraged. It may lead to total loss of a plant or vessel when a disaster strikes the vessel. Security in the maritime industry is just as important as safety to maintain the sea borne trade if it is to operate effectively.

The purpose of security is to implement and manage a security programme in accordance with the international agreements and conventions. The benefits of the security programme will be

(a) Prevention of unlawful acts against the crew or passengers on board ships and at port facilities.

(b) The safeguarding of the vessels and port facilities against natural hazards, accidents, or intentional acts of sabotage.

(c) The suppression of the level of threats, and risks in order to lower the level of the vulnerability of vessels and port facility.

Maintenance of the security programme will ensure periodic inspections of the equipment which will in turn ensure safety to people, property and liability.

3.12 EFFECTS OF AUTOMATION IN MAINTENANCE.

Control and automation of machinery or equipment began as an engineering discipline over a long period with the notable discovery of the centrifugal governor by James Watt in 1798-1806. This started off control engineering in the industrial revolution. Mass production of machine tools and other primitive agricultural and mining equipment was then manufactured to ease the burden of work on human operators.

In the marine field automatic controls were necessitated by the following duties: In the engine room.

(a) Machinery speed control with load changes.

(b) Automatic feed water control as for the boilers.

On the deck department.

(a) Automatic course steering.

(b) Automatic depth finder.

The impact of this control concept in maintenance activities was a tremendous achievement in the industry. These controllers were then developed to control equipment functions and processes. They have one or a combination of one or two proportional, integral or differential actions with respective transfer functions.

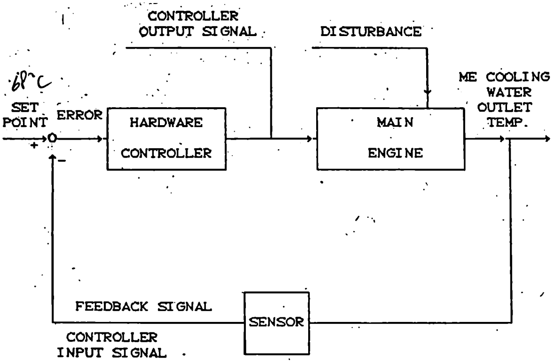
The purpose of the controllers is to regulate the process outputs to meet the standard output. On receiving a signal from a controller the process will react in such a way to correct any deviation in the performance. The output of the process performance is monitored and a feed back signal is constantly compared to ensure the same output performance is maintained after a disturbance on the process.

In the maritime industry automation has been given tremendous support especially by the ship owners. This makes the industry a highly sophisticated and complex concern. The reason is to reduce of operational costs by reduction of the level of manning. Inter alia the ships safety status improves a great deal. With automation, failures that are caused by the human element, are now reduced by the use of sensors which are ever vigilant to monitor the various parameters of machinery performance. Thus, continuous monitoring and simultaneous adjustment of machinery performance is achieved. Alarms of both visual and audible modes are installed to warn of any pending failures before occurrence; then preventive action can be taken in time.

Apart from automatic speed control by the mechanical governor other control devices have evolved using electric, electronic, and pneumatic systems for control of other parameters like temperature, pressure and flow rates. The development in control and automation is now possible for monitoring all kinds of parameter at critical areas of machinery to ward off breakdowns. Thus machinery can be designed to work at predetermined load of, say, 85% with automatic regulation, of temperatures, and other conditions. These control devices have also prevented abuse of equipment by inexperienced operators. Basic automatic is shown in the figure 3.12 (a and b)

Figure 3.12 (a and b) Basic Automation.

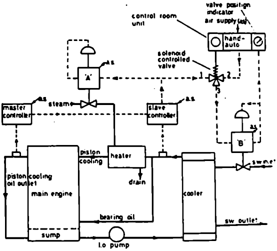
(a)



Source: Lecture Notes; Proffessor A. Wiewiora, WYZA SZKOLA MORSKA, Poland.

(b)

Jacket (or Piston) Temperature Control.



COOLING AND LUB OIL CONTROL

Source: General Engineering Knowledge,
By, McGeorge 1982
Marine Engineering Series.

However, automation is not foolproof in the prevention of failures. Maintenance on the installation and the need for efficiency and reliability in performance still requires the following:

(a) Personnel of higher skills to be available on board ships to trouble shoot and interpret all the conditions for healthy and defective modes.

(b) Clean working media e.g. control air or oil for the controlling system.

(c) Fewer fluctuations in the power supply will also be important factors to be maintained for the proper functioning of electronic controllers.

(d) Ideal control room with air conditioning facility must be provided. Tempering unnecessarily with automatic system and safety limits is the main reason for premature failures in equipment.

The effects of automation is an advantage to prolong the life of the equipment if it is installed and operated well.

3.13 PROGRAMMABLE COMPUTERS AND MAINTENANCE.

Computers comprise a central processing unit in which a number of transistors and integrated circuits are connected to give binary outputs. The outputs are two states which are actually voltage levels. Thus a computer central processing unit can be synonymous to a combination of tiny electronic switches, whose function is to output voltages of five or zero volts which can be represented by digital numbers, 1 and 0. These logic states can be monitored, modified, or stored. A combination of this logic circuitry is arranged to form the basis of the integrated circuit chips with specific functions for the microprocessors in the central processing unit. There are special types of computers which can be interfaced with the control system of a plant to form an industrial programmable computer for use in the industry.

By means of bus cables input and output data can be interchanged between the central processing unit and the key board. Memory and address units in which registers and clocks are an integral part to interpret the data will execute the commands as instructions in a step by step process in a programmable computer. The advantage with computers is that the speed of processing the data is extremely fast. Hence a great deal of data can be worked out in a short time interval with the added advantages of a visual display unit.

With these peripheries graphics, list of figures of the parameters being monitored can also be viewed.

The monitoring system is either digital or analogue (which can be converted by an analogue to digital converter for the computer). Thus the signal is conveyed via an interface to the computer for an alarm condition, or any abnormality that may need attention.

With a modern unmanned engine room the signal can be responsible for actuation of a controlling regulator to adjust the process performance automatically.

These programmable computers are mainly electronic and they need very little maintenance once installed in an optimum place.

The main advantages of programmable computers are that they can be set to highlight the condition monitoring, relieve the human operator of a constant watch, quick data process, and decisions for further maintenance on machinery can be taken faster. Automatic record history of failures and factors of the performance are easily possible for future planning.

3.14 EVALUATION AND ASSESSMENT OF MAINTENANCE SYSTEM.

Evaluation of the performance of the maintenance system is an important procedure to measure the tasks conducted against the normal standard criterion set out by the plant objectives. This is a function which is normally carried out by the planning section in the maintenance department to establish the time allocation for a particular task and the costing of the labour, material, and any other overhead expenses. The reason is to make sure that a higher percentage of the allocated time is actually spent at the repair works. This will highlight the labour productivity at the completion of the task. In many instances the no-availability of equipment or loss of production is not due to equipment failure as much as for other factors. Other factors like nonavailability of tooling, travelling time to look for spares, material, or even operators may cause a prolonged lead time which count for downtime. These factors need to be identified so that each can be rectified until the productivity is brought back to the normal level.

However an annual evaluation must be conducted by reviewing the analysis of the data of performance for the trends in the annual costs of:

(a) Operation and maintenance.

(b) Downtime and unavailability

(c) Evaluation and comparison of the above costs.

A characteristic curve will evolve as shown in the figure 1.03 sub chapter 1.03. Optimum areas indicative of focus of maintenance or, even profitably will show that no maintenance and excessive maintenance will not yield high profitability.

In order to have a comprehensive evaluation, technically competent personnel must be deployed to assess and evaluate the failures and performance according to the instructional and operational manuals. The personnel will be able to discriminate all types of failures and make sound judgment of remedial actions. The personnel will also establish a record history of equipment failures and their scope, record the frequency of occurrence of breakdowns, and the manpower requirement. Recommendation of appropriate tasks for reducing or for new equipment and attention to other equipment.

A measure of manhours for a particular work will evolve. The cost of material expended for a particular work order will give a standard for future planning.

The benefits of evaluation in maintenance are:

(a) Improvement of operation and maintenance costs.

(b) Organized labour force by proper work schedule will give high productivity.

(c) Future planning for the maintenance requirements will prevent operational crisis.

At the end of some period the maintenance performance must be seen to achieve the goals set. Thus an assessment of the level of the maintenance labour and downtime must be made.

The purpose is to establish causes of low productivity and downtime in order to relate the costs incurred to the relevant sections in the plant. This is important so that each section will be responsible for the losses caused by their section and therefore costing of maintenance will be reflected in the individual allocation for that section. It will give an incentive to all the sections to analyze the various factors that contribute to low productivity. Improvement on the utilization of resources will be possible for the future performance. The objective of assessment is to discover:

(a) Competent labour force with multidiscipline technical ability to repair any breakdown.

(b) Logical work assignment where there is no need to fabricate a broken item when replacement by available spares is cheaper.

(c) Identification of the factors affecting the productivity and production can be done so that each can be eliminated to reduce the maintenance costs.

(d) Labour productivity improvement can be achieved once the volume of the maintenance task is equitably allocated.

(e) Feed back information and the data from completion of a maintenance task will enable appropriate adjustment to be done.

3.15 CONCLUSION OF THE SELECTION OF MAINTENANCE.

Effective maintenance procedures requires a wide knowledge of the various aspects related to maintenance activities. Awareness of the resources available, the assets in terms of facilities, vessels, machinery and other equipment is the initial step to choose the required maintenance system. The operation and functions of the resources must have their basic operational principles known so that to have safe and economic management. Changes that take place in the sea borne trade, commercial shipping should not overshadow the basic standards of the maintenance activities. Negligence in this area will only result in noavailability and unreliability of essential equipment for the continuity of the commercial enterprise.

The main reason of describing a diversity of the maintenance areas is due to the fact that any investment made to a facility must be backed up with maintenance expenses. This is important consideration because the facility must have economic operation life. So preventive maintenance to ensure availability will realize the return of the investment in a short time. Hence preventive maintenance system should always be considered before huge capital investment are made to equipment or port facility. Figure 3.15 shows the various maintenance systems

- PLANNED MAINTENANCE
  - CORRECTIVE MAINTENANCE
    - -Correct occurrence of faults
  - PREVENTIVE MAINTENANCE
    - -Prevent occurrence of faults
    - INDIRECT MAINTENANCE
      - -Condition monitoring
      - -Functional control
      - -Test program
      - SUBJECTIVE ACTIVITIES
        - -Personal judgement of condition
      - OBJECTIVE ACTIVITIES
        - -Measurement by using instruments for objective judgement
    - DIRECT MAINTENANCE
      - -Exchange of spares
      - -Renovation
      - -Greasing
      - -Cleaning

Source: Marine Maintenance Manual

Saltech VOl 1

Salen Technologies. A B 1985.

4.00 CHAPTER FOUR, MAINTENANCE IN THE ENGINE ROOM.

4.01 APPLIED MAINTENANCE AND CONDITION MONITORING

In the previous chapters the analysis of the maintenance elements and procedures were made. It was found that for both ashore and off-shore based maintenance procedures were common in many respects. The only difference is that of the unpredictable and unfriendly environment with no service support once a major breakdown occurs while the vessel is at sea.

Application of the maintenance activities will now be discussed in the maritime and related industry so as to high-light the essence of the applied maintenance with respect to national economy, energy savings, and sustainability of the human and environmental resources for the betterment of the society.

Any machinery, equipment or plant comprises simple and complex items with specific functions in the process of the operation. The equipment can be any machinery, a vessel or port facility e.g. the windlass, cargo cranes, capstan, and the main and auxiliary diesel engines, hydraulic, centrifugal pumps and the air compressors are some of the others. The operation of the equipment relies on the components and their functions in an designed manner to give a manageable output with the added advantage of doing work. Hence periodic inspection and checking of the machinery and equipment provide crucial steps to ensure reliability and durability before applied maintenance is carried out. This can also lead to decide easily the shut down period for a plant to execute the applied maintenance work. In this way, prolonged stoppage in operation can be avoided. Otherwise stoppage can affect the production adversely.

The preparation and planning for the maintenance activities are the prerequisites in order to capitalize the shut-down period. It will consist of the availability of instrumentation, tooling, spares and materials with technical know-how of the operation of the equipment.

Skillful maintenance workers are crucial for the applied maintenance activities. These will require to to have the following capabilities:

(a) The know how to identify the purpose, function of all the items and the problems in the machinery.

(b) The safety precaution and arrangements are adequate to carry out the working with no injury or accidents to the personnel or the equipment.

(c) The ability to test the completed overhaul and recording all the spares, materials and the manpower expended on the work.

(d) Trouble shooting any failures in the performance.

In this respect the basic procedure must be:

(a) Isolalation of the equipment from the prime mover or both mains and controls of electrical power.

(c) Warning notices and protective gear need to be used.

(d) Proper tools, with the skill to use special tools like hydraulic jacks with pressure gauges, e.g. Special spanners to undo pre-stressed hydraulic nuts to the required stress.

The above preparations are necessary in order to execute the applied maintenance without any delay.

The applied maintenance is in two types, direct and indirect maintenance. The former comprises a set up of procedures after following the manufacturers manuals for the actual physical stripping off equipment for repair. The later is condition monitoring as explained in the sub chapter 4.01 (e). These procedures apply to most of the items or components of machinery.

The physical aspects of the applied maintenance procedures will be conducted as in the following steps:

(a) Easy accessibility to the item.

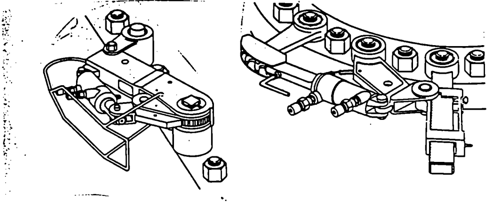
(b) Dismantling, cleaning and inspection.

(c) Calibration and assembly.

(d) Safety procedures.

Figure 4.01 the hydaulic ratchet wrench for dismantling cylinder head nuts.

Figure 4.01 Application of the hydaulic ratchet wrench.



Application of hydraulic ratchet wrenches.

Various hydraulic ratchet wrenches.

SourceMarine Maintenance Manual, Vol. 1. Saltech, Salen Technologies A B 1983.

[a] Accessibility, Cleaning and inspection.

The very first thing in maintenance practice is the ability to have easy access to the item intended for the applied maintenance work. Time is saved when accessibility lends itself to maintenance from design. The greater percentage of the maintenance work is taken up by the removal of other items which are on the way. With good accessibility it is possible to carry out on line maintenance work where there is the possibility of isolating the individual units.

Assuming that the component has been isolated for safety reasons a thorough cleaning of the parts with cleansing fluid must be done. Care must be exercised that all the nooks and corners are cleaned with a safe detergent. Inspection of the equipment for defects, wear, damage and cracks will be done after the cleaning.

[b] Dismantling Procedure.

In this procedure it is wise to start off with your own observations and analysis of the plant operating condition before commencement of the applied maintenance work. It pays to make your own marks and reliable points of reference of the working parts as well as the plant capability so that cross check can be made before assembly. Evaluation and assessment of the work can then be more meaningful. The effectiveness or non effectiveness will determine any changes of the applied maintenance. Reference to the manufacturers manual will be of great help. These items can easily be checked by an experienced worker. Nonetheless instruments are available to measure all defects to give accurate record of the defects

Overhaul or dismantling of the machinery is costly.
This is even more so if the machinery is the only one and it is a critical item. With a plant stoppage the following

losses should be be expected:

(a) Costs of loss of the plant production.

(b) Operators costs of idle time with lost of services.

(c) Replacement costs and costs of extra energy and costs of hire.

So timely planning of the maintenance tasks is an essential consideration in optimizing operating costs.

[c] Calibration, assembly and Testing.

The items which are susceptible to wear are measured and recorded. The result from the readings are compared with the standard sizes for determination of the wear. Then reconditioning or replacing parts can be done. These are items like :

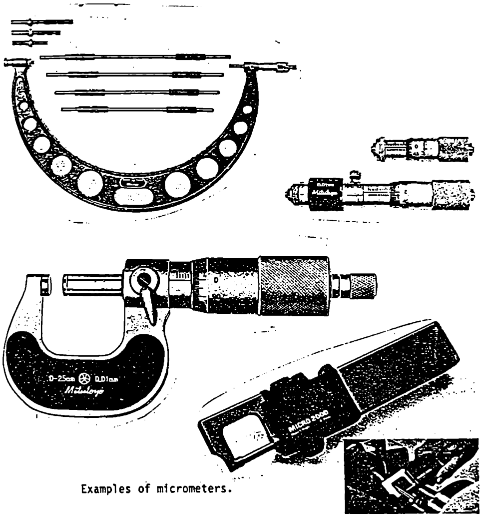
(i) The cylinder liners,

(ii) Main and bottom end bearings, piston rings as well as sealing rings.

The common instruments for the calibration purposes are the micro-meter and feeler gauges, bridge gauges for the main bearings. These will be used to measure the wear in components mentioned above. Wheather the parts are replaced or reconditioned the clearances between the moving parts should be maintained as the original clearances or within the acceptable tolerances before assembly. The assembly will be done in the opposite order of the dismantling procedures.

Other measuring instruments consists of the pressure measuring pumps like fuel injection test pump. Figure 4.00 (c) illustrates these instruments for the calibration of the wear and injection pressure.

Where it is feasible, testing of the system for leakage, in working modes is essential before running the plant.



Examples of micrometers.

Source: Marine Maintenance Manual vol.2 Saltechnologies A B 1983.

[d] Safety Procedure.

Observation of the safety procedures during the applied maintenance is very important. This can be done by the communication to the safety personnel to ensure that permssion to work on an equipment is obtained and all the safety measures have been considered. As far as marine practice is concerned, to carry out major maintenance work in the port, immobilisation permission must be obtained from the port authority. This is a precautionary measure so that in case of a disaster, the vessel which cannot use its own power, can be assited.

The importance of this procedure cannot be overemphasized especially where the item is likely to be started by automatic means, or at remote locations with no warning to the maintenance workers. It can result in an accident. It is a wise procedure to warn personnel working at the plant of the shut down equipment so that no one can start up machinery while men are working on the equipment.

The other safety areas that need care are the ones dealing with heavy lifts. The maritime machinery is highly rated and most of the items are robust and heavy. The lifting tackles, chain blocks with their wire ropes must be checked out for safety. It must be ensured the capacity is adequate for any load that may be carried. These items must also be inspected regularly before the operation of applied maintenance work.

[e] Condition Monitoring.

In order to achieve effective applied maintenance at first indirect maintenance is a practice that must be adhered to. This comprises chiefly studying the data of the:

(a) Condition monitoring of the machinery in a plant.

(b) Visual inspection of the various items and parameter in an equipment at regular intervals. This will indicate malfunction to an experienced operator.

(c) Checking by reading the gauges gives accurately the operating conditions of the equipment. The result of these periodic inspections are logged in a record book which will have the following descriptions:

[a] The date, time and location of the observation of the condition of the item.

[b] The load and the speed level of the machinery.

[c] The ambient and sea temperature of the floating vessel.

[d] The input and the output temperatures, and pressures of the lubricating, fuel oil, air, and cooling medium.

[e] Replenishment of the fuel oil tank, lubricating tank and the levels of the cooling water.

[f] Vibration and abnormal noises from the velocity of the moving parts of the machinery.

Careful interpretation of the above items will give a good account of the general condition of the equipment. Performance trends will be established for the equipment and the failure pattern will be formulated over a period or voyage. It is also a most beneficial method for the major preventive maintenance tasks due to the fact that the failure onslaughter can be predicted and timely action taken. Classification societies recommend the practice of condition monitoring because the practice can save premature dismantling of the major equipment which will extend the periodicity of the major overhaul. Saving on the investment for new equipment or spares will be possible.

The snag with condition monitoring maintenance is the investment in the instrumentation of the machinery. The investment can also be substantial. Nonetheless a comparison with the costs of a major replacement, the loss of operation and downtime costs will offset the disadvantage.

The costs of measuring and indicating instruments are not necessarily expensive items compared with the overall operating costs of the plant.

Arrangement for the automatic logging of the parameters can be made possible. With automatic condition monitoring the following additional advantages will be realised:

(a) Savings in the operational and maintenance costs by the efficient use of the crew.

(b) Permanent vigillance of the machinery with acurate and reliable inforamtion will limit the fuel consumption and also the the fuel oil costs.

(c) Reduction of the break downs, maintenance costs, and extensive maintenance work due to the extension in the mean time between overhauls.

(d) Close check on the thermal load and safety from black out.

(f) Noise and Vibration Warning.

A specific mention of the condition monitoring must be made to highlight its usefullness in noise and vibration warning. It is an important element in condition monitoring related to the appllied maintenance tasks.. This is caused by the velocity, acceleration and displacement of the moving parts due to the cyclic motion of the rotating or reciprocating masses of the machinery. This phenomena causes machinery vibrations.

Defects developing in these items will only increase the vibration with the result of the abnormal sound or noises.

Machinery spaces invariably are associated with noises. Acoustic installation is sometimes installed in the machinery spaces to reduce the noises. It merely causes some of the irregular sounds to be elusive and makes it even more difficult to detect the onset of incipient problem. A certain rythmatic pattern of the noises from the machinery gives an experienced operator a certain feeling to tell if the machine is running normally or under certain strained condition. Deviation of the noises from the regular pattern should be taken to be an imminent trouble within the machinery. Hence it is imperative to investigate these irregular noises or sounds particularly if they are within the vicinity of an equipment to remove the risk of a major breakdown. The list below shows some of the common sounds with their respective causes.

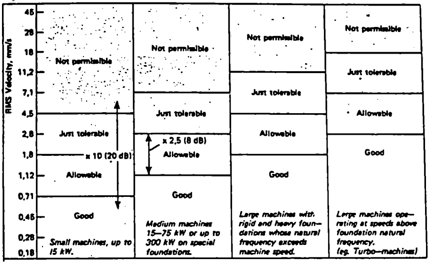
SOUND....................CAUSE

1. Heavy rambling.......... Torsional vibration.
2. Heavy knocking.......... Loose fly wheel.
3. Intermittent hard tapping..................Broken piston ring.
4. Occasional hard tapping..................Partly stuck ring.
5. Fast rythmatic tapping..................Valve gear clearance excessive.
6. Slow heavy knock.........Loose mounting main engine.
7. Irregular intermittent knock....................Slack fastening.
8. Heavy over head tapping..................Weak valve spring
9. Intermittent hissing.....Blown gasket.
10. Rythmatic heavy knock....Connecting rod bearing too large.

The above list is just a general observation. The operator must be familiar with the particular equipment under his control.

When the machinery is running well, little or no vibrations can be felt. If the deterioration is minor or gradual it may not be easy to perceive by human ear. Instruments for measuring noise and vibration levels are now available to give a spectrogram which can be compared with standard levels at trials. Figure 4.01 (f) shows the frequency level of the tolerable and impending failure.

Condition monitoring will therefore be preceded by applied maintenance on the specific equipment and machinery systems.



Vibration severity criteria.

Source: Lecture Notes: On vibration . By lecture, Proffessor Saxenna.

4.02 DIESEL ENGINES AND SPECIFIC SYSTEMS.

Since the invention of the diesel engine in 1782 by the German, Rodulf Diesel, development has been on going regarding the production of engines from the smallest to the largest powers by increasing the number of cylinders and the geometry of the cylinder. Research on this line to improve the engines durability, reliability, efficiency and exhaust emission is still underway to make the diesel engine the main prime mover for propulsion, power generation, traction for the locomotives and cargo handling equipment.

It is therefore necessary to understand the maintenance requirement of this very common piece of machinery which keeps the modern industrial, agricultural and commercial wheels turning.

It is not possible to cover all the nuts and bolts of diesel maintenance. The main structural components and specific functional systems of the engines will be considered. These form a common features of practically all the diesel engines, for example:

[a] The crank shaft and the main bearings.

[b] The bed plate, entablature, and cylinder head.

[c] Liners with the lubricator fittings.

[d] Piston, ring and connecting rod.

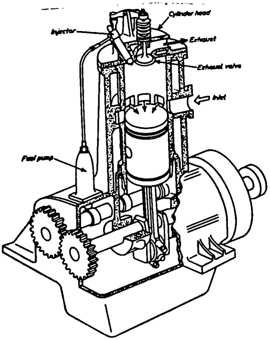
[e] Top valves like injectors, air inlet and exhaust valves, starting air valves and relief valves.

[f] Cam shafts with associated valve operating gear mechanism like the push rods or the hydraulic system. For maintenance workers it is imperative to have adequate knowledge of the engine nomeclature, component purpose, and function for efficient applied maintenance on diesel engines

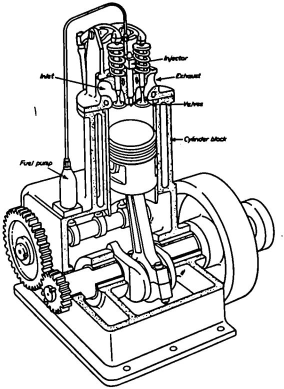
The above mentioned items are critical. Diesel engine design and construction are given specific consideration because any defect may result in the plant shut down. Figure 4.02 shows all the equipment and components of the two and four stroke Diesel engines.

Figure 4.02 (i) Two and Foyr stroke Engines.

Two Stroke



Four Stroke-

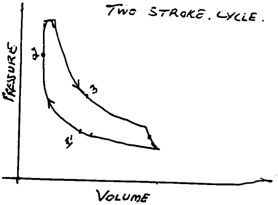


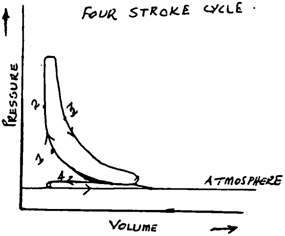
Source: Marine Engineering Practice,
Marine Medium Speed Diesel Engine Vol. 1, part 3
By S.H.Henshall.

The other requirement is the know how of the operational behavior of the common diesel engines from the basics to the application of the engines in different areas. It is observed that the diesel engine is a compression ignition engine and operates in either two or four stroke cycles. Figure 4.02 (ii) shows the operational cycles.

The power developed in each cylinder is transmitted to the crankshaft via the piston connecting rod and the crankshaft which is connected to the flywheel. The output drives the propeller shaft.

Figure 4.02 (ii) Diesel Cycles.





Source: Own.

The operation of the other specific systems are also important in the running of the diesel engines and these will be considered separately.

Last but not least in the applied maintenance of the diesel engines the use of hand tools, testing equipment, and measuring instruments for dismantling and measurement of the defective component is very important. Tools vary from hand tools to special tools with lifting equipment for transporting of the heavy items. Hand tools are the ordinary spanners and wrenches, while the special tools comprise hydraulic spanners to work with pre-stressed hydraulic nuts. These must be regularly inspected.

Hence precautions must be in the forefront in the process of the applied maintenance work. Hence with the inspection of the lifting gear regularly for the transport of the items such as large pistons, liners, and exhaust valves.

In this way maintenance of the items will be given a more detailed exposure with their various component in the specific systems of the engines. So the best way to view these individual items is to consider them with respect to their specific systems in which the items form part and parcel of the system.

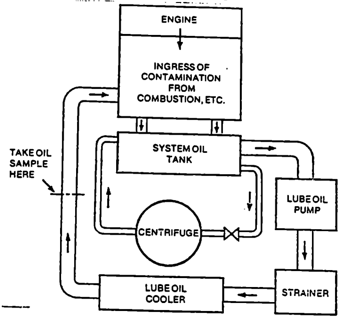
4.03 LUBRICATION SYSTEM

Lubrication system is the most critical of all the systems in the operation of the diesel engines and other running machinery. The purpose of a lubrication system is to reduce friction between two running faces of the machinery. Inta alia this improves the efficiency of the machinery.

It is achieved by the important property of the lubricating oil namely viscosity. It provides an oil drag between the surfaces to cause boundary lubrication and later oil wedge formation which enhances the oil molecules to slide over themselves while adhering to the moving surfaces. The frictional power loss due friction is reduced a great deal and machinery seizure will be unlikely to occur. Wear rate under this condition will be well controlled and will be well extended. A basic lubrication system is shown in figure 4.03. (a) and (b)

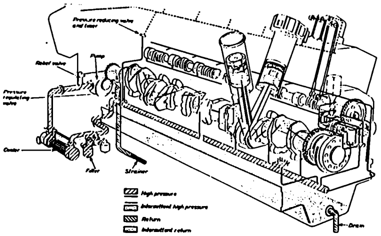
Figure 4.03 Lubrication System.

(a) Slow Speed Engine.



Source: Marine Maintenance Manual, Saltech. Salen technologies, A.B, 1985.

(b) Medium Speed.



Source: Class Notes.

Since the lubricating oil is a compound of the hydrocarbon [basic bonding formula C_5H_{10}] the oil after a prolonged period it will begin to breakdown due, oxidation, and other chemical including bacterial effects.

It is important to take care of the lubrication oils to give the machinery a long service life. This can be achieved by the following steps:

[a] The use of the right type of the lubrication oil which will maintain its constituency for all the loading conditions of the machinery.

[b] Periodic inspection of the amount and quality of the oil in the sump and its condition is maintained all the time to prevent seizure.

[c] Maintenance of the initial boundary lubrication to prevent abrasive wear on the moving parts. After initial movement a wedge formation of film of oil will separate the moving surfaces to avoid metal to metal contact.

The other functions of the lubrication system are to provide the following:

[a] Cooling effect of the engine parts. Heat generated as a result of friction is removed at almost the rate so that the moving parts do not work under excessive temperature to expand and deform the components.

[b] Cleaning of the engine parts of any debris or dirt that finds its way into the oil will be carried away with the oil. The dirt will be entrapped in filtering devices.

During a shut down period, rust prevention is achieved by the engine parts well lubricated.

[c] Sealing effect. The lubrication oil has a sealing effect as it lubricate the moving parts. This is very paramount at the piston rings. It creates a compression effect and improves the engine starting performance characteristics.

[d] A shock absorber effect. Alternating impulse power shocks on the main, connecting rod and cross head bearings are evident at these ares. The oil film between the crankshaft and the moving surfaces will take up the shock and prevent the effect of the shock impulses.

[e] Reduction of the friction. As the oil film is interposed between the moving surfaces the friction is reduced by the movement of the oil molecules between the adhering surface of

the moving surfaces. This make the moving parts not come into direct metal to mental.

The above functions are inherent in the lubrication systems but must not be taken for granted. Utmost care is needed to ensure the lubricating oil maintains its property. All the components in the system must be adequately lubricated during the operation. The pressure of the lubricating system should not go below the minimum required value. Other important characteristics of the lubrication are the viscosity, alkalinity and detergency. These will be explained more in due course. Meanwhile the classification of the lubrication systems are:

[a] Splash lubricating system. This type is mainly by the virtue of the slashing of the lubricating oil in the engine sump. There is no pressure build up. The crank webs dip into the sump or oil reservoir and spread the oil onto the moving parts while in operation. Hence the external parts like the rocker arms do not get lubricated by splashing.

[b] Forced feed lubricating system. Normally a gear pump enables the lubricating oil under pressure to reach the moving parts of the machinery such as bearings, rocking components and other moving items.

The system comprises the gear pump attached to the machinery or separate from machinery. The suction suction of the pump is from the sump and the discharge is connected to a pipe gallery which leads the oil to all the points to be lubricated. Normally a means of priming the pump by a hand pump is provided so as to ensure that an oil film is maintained when starting the machinery.

[c] Full forced feed lubricating system. In this case the lubrication pump supplies lubricating oil into drilled holes of the crankshafts, connecting rod of the piston and also through the lubrication oil piping to all the point for the lubrication. The lubricating oil also is sprayed through special nozzles as in the chain drives. Thus it gives a cooling effect at the same time.

[d] Hand lubrication. The use of the common oil can for lubrication purposes can not be ignored as it is the initial lubrication of the machinery. It is normally used where little lubrication is required. For example in the air compressor cylinder a drop of the lubrication issued from the cylinder on top of the cylinder head by the use of a wick.

The reasons for the different modes of the lubrication system is due to the lubrication requirement of different types of the machinery. Where the load is enormous, forced feed is used in order to ensure a constant supply to sustain the oil wedge to support the above condition.

It is also observed that the type of engine influences the characteristics of the lubrication system. A trunk type engine or cross head will have a marked difference on the type and method of lubrication.

In this regard consideration of the type of fuel used and combustion characteristics affect the lubrication system and a word or so in this respect is necessary to high-light this effect. Fuel oils in Diesel engines are in the type of: Diesel fuel oil which does not need pre heating. Bunker fuel and intermediate fuel oil need pre-heating in their application.

However all the fuel oils contain sulphur, in some degree. This element is not useful, as such, because of the chemical combination of the sulphur oxide and water will form harmful the sulphuric acid. When this acid finds its way to the sump it, with products of combustion, will have ancause corrosion and will damage the lubricanting oil.

4.04 INJECTION SYSTEM.

The figure4.04 shows the layout of small and/or large Diesel engines.

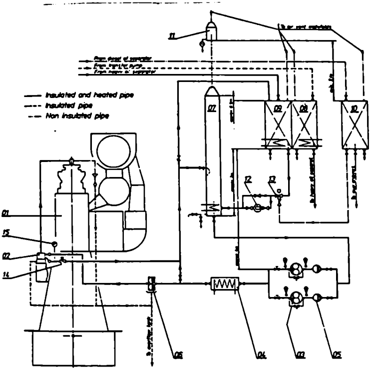


Figure 10.5 Fuel system for Sulzer RND..M engines (Sulzer drawing).

01 Main engine
02 Fuel injection pump on main engine
03 Fuel oil booster pump
04 Steam fuel end-heater
05 Suction filter, heatable
06 Duplex filter, heatable
07 Mixing tank, heatable and insulated
08 Heavy oil settling tank, heatable
09 Heavy oil daily tank, heatable
10 Diesel oil daily tank
11 Condensation water trap
12 Fuel oil flow meter
13 Three-way valve, pneumatic or electric operated
14 Spring-loaded adjustable relief valve on main engine
15 Pressure gauge

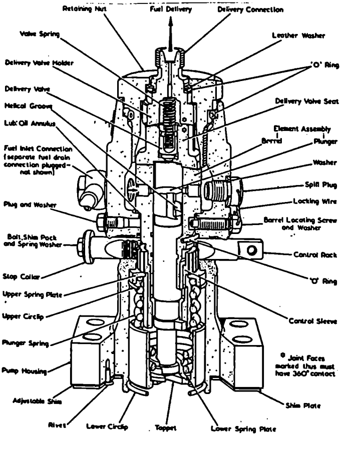
Source: Low Speed Marine Diesels.

By, J. B. Woodward.

This consists of fuel oil tank, feed pump or booster pump filters injection pump (jerk pump type) injectors and pipe lines and a heat exchanger. The system function is to supply the engine with a metered quantity of fuel oil related to power required very accurately to run the engine smoothly with high level of economy. This process has to be maintained at varying load and speed to ensure consistency in engine performance.

The applied maintenance work for the system is to ensure the efficiency of the injection is high. The injection pump is the item which provides the presure. The components of the pumps are made of special hard steel and rarely require maintenance. They are inspected during the five year survey, classification requirement for large engines. The illustration in figure4.04 (i) reveals the various components of the system.

Figure 4.04 (i) Injection Pump.



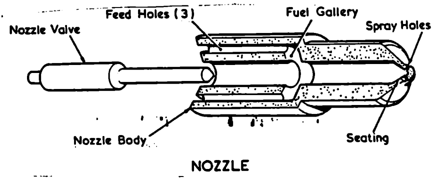
Source:

Maintenance Manual Ruston Diesel, 12RCK Engies.

The fuel valve is prone to failures especially when contaminated fuel oil is used. Checking of the cylinder pressure and power developed by the indicator diagram and the exhaust temperatures will indicate failure developing in the injection system.

The applied maintenance for the injection system is concentrated mainly on the injectors and the fuel oil filters. Figure 4.04(ii) shows a representative of the injector nozzle.

Figure 4.04 (ii) Injector Nozzle



Source: Maintenance Manual, Ruston Diesel, 12 RCKM Engines.

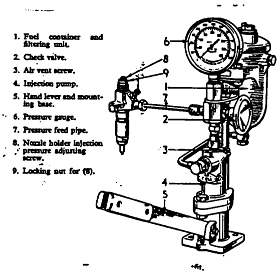
The injector consists mainly of two parts, the injector valve and the injector body. The atomizers are the tiny holes at the tip of the nozzle. These are responsible of the spraying of the fuel oil into the combustion chamber.

The mating faces of the injector form the crucial items for maintenance purposes. The reason is injection takes place at very high pressure. The mating surfaces will have to seal off the pressure with no leakage of fuel oil. So maintenance on the injectors involves testing and replacement of the nozzle tips. It is best accomplished at the factory or specialized workshop. Grinding of the sealing faces rarely achieves the sealing effect under the high pressure in operation. Thus adequate spares must be kept onboard for replacement.

Another important feature of injector maintenance work is the safety precaution needed during testing and assembly of the injector. The spray under high pressure should be avoided to contact any part of the human body. This can penetrate the skin and enter the blood stream posing serious health hazard.

Assembly of the injectors must be carried out in a clean environment. Special equipment for dismantling, assembling and testing normally are provided. Figure 4.03 (iii) shows the testing equipment for the injector.

Figure 4.04 (iii) Injector Testing pump.



Source: class Notes.

Adjustment of the pressure can be made during the assembly and the test equipment is has been vented of air. Well serviced fuel valve must open and spray with;

(a) No leaks or dribbling of the fuel oil at the set pressure

(b) Correct spray angle for a long time.

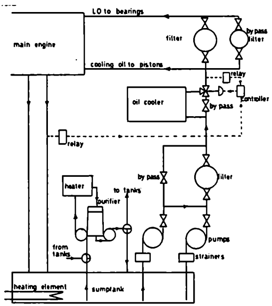
(c) Snappy operation and buzzing sound.

(d) Holding of the pressure for a prolonged period.

4.05 Cooling Systems

A typical cooling system is represented in Figure 4.05 (i). The system normally comprises cooling medium, e.g. water, oil or air, heat exchanger and pressure pump. Fittings in the system usually are in-line control valve and bypass valves.

Figure 4.05 (i)Cooling and Lubricating System.



Source: Reed's, Engineering Knowledge Instruments and Control for Deck Officers.

By W. Embleton.

The medium is under pressure to maintain the mass flow rate through pipe line.

The function of the cooling system is to extract heat from the running items of machinery so as to maintain normal working temperatures. Where the rise in temperature is unavoidable e.g. exhaust temperature of diesel engine, heat insullation of the exhaust manifold must be sufficient to confine the heat to the hot exhaust piping. This can be a serious fire hazard if unsuspected fuel leakage takes place n to the bare hot exhaust piping.

There are two forms of the cooling systems; closed loop and opened loop systems. The former type heat extraction from a source and rejection through heat exchanger, e.g. cylinder jacket water cooling for the Diesel engine and the fresh water cooler. The coolant circulates continuously through the jacket spaces, the piping and the cooler system. Sea water extract the heat and reject it from the cooler into the sea water.

The latter one heat in the coolant or the source is directly rejected into the sea water, example of this is in the by pass cooler of the scavenge air system.

In both types of the cooling system areas of concern for the applied maintenance purposes are:

(i) The maintenance of the coolant pressure and the flow rates.

(ii) The areas where the heat transference takes place at the heat exchanger.

Different pumps are installed for pressure and flow rate availability. These are used as follows;

The centrifugal pumps mainly in water cooling system;

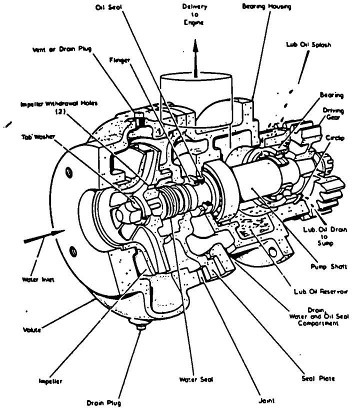
The gear pumps in the oil cooling medium.

The blowers in the air as coolant.

Different pumps used in the cooling are indicated in the Figure 4.05 (ii)

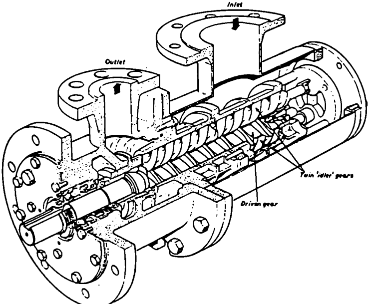
F

Figure 4.05(ii) Cooling Pumps.



Water Pump (Centrifugal)

Source:
Maintenance Manual,
Ruston Diesel
12 RCKM Engines.



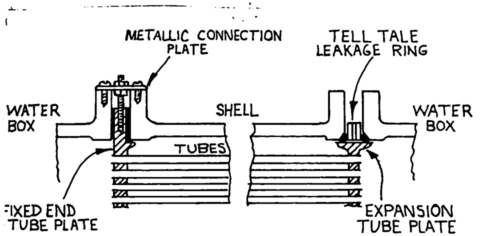
Oil Pump (Screw Type)

Source:
Marine Engineering
Practice, Vol. 1
Part 7, Hydraulic Powe
Transmission in Marine

The flow rate can easily be affected by choked filter, any other restriction air in the system. This however can be indicated by the drop in system pressure.

The most sensitive item in the maintenance of the cooling system is the heat exchanger. Exploded views of the shell and tube type is shown in figure 4.05 (iii).

Figure 4.05 (iii) Tube Heat Exchanger.



Source: General Engineering Knowledge,
Marine Engineering Series.
By H. D. McGeorge

Heat extraction and rejection depend on the mass flow rate, specific heat and the temperature difference between two objects. However the heat transfer is related to the surface area and the heat transfer coefficient of the different materials because each material has different heat conductivity. It is important then the maintained cleaned with no deposit formation, for efficient heat transfer.

There are different types of heat exchanger;

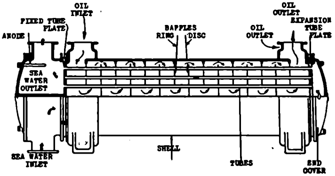
(a) Straight or coiled tube coolers.

(b) Plate type coolers.

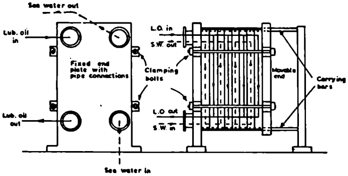
Figure 4.05 (iv) and (v) give a representation of both types.

Figure 4.05 (iv) and (v) Heat Exchangers

(iv) Tube Type Cooler.



(v) Plate Type Cooler



Source: General Engineering Knowledge,
By h. g. McGeorge.

The tubular coolers are conventional type while the plate coolers have now a wide universal application. The functions of the coolers are the same but the plate coolers require less space and have proved to be more efficient. The snag however with the plate coolers is that a lot of skilled work and care is necessary for the maintenance work. For assembly extra care is needed due to the delicate parts involved,in sealing off the latings.

Applied maintenance on cooling systems of machinery items and machinery spaces provides for good work performance of the equipment and the operators. The areas which require this system most are;

(a) Cylinder liner and piston cooling of Diesel engines.

(b) Lubrication coolers for the bearings.

(c) Injector coolers for the fuel valves.

Oil or water can be used for cooling purposes. However when water is used care must be exercised to watch for corrosion effect of the cooling fluid. Hence water treatment of the fresh water side and protective sacrificial anodes on the sea side must be also a maintenance requirement to maintain the system in perfect condition most of the time.

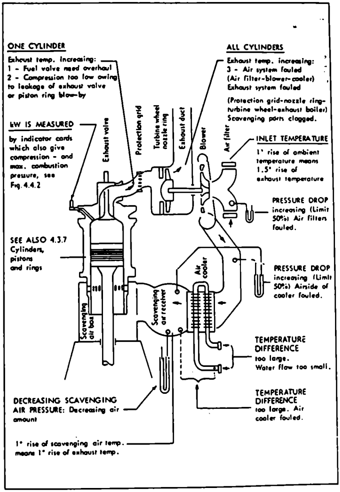
4.06 Scavenging System.

Applied maintenance work on the scavenge system will comprise mainly reducing of any restriction in the passage for the air flow to the cylinder liners or engine trunking.

The function of the system is to provide scavenge air to clean the cylinder of the product of combustion and recharge the cylinder with fresh air. The process is easily achieved in the four stroke cycle engine design.

In the two stroke engines the applied maintenance on the scavenging system has more relevance than the four stroke engines due to the basic design difference of achieving the scavenge stage in the operational cycle. Representative sketches in the figure 4.06 clearly demonstrates the different arrangement of the system to improve this process in two stroke engines.

Figure 4.06 Burmeister and Wain Scavenge Systems



Source: Marine Engineering Practice Vol. 1S. Operation of Machinery in Motor Ship, Main Diesels, Boilers and Auxiliaryy Plant. By, A Norris.

The maintenance procedures involve regular inspection of the trunking, scavenge spaces and the control valves for any burnt oil deposit. This maintenance work represents a messy type of work to be done in the engine room department. It is however very necessary because with efficient scavenging system more power output is feasible as a result of complete combustion of the fuel oil. The benefits of efficient scavenging systems are the following:

(a) The specific fuel oil consumption will be relatively low. with improved output power.

(b) Low exhaust and cooling temperatures of the cooling system will be realized.

(c) Scavenge fires will reduce with clean scavenge spaces.

It is more advisable to execute applied maintenance procedures periodically on the scavenge system especially where a turbo charger is installed for supercharging the System. The scavenge spaces then are more sensitive to the restricting of the air passage. Surging of the turbo charger will take place.

Chemical arrangement is nowadays arranged to clean the spaces in line. It is good practice to have a physical inspection after every voyage.

With modern machinery the temperature and pressure are raised to avoid dew formation at the scavenging system. This is another item to be observed during the maintenance work because it causes corrosion on the exhaust stack and economiser piping.

4.07 Filtration Systems.

In all the systems for the operation of Diesel engines filtration of the working fluids plays an important role. Air for combustion, fuel oil and lubrication oil are the main fluids that require filtration. The reason for this requirement is to have a pure state of the fluids; and the fluids should not contain any solid particles that can be detrimental to the machinery items and their functions.

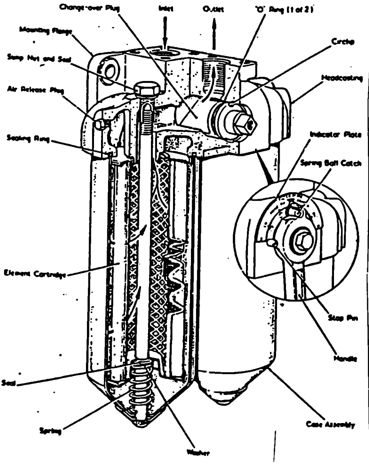
There are various types of filtering systems. These can be classified into three major divisions. They are described below as follows:

(a) Filtering Devices, (elememts)

The filter elements are in different types of materials, ranging from metal wire gauze of fine mesh, edge slots or fabrics.

The principle of operation is to entrap solid particles whose size is greater than the mesh eye. In this case the filter element is located at the inlet to the machinery so that to prevent off any solid particles entering the engine. Figure 4.07(a) represents different types of the filter element for the lubrication and fuel oil systems.

Figure 4.07 (a) Filter elements



Source:
Maintenance Manual,
12 RCKM Ruston Engines.

The applied maintenance procedures will involve;

(I) Monitoring the pressure drop at the filter and the whole system.

(II) Draining the entraped sludge and water at the drain cock.

(III) Inspecting, cleaning or replacement of the element or cartridge.

(IV) Removing the air or gas entrapped in the system.

(b) Static Filtration

This type of filtration is possible by the use of gravitational force on heavy particles in fluid in a settling container. Figure 4.07 (b) represents a tank with a fluid being pumped into it and allowed to settle. After some time the heavy particles will gradually settle down at the bottom of the tank. Relatively lighter fluids will settle on top.

The process is aided by the;

(I) Temperature rise to reduce the viscosity of the fluid mixture.

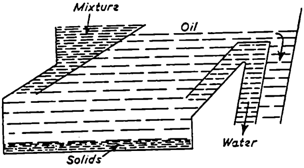
(II) Large container increases the quantity of settlement of the solids at the bottom. This is then referred to as sediment or sludge

(III) The high difference of the viscosity between the fluid and the solids.

(IV) Optimum flow rate

A special constructional feature of a tank for continuous filtration of the solids from the fluids is shown the figure 4.07 (b). For efficient filtration the optimum flow rate is determined. With this construction the basic of the dynamic filtration is evolved. The sketch in the figure 4.07 (b) will show the basic construction of the normal centrifuge.

Figure 4.07 (b) Filteration



Source: Running and Maintenance Marine Machinery, By A.N Sealet al.

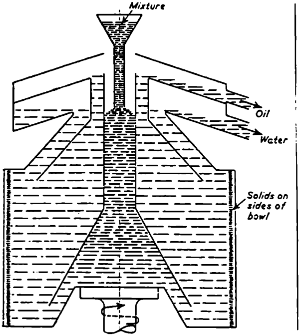
It consists of a bowl with a central stem to hold the conical discs. The discs with a cover are all held together by a cover ring. Special gravity ring is fitted to operate at the required specific gravity of oil. The bowl us driven by a two pole electric motor to give a very fast speed.

(c) Dynamic Filtration.

This type of filtration is a centrifuge, oil-water seperators, purifier or a calorifier. A mixture of lubrication or fuel oil and water is subjected to a very high centrifugal force by rotation of the purifier bowl at very high speed. Any tiny particles will of heavier mass or heavy fluid will gain greater forece than the lighter fluid particles. The result will be forced towards the periphery of the purifier bowl. The solids are regularly removed manually or automatic devices.

The mixture is fed from the center as shown in the figure 4.07 (c).

Figure 4.07 (c) Centrifugal Force Filter



Source: Running and Maintenance Marine machinery. By A.N. seal et al.

The heavier particles are thus forced towards the side of the bowl. Lighter clean oil is discharged from center of the bowl. A water seal is naturally created to separate the lighter and heavier particles. This seal must be maintained all the time. Discharge of the sludge is led to the drain tank and the clean oil is led to the daily service tank.

For efficient effluence, the temperature of the mixture is raised to reduce the viscosity of the mixture and allow it to seep through the plate spaces due to the low viscosity. The flow rate is adjusted to suit optimum filtration.

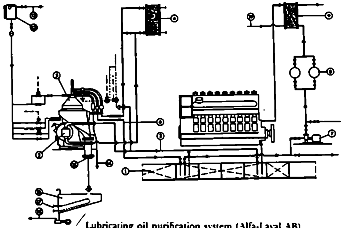
The applied maintenance of the centrifuge is very important because invariably the fuel oil will contain water. This has to be extracted before entering the injection or lubrication systems. It is therefore crucial to understand the construction and some of the latent features of the purifiers to ensure efficient operation.

Thus regular clean up of the bowl and the discs of all the sediment and the sludge must be done. Availability of the water tap, heating system for the purification and cleaning process is necessary.

Other automatic disludging mechanism ensures automatic discharge of the detrimental matter.

The main area of the maintenance to watch carefully is the drive end. The couple usually is prone to failure most of the time. Precaution must be taken when filtering oil with soluble additives. These will be washed away in the process of purification.

Purification of lubricating oil is shown in the figure 4.07 (d). Figure 4.07 (d) Purifier System, Alfa Laval Type.



Lubricating oil purification system (Alfa-Laval AB).

1 Sump tank for dirty oil from engine
2 Dirty oil to purifier
3 Pump
4 Heater
5 Alfa-Laval purifier
6 Purified oil
7 Pump for lubricating oil
8 Filter for lubricating oil
9 Cooler for lubricating oil
12 Cold fresh water
13 Operating water tank
14 Water outlet
15 Sludge outlet
16 Sludge tank
17 Heating coils
18 From sludge pump
19 Cooling water inlet

Source: Low Speed Marine Diesel. By J. B. Woodward

Source: Low Speed Marine Diesel. By J. B. Woodward.

The system consists of the centrifuge, a heater and pre-pumps and coarse type filters. Suction of the dirty oil is taken from the engine sump. The pre-pumps feed the oil heaters before the purifier to reduce the viscosity for good purification with the rise of temperature. After purification the oil is discharged back in the engine sump by another pre-pump. Elaborated system is shown in the above.

A header tank for water seal and washing of the lubricating oil as well as for cleaning purposes is normally installed. Sludge tank collects all the sludge during the process. By pass arrangement is the normal installation for deep sea vessels. The function of the system is continuous purification of the lubricating oil when the main machinery is in operation at sea passage.

The purpose is preserve the lubricating oil conditions. These have to be kept at optimum level to prevent damage to the running parts of the machinery, viz:

(a) Specific gravity (0.8-0.98). A higher or lower value will impair the oil lubrication characteristics, e.g. increase in the oil drag or diesel dilution. Purifiers ensure optimum S.G. by a dam ring or gravity disc for the respective specific gravity of the oil.

(b) Water content allowable is 0.2% of the system oil. Excessive of this gives indication of emulsion or macrobial presence in the oil sump.

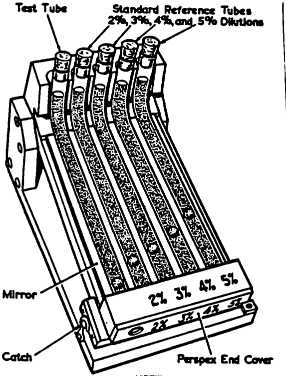
(c) Oxidation of the oil forms organic and inorganic acids. The total acid number (TAN) should be kept at low level by minimum water washing.

(d) Control of the strong acid number, (SAN), caused by sulphur content from the combustion products must be neutralized. It is achieved by alkaline additive in the oil.

(e) Metal ingress in the oil have catalystic effect to enhance the acid formation.

Hence regular inspection of the oil is essential because deterioration in the oil can cause corrosion and eventual damage of the machinery parts. Rough measure of viscosity is possible in line by the instrument shown in the figure 4.07 (e)

Figure 4.07 (e) Rolling Ball Viscometer



Source: Ruston Diesel, 12, R.K.C.M. Engines.
Instruction Manual.

Sample analysis should be conducted at the laboratory to keep efficient lubrication system. There are different types of purifiers, e.g. Alpha Laval etc. The operation and maintenance manuals must be used for maintenance of the respective manufacturers centrifuge.

4.08 Bearing Maintenance.

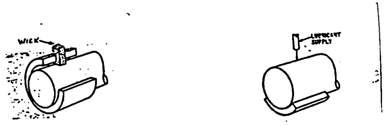
Bearings are common items in mechanical and electrical machinery. They can be classified into two main divisions:

the sliding and the rolling types. The former is sometimes referred to as journal or plain bearings, e.g. the crankshaft and the cylindrical surface pair of the bottom and bearing of diesel engine crankshafts. (shell and journal pin).

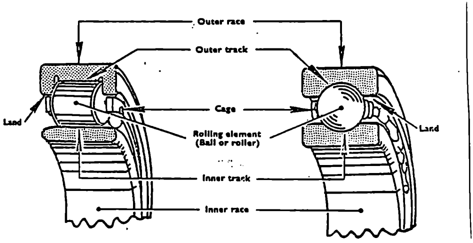
The rolling bearings comprises the rolling element, the steel balls or rollers encased in two raceways. Both types of bearings have the function of allowing motion between two surfaces under load condition. These bearings are usually made of precision measurement to enable replacement and spares availability. A representative of both types of the bearings is shown in the figure 4.08 (i) and (ii)

Figure 4.08 (i) and (ii) Sliding and Rolling bearings.

Sliding Bearing.



Rolling Bearing



Source: Tribology Lecture Notes. By Proffessor J.Schoefield. Liverpol Polytechnic, 1983

The maintenance requirement for the bearings will depend on various factors which can cause premature failure;e.g. bearings; e.g.

(I) Exceeding the load capacity or impact loading.

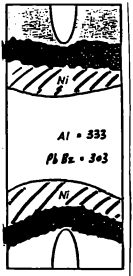
(II) Using bad quality of the lubricating oil and bad operational environment.

(III) Wrong fitting of bearings or misalignment.

(IV) Effects of vibrations.

Bearings are normally expected to have a long service life in normal operation. However they do not have unlimited life despite operating at normal load and speed. Other causes like corrosion, fatigue, wear or abrassive matter can fail the bearings. Therefore periodic inspection of the oil, clearances, wear rate records are necessary to prevent unexpected failures. Figure 4.08 (iii) shows a failed bearing shell.

Figure 4.08 (iii) Failed Bearing shell.



Overlay and Ni layer worn (running on Sn-Al)

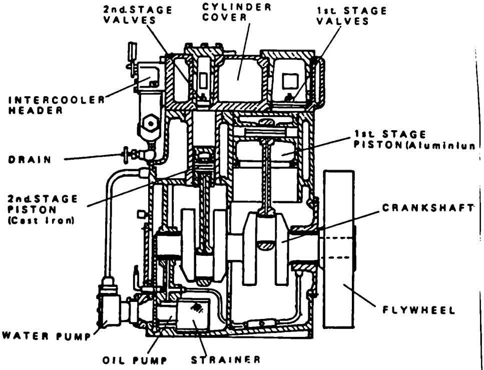
Source: Lecture Notes, by professor Listewnik.

4.09 Air Compressors and Starting Air System.

Maintenance requirements for the air compressors are directed to ensure adequate compressor capacity for the the required statutory regulation. The regulation is to have two air compressors with each having the capacity to fill the air receiver in one hour. There should be also an emergency air compressor.

As for the compressor itself the air pressure must be delivered at the required values at the stages of the compressor. This can be possible when the cooling system is efficient in all the stages of compression. Figure 4.09 shows the air compressor.

Figure 4.09 Air Compressor.



Source: Diesel Enginess, Marine Engineering Series.
By A. J. Whatton.

So the intercoolers between low and high pressure stages are maintained at perfect condition. The other item is the lubrication pump. This item often neglected due to its location and the assumption always low lubricating oil pressure is caused by the chocked filter. Being a positive displacement pump (gear pump) it incoporates a relief valve Dirt or a tiny grit is entrapped between the valve and the valve seat resulting in low pressure. This can damage the bearings, the crank shafts or increases the clearance volume. Thus the compressor efficiency may drop.

General maintenance procedures will involve :

(I) Compressor overhaul. This will consists of opening up the cylinder head and servicing all the low and high pressure valves. Pistons and piston rings will need inspection and calibration. Lubrication system both the forced and wick type for the cylinders should also be inspected and adjusted.

(II) Both the air and oil filters will have to be inspected and changed according to their condition.

The main point in the starting air system is to ensure the system is well drained of any traces of oil and water in the piping, for safey reasons; and externally the piping system does not develop corrosion. Thus special automatic or manual oil traps and drain cocks are operated regularly. This is important to prevent explosion risks.

5.00 CHAPTER FIVE, MAINTENANCE ON DECK.

5.01 Applied Maintenance On Deck.

The objectives of maintenance work on deck are the same as for the engine room department. The aim is to prolong the economic service life of a vessel and save enormous costs of the scheduled and unscheduled repair costs. These costs are unavoidable but can be minimized by effective maintenance programme.

However since the deck department is responsible for the hull integrity, in general, focus on maintenance work will be on the following areas:

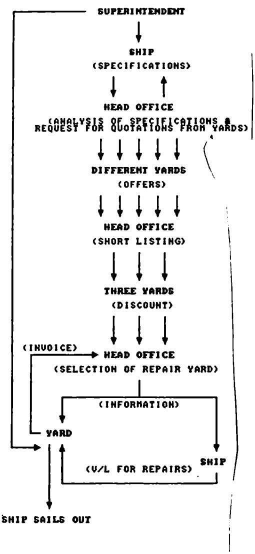
(I) Hull structure and the fittings on the hull.

(II) Deck equipment and machinery.

(III) Operational damage on the hull.

The maintenance work will depend on the owners policy and the size of the vessel. However maintaining the strength of the hull structure is such that it will not jeopardize the safety of the vessel. Hence the requirement for the International Convention on the Load Line for the safety of the vessel, cargo and the crew under normal and severe weather conditions. Cooperation of the ships head office, ships crew is important to achieve the goal. Where major dry dock repair is required the ship yard assistance will be sought as well. Figure 5.01 shows the organization set up of the parties involved in the dry docking process.

Figure 5.01 Organizational Chart.



The vessel at sea is like a beam under the influence of varying forces resulting from the effects of:

(I) Buoyancy, hydrostatic and hydrodynamic forces.

(II) Waves and winds actions on the ship.

(III) Random loading of cargo and the vessels own weight.

Moments and shear forces are therefore induced on the structure. These produce severe stresses on the hull and particularly the deck section. Where stress risers are present in way of structural discontinuity e.g. deck opening for the cargo holds, fatigue cracks will gradually initiate and propagate at a fast or slow rate depending on the stress concentration and the environmental conditions. The effect of these forces produce fluctuating loads on the same places with stress risers. Eventually the stress induced in the hull exceed the fatigue strength of the steel resulting in fatigue cracking as brittle failure. It is recognized brittle fracture amount to be one of the main causes of ship losses especially within the bulk carrier trade. Table 5 below shows the number and causes in the world.

Table 5, Marine Casuality.

Year	Foundered		Fire/Explosion		Collision		Wrecked/** Stranded		Lost	
	No.	Gross Tonnage	No.	Gross Tonnage	No.	Gross Tonnage	No.	Gross Tonnage	No.	Gross Tonnage
1980	152	504.934	55	647.116	39	67.661	127	277.536	6	122.059
1981	120	243.822	67	469.222	41	123.015	100	232.029	11	125.948
1982	142	223.459	79	570.126	32	48.543	108	391.930	32	371.961
1983	127	160.191	58	675.076	35	51.493	93	453.872	20	114.910
1984	131	212.936	57	364.729	35	65.990	69	360.648	24	1.304.298
1985	108	242.234	48	276.126	35	89.481	74	257.429	30	743.700
1986	99	182.985	47	304.061	21	32.158	51	528.256	35	1.519.329
1987	101	395.217	27	95.672	24	96.031	43	298.209	13	336 697
1988	105	169.575	31	125.229	20	17.671	53	227.364	11	293 430
1989	101	228.506	27	150.251	29	58.527	38	151.119	5	34 202
1990	72	385.762	32	162.700	21	33.762	44	262.720	4	23.098

	No.	Gross Tonnage	% of Tonnage Lost
Foundered	72	385,762	34.26
Missing	6	186,128	16.53
Fire/Explosion	32	162,700	14.45
Collision	21	33,762	3.00
Contact	9	71,856	6.38
Wrecked/Stranded	44	262,720	23.33
Lost, etc.	4	23,098	2.05
TOTAL	188	1,126,026	100.00

Source: Lloyd List 1980-19990.

The maintenance work in this respect will be from the design, fabrication of the vessel, selection of the material used and the workmanship of ship construction. Maintaining the continuity of deck plating is a desirable element in the construction because it enhances the strength of the vessel. It is nonetheless incompatible with the functions of loading and discharging the vessel. A compromise has to be reached in strengthening the areas where high stress concentration are unavoidable.

During the operation therefore sources of stress concentration, and the causes which diminish the sizes of the structural material, e.g. corrosion or damage, will form the focus of the maintenance work on deck. Figure 5.01 (ii) shows the table of the composition and mechanical strength high tensile steel used for the hull construction.

Figure 5.01 (ii) Typical Strength, Higher Tensile Steel.

TYPICAL HIGHER TENSILE STEEL

COMPOSITION		MECHANICAL PROPERTIES			
CARBON	0.15 %	Yield Point tons p.s.i.	U.T.S. tons p.s.i.	Elongation per cent	Charpy V-Notch ft./lb. at 0°C. (average of three)
SILICON	0.48 %	26.5	35.4	30	76
SULPHUR	0.015%	HEAT TREATMENT			
PHOSPHORUS	0.029%				
MANGANESE	1.36 %	NORMALISED AT 910°C.			
ALUMINIUM (SOL.)	0.026%				

Source: Metarllugist and Shipping. By B. Todd, Alfred and Company. 1965.

5.02 Corrosion, Protection and Marine Growth.

The hull and deck in all modern ships are made of steel shell plating called strakes. These are strengthened by longitudinal, transverse and vertical stiffeners in the frame work of the vessel. The steel is badly affected by corrosion particularly in the environment of sea water. The mechanism of corrosion has been discussed in Chapter Two. Corrosion is the main enemy in the maintenance of the deck and hull of the vessel. It will therefore be discussed a little further because the effect reduces the size of the shell plating of the vessels. Consequently it reduces the strength of the ship.

Corrosion also accounts for a single cause of high expenditure in the maintenance cost of the vessels, right from new building to the time in operation. Figure 5.02 shows a table of expenditure from the effects of corrosion.

High tensile steel has been optimized in special areas to improve the structural strength. General or local corrosion still means reduction of the material of the plating in other areas, e.g. Salt water ballast tanks.

Maintenance requirement to combat corrosion will involve actions for the protection of the plating from design and during operation.

From design:

(I) Protective coating of the shell plating is essential. This should be applied on both sides of the plating.

(II) Selected steel which is inspected by classification society should be used for ship construction. These must meet the standards tests for the notch ductility by Charpy V-Notch testing.

(III) Optimize corrosion prevention on critical areas of the hull by thicker plating and installation of anodes.

(IV) Installation of the impressed current cathodic protection.

(V) Installation of drainage system from superstructure to deck through to overboard, to drain off pocket of sea water which may act as electrolyte.

(VI) Where high tensile steel is used consideration of the weight reduction and stability should be realized.

In operation:

(I) Deck and shell plating must have insullation of coats of special paint in specific parts of the vessel after removal of the mill scale and cleaning of the plating. The paints are anti-corrosive and anti-fouling. The paints must be environmental friendly.

(II) Maintenance of the impressed current installation and installation of the sacrificial anodes at critical areas e.g. sea inlets to ships, ballast tanks, and sea cooling systems.

Marine growth onto the hull plating at the bottom side of the vessel is another area which requires maintenance attention from deck.

The growth consists of biological sea growth of the sea weeds and creatures known as; barnicles, slime, entermopha, ectocarrous and marine growth take place in the sea environment. It consists of biological sea weed and sea creatures. The effect of this is to increase hull resistance of a vessel in the passage. Thus for the same speed of the vessel as before the build up of the marine growth an increase of the fuel oil consumption will be experienced. This effect raises the energy expenses in the operation. The marine growth has to be controlled so that a vessel can operate at an economical speed. **Table 5.02** shows the relation between the speed and the fouling of the hull.

Table 5.02. Loss of Speed by Foulness

V L C C 270,000T on Ballast.

Speed knot	Loss of speed ΔV in knot				
	6 months	12	18	24	30
8	0,079	0,133	0,164	0,193	0,207
10	0,176	0,292	0,359	0,421	0,452
12	0,333	0,547	0,669	0,780	0,836
14	0,563	0,912	1,106	1,280	1,367
16	0,877	1,394	1,676	1,921	2,044

Source: Lecture Notes by the visiting professor, Y. Matge.

However removal of the marine growth requires the vessel to be in dry dock so that to have accessibility to the ships bottom. Modern trends are deployed by using the under water divers with special equipment for scrabbing the bottom while the ship is afloat. This will result in relatively smooth hull for improved speed.

Opportunity is taken also to avail of the periodic survey inspection and repair the bottom fittings of the vessel while at drydock.

After the growth removal the shell plating by high pressure water jet or sand blasting cleaning of the plates is done and thickness test is recorded at random areas of the plating so that to record the wear rate on the shell plating.

Then special paints are applied with the property of anti-corrosive and anti fouling.

Maintenance requirement comprises periodic dry docking after every two years and vessel movement to avoid rapid marine growth at lay off anchorage.

5.03 Maintenance on Deck Equipment.

The main equipment on deck are for cargo work, mooring and un-mooring the vessel at quay. The need for ships cargo handling gear has made the installation of the lifting equipment to be on the main deck. This has created weak points on deck which has to be strengthened at the base foundation of the equipment. Hence maintenance on deck will start with the inspection of the base for any development of incipient cracks.

The cargo winches have additional item the derrick for supporting the lifting gear. This must be given the same maintenance attention as the hull plating.

The discussion of their primemovers will form the topic of the sub chapter below. However all the deck equipment will have to be:

(I) Inspected and certified by authorized institute to ensure the capacity is adequate for the work.

(II) Wear and tear of the wire ropes, slings, and hooks will have to be inspected regularly and replacement made as necessary.

5.04 Hydraulics, Pneumatic, Electrical and Steam Installation

The deck machinery use any one or a combination of two of the following systems as a means of the prime movers for the cargo machinery:

(I) The hydraulic system.

(II) Pneumatic system.

(III) Electrical system.

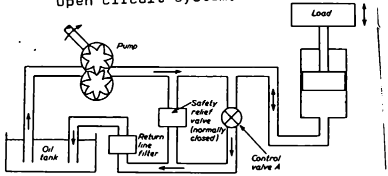
(IV) Steam power for their prime movers.

(V) Mechanical system.

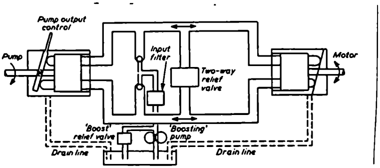
One system may be the main power medium while the other is the controlling medium, e.g. Electric, solenoid for the hydraulic directional valve. Specific systems will be explained. However the common feature for any system is the flow pressure, torque, speed and power from one source to the prime movers. The open and closed loop for the hydraulic systems are shown in figure 5.03 (I) (a)

Figure 5.04 (I) (a) Hydraulic Systems.

Open Circuit System.



Closed Circuit System.



Source: Marine Engineering Practice, Vol. 1, Part 7, Hydraulic Power transmission in Marine Machinery. By C.M. Roy. The system consists of the following items:

(a) Hydraulic pump of positive displacement. to convert mechanical power into pressure flow energy.

(b) Control valves in line, bypass and relief valves.

(c) Hydraulic cylinder for linear forces and motion or semi-rotary actuators for part rotation.

(d) Hydraulic motors for continuous rotary motion.

(e) Filters, coolers, tank and the piping system.

(f) Gear pump driven by electric motor.

The electric motor imparts energy in the form of force and velocity to the fluid medium by means of the positive gear pump. The force is converted into pressure in the piping system. The pressure reconverted into linear or rotary force and motion. Hence power is transferred to the prime mover.

The power in the piping system will be:

Power = Force x velocity, in kilowatts.

= pressure x area x velocity.

Energy = Power x time, in Joules.

The power transfer is seen that it varies with the pressure and the velocity when the area of the piston or rotary blade is same. The system items and fittings must therefore be able to withstand the system pressure. The relief valve determines the maximum value of the pressure.

Application of the hydraulic power drive for the prime movers on deck is in the following sections:

(a) Deck cranes, winches, windlasses, capstans, and steering gear systems.

(b) Actuating of cargo hatch covers and cargo or bunker valves.

(c) Remote control of the water tight doors and quick closing valve for the oil tanks.

Maintenance requirement on the hydraulic system comprises:

(a) Filtration and maintaining cleanliness of the oil. Any minor dirt in the way of the fine surfaces between the oil ports may easily foul the system.

(b) Tightness of the pipe coupling unit and the item covers in the system regularly e.g. the block valves ensures no bypass leakage of the pressure flow rate in the system. This effect renders the system inoperative. This failure is concealed most of the time.

(c) The efficiency of the oil coolers must be maintained at high level because as the system is running idle when on no load the heat developed must be removed by the coolers effectively.

Pneumatic system

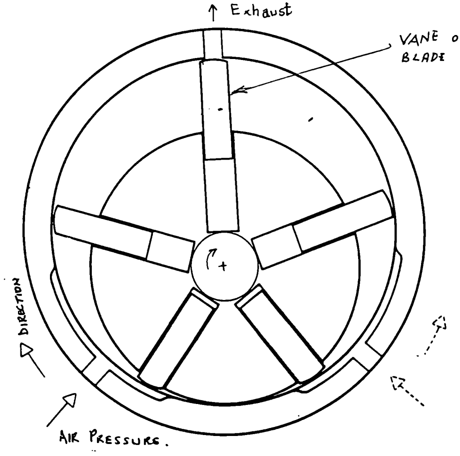
The power drive by the pneumatic system is restricted to small power rating equipment on deck, e.g. for running portable centrifugal pumps for stripping work, deck chipping hammer drive, decanting of oil drums on deck, life boat devits winches and for the control of the other medium.

The principal of operation is explained with the help of the sketch in figure 5.04 (II) (b). Air pressure on the rotary vane or blade produces a torque which turns the pneumatic motor for required drive.

Maintenance required is the to have clean air in the pneumatic system. This is obtained by the clearing of the filters regularly. Pressure leakages must be minimized.

The disadvantage of the pneumatic system is to overwork the air compressor when on prolong service. A portable air compressor is used to supply high pressure air for chipping services on deck to releave the ships compressor. These are air cooled and diesel.

Figure 5.04 (II) Pneumatic Motor.



Source: Lecture Notes, Flensburg Research Institute for Ship operation By, Dr. Rickert. 1991.

Steam system

The steam system was most popular as power drive medium for cargo work during the steam era. In modern times of diesel engine driven vessels steam is restricted to drive the cargo pumps in oil carriers and provide for the heating services of the oil cargo tanks and accommodation. The steam power drive utilizes the steam expansion principle for the operation. This process provides a reciprocating movement for the piston which is transformed into rotary movement by a crank shaft. Expansion in the steam turbine is used with the generators.

Maintenance required is to ensure the before operation the drains are open, and gradual bringing up the pressure, the shaft glands are effective with no leakage to cause pressure drop. The steam delivery and suction valves must be maintained with no leakage between them.

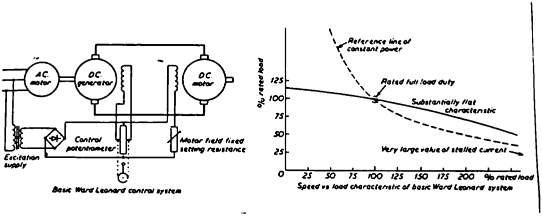
Electrical System

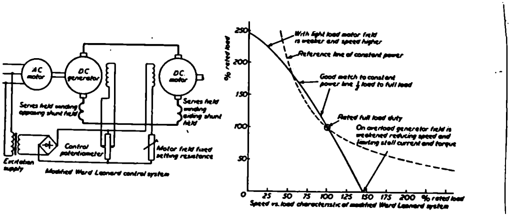
Electrical installation for ship prime movers on deck is popular only in the conventional cargo ships. With tankers electrical installation on deck is extremely minimal because of explosion or fire risks. This is due to presence of explosive mixture and the electricity provides ignition source from sparks that may come from the electrical terminal connection inadvertently.

There are two types of electrical installations, the direct current and the alternating current. Both types rely on the magnetic lines of force to produce a torque for the respective prime mover. The direct current has an advantage over the alternating current with respect to speed control of the prime movers. It is more cost effective to have a D.c. speed control device than the A.C. However a.c installation has a cheaper operational and maintenance costs.

A good compromise is to have both systems as in the Ward Leonard speed control method. This system gives smooth speed and torque characteristics at a high and low rating capacity of the prime mover. The costs of the extra machinery is offset by the high reliability, efficiency with low maintenance costs in the long run. Figure 5.04 (IV).. illustrates the two different systems in the application of the Ward Leonard speed control.

Figure 5.04 (IV), Ward Leonard System of Speed Control



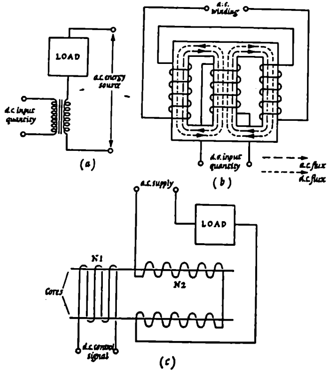


Source: Marine Engineering Practice Vol. 2, part 16.
Ships Gear: By D.H. Beattie et al.

The system consists of the following items:
Alternating current motor driving a direct current generator. The generator supplies the armature voltage to the prime-mover motor. A transductor is used as the speed controller of the prime mover. Schematic sketch in figure 5.04 (IV) (I)

shows the basic circuit of the this type of speed control.

Figure 5.04 (IV) (I) Transductor. Schematic Circuit.



Source: Control Circuit for Technicians,
By. G. T. Brayan, 1967

The speed controller. Transductor.

The transductor consists of alternating current winding round a laminated iron core with a direct current winding in the same core. The D.c. winding is able to vary the a. c. impedance of the A.C. winding from 0, to the maximum value of the respective winding. Thus variation of the output voltage of the transductor is achieved smoothly with minimum losses. Hence the armature voltage to the prime mover motor is accordingly varied with smooth speed control.

Application of the transductor is in cargo winches, windlass and capstan. Maintenance requirement for the controller are minimum due to the static nature of the transductor. The only worry will be for the aging rectifiers and protection of moisture entering the controller. Thus the sealing for the cover must be inspected regularly

Other areas of the electrical installation on deck will be on the lighting, general and navigation lighting on deck and accommodation.

Maintenance required with the electrical installations depends on the type of the installation of the power, lighting, and ancillary circuits on the vessel. However the main thing to bear in mind always when electrical maintenance work is involved is to remember that electricity can be dangerous and so the following safety procedures must always be followed:

(I) Isolate the circuit from the mains and any other power.

(II) Remove fuses and lock the isolator in an open circuit position.

(III) Prove the circuit is dead by a good instrument before commencing maintenance work.

(VI) Familiarity with the switch board and the various circuits will be a dividend in the event of a blackout.

The maintenance required with the electrical installation is conveniently done while the vessel is at sea, and basic element to be carried out are:

A.C. Installation.

Insulation resistance tests to be carried out for the starting contactors, lines and phase circuits and the motor windings. The value of the insulation resistance should not be less than 0.5 Megger ohm. In case of lower reading the circuit insulation will have to be improved.

For all the fuse holders it must be ensured that the fuses do not fall loose due to the vessel vibration. Line and phase voltages must be ensured to be at the right values to detect any single phasing that may cause motor winding damage by over heating.

D.C. Installation.

Before and after maintenance work insulation resistance of the equipment must be taken and recorded.

Carbon dust at the brush gear must be blown off and cleaned by electrical cleansing fluid which is not harmful to health, e.g. armaclean (an electrical cleansing fluid.)

The end covers for the motors must be properly sealed to avoid any ingress of moisture into the motor winding.

Inspection of the electro-mechanical brake must conducted and any adjustment to be made. All the readings and performances of the maintenance work must be entered into the ships log book for future
reference.

Mechanical System.

Mechanical prime movers comprise crane and forklifts driven by the diesel engines. The diesel prime mover will undergo similar maintenance procedures as a normal diesel plant. The forklift is a combination of the electrical and hydraulic maintenance procedures that are required. However diesel forklifts are used mainly at the cargo yards because they are not suitable in confined spaces, e.g. cargo holds or inside a container, because of the exhaust emission. So the only mobile deck machinery is hydro-electric fork lifts.

The maintenance required on them is to ensure battery power is adequate for the intended work. This procedure will involve checking specific gravity of the battery electrolyte, regular battery charging and the hydraulic section is upto the required standard.

6.00 CHAPTER SIX, MARITIME RELATED MAINTENANCE.

6.01 Port Facility and Maintenance Requirement.

Port facility consists of all the infrastructure, the assets and equipment in and around the sea or port terminal. These will be in the form of:

(I) Civil work infrastructure e.g. roads, railway, bridges, building offices, quay or berths for ships, lay off piers anchorage facility, electrical and mechanical work shops.

(II) Marine crafts and navigational aids, tugs, barges, pilot boats, and floating cranes.

(III) Mobile plant will be consisting of the vehicles, cars and lorries for the maintenance work and the staff.

(IV) Cargo handling equipment, cranes, forklifts, ware houses for cargo temporary storage, staff administrative buildings, electrical and mechanical workshops. The workshop facility will be located near the cargo yard but will not occupy more space than necessary. The priority is for the cargo space.

The objectives of the port facility is to provide the following functions:

(I) Safe and efficient ship movement in and out of the port for quick discharging and loading of cargo with minimum delay so that to lower the turn round period for the vessel.

(II) Availability of the operational equipment all the time.

(III) Rapid movement of the inland transport infrastructure so that there is no congestion at the port of cargo or ships.

The efficiency and profitability of the port facility will require effective maintenance policy over all the assets at the port facility. The main reason is the investment in the equipment involves clossal fiscal input, in the region of 20-300m US dollars, for a medium size modern port. The maintenance costs will be in the region of 20-40% of the operational costs. This capital input will normally be a loan from the international financial institutions like the World Bank or the International Monterey Fund. So the money together with interest accrued will have to be repaid in foreign currency in the long run. Therefore maintenance procedures must be taken seriously in order to produce a high level of productivity and availability of the equipment for continuous port operation. At the same time the level of indirect and direct expenses will reduce, due to the effective maintenance, to realize a high profit margin in the port facility.

Organization of the Maintenance Department.

Organization of maintenance department must be set up. This will be under the engineering section because of the technical nature of maintenance tasks. The functions of the maintenance department will be the following:

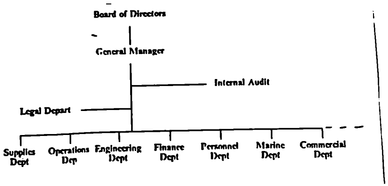
(I) To formulate maintenance policies, strategies and tactics to involve all the aspects of work related to maintenance requirement, e.g. Register of assets, maintenance budget, equipment procurement, stores and supply control, record keeping of the maintenance work and procedures. Allocation of the labour force, evaluation of the maintenance work and accountability of the various sections of the organization. This will form important incentive for the work force.

(II) To plan out the maintenance procedures so that maintenance tasks can be carried out with minimum lead time, optimum labour force and a high productivity.

(III) To control maintenance expenditures and evaluate maintenance performance so that maintenance goals are achieved.

A model of an organization structure is shown in the figure 6.00 (i).

Figure 6.00 (3) Organizational Chart, Port Facility



Source: Port Equipment: Policy Management and Maintenance I. P. P. 3, series. (Seminar), (Untacd) 1990.

It is observed different skills are involved in the organization chart.

The advantage from effective management of maintenance work in port facility are:

(I) The increase in the national foreign reserve which will enable to service and pay off the foreign loans.

(II) Participation in the international maritime trade and having a say in the world shipping market.

(III). Stability of the local commodity prices of the manufactured and agricultural goods. This will reduce also the rate of inflation in a country.

The primary aim of the dissertation is to explain the concepts of maintenance with particular reference to the Kenyan ports.

6.02 Dockyard and Workshops.

Dockyard and marine workshops form part of the marine and related maintenance facility. The size and scope of the dockyard will depend on the maritime trade prevailing in the geographical area of the port. However it is considered for a port of international standard these facilities are necessary. They will enable minor and major maintenance works on the port equipment to be done within the port facility

The dockyard will take care of all the major maintenance work on the marine crafts and floating equipment at the port, e.g. tugs, pilot boats floating cranes, cargo barges and labour boats. Facility for docking the crafts like a small drydock or slipway are essential items. Periodic inspections and repair works needed for the water line of the boats or vessels can then be conducted conveniently.

The dockyard can farther be split into two sections, the dockyard and the afloat sections. The afloat section will concentrate on the floating crafts while they are in operation. It will carry out mainly short term maintenance work, to keep the crafts mobile and supervise the availability of the floating crafts on a daily basis. At the same time the float section will liaison with operation section to ensure maintenance of the navigational aids is maintained; this will ensure the port approaches can safely be navigable at any time of the day.

Since the dockyard will be responsible for the major maintenance work on the floating crafts. It will be equipped with workshops of multiple disciplines to cover all the repairs of the vessels.

These workshops will be in the following manner:

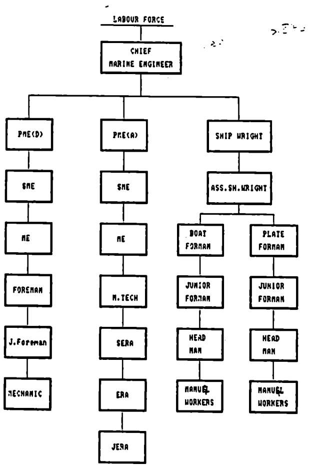
(I) Machine shop consisting of engine, plumber, electrical, and light shop for the navigational aids.

(II) Hull shop which will consist of the plate, welding and slipway sections for slipping on and off the floating crafts as and when necessary for bottom inspection and repair works.

(III) Boat shop where all the carpentry repairs will be done and the wood work for the slipway purposes.

Organizational chart of the dockyard is shown in the figure 6.00 (ii).

Figure 6.00 (ii) Dockyard Organization.



Source: own.

KEY:
PME(D)=Principal Marine Engineer (Dockyard)
PME = " " " (Afloat)
ME = Marine Engineer

The workshops will be equipped with various types of equipment for all the trades in order to manage any type of marine repairs. Special tools will be available like the heavy duty hydraulic press, pneumatic hammers, automatic welding machines and others like high pressure installation for air compressors and pneumatic chipping hammers. Lathe machines and milling machine will form part of the tools for workshops.

The labour force will form a variety of categories in the engineering discipline. These will range from the marine chief engineer, technician, artizan, craftsman, and the manual labour force which know the state of art and technology of the marine operation.

6.03 Stevedoring and Cargo Handling Machinery.

The function of loading and discharging cargo from a vessel is referred to as stevedoring. This involves skilled and nonskilled labour force which will operate the cargo handling machinery for this function.

In the historical past of commercial shipping stevedoring was done by the manual workers. The development in the maritime commercial industry has brought changes in the packages of cargo and also the manner in which it is handled in and out of the vessel. The reason is to reduce damage to the cargo and speed up the operation. The modern times relies on machinery for the stevedoring. So the relationship between stevedoring and the cargo handling gear is very important in the management of effective maintenance procedures in equipment and port facility.

(I) **Ships Gear.**

(a) Deck winches and derricks.

(b) Deck cranes.

(II) **Shore Gear**

(a) Quay side cranes.

(b) Gantry cranes for containers.

(c) Others, e.g. Conveyor belts, elevators, liquid and slurry pumps.

It is clear in this context that maintenance response to a breakdown must be fast. Otherwise downtime of a single day may mean a lot of expenses and disruption of the schedule for the arrival of vessel to other ports. This can cause mitigation of liability and demurage the port facility by the ship owner; the consequences are reduction in port revenue. Hence stevedoring must be supported by highly skilled maintenance section to ensure the level of the equipment availability is high.

6.04 Stevedoring Personnel and Maintenance.

The personnel in the stevedoring section comprises cargo superintendent, supervisor, foreman and the coolies, (the manual labour force). The maintenance personnel is allocated at the workshop near the cargo yard and others in the field for on site repair. The maintenance workers will consist of a foreman, technician and craftsman.

As the port is normally on twenty four hour operational schedule arrangement for the maintenance shift work will have to be made so that to cater for all the shifts. There will be also a duty engineer to make up decision on major breakdowns if they occur at night time.

Maintaining operation and maintenance of the port facility can be a very sensitive issue. So the relation between the stevedores and the equipment they use for their work must be a positive one. This element must provide for good labour relation so that to enhance the output at the port facility. This element is more critical in the developing than the developed countries due to lack of technically orientated labour force.

Improved equipment utilization will depend on the caliber and attitudes of the stevedores. Intentional and maloperation of the equipment must be discouraged by creating positive labour relation with the stevedores for improved equipment operation and performance in port. This will yield maximum productivity from the equipment.

Maintenance of good relation means motivating the stevedores when the output of cargo tonnage is commensurable with the stevedoring. To achieve this goal it must be planned for good incentives in the employment and social activities of the following description:

(I) Salaries and wages must provide for the basic needs of the employees.

(II) Welfare and social benefits must be available to encourage the employee and make stevedoring attractive employment in the port.

(III) Institute a programme of reward for incentive.

(IV) Training for promotion for all the port workers.

The difficulty in the stevedoring is in pin pointing accountability whenever a breakdown in equipment occurs. This can easily be considered as normal breakdown on the equipment or machinery. It is difficult to qualify this due to the fact that failures do occur even with new equipment. However whenever safety or overload protection devices have been interfered with it is hardly surprising to assume that the failure is not a man made.

The solution for this type of problem or behavior is to educate the stevedores in the accountability of the equipment they are responsible for. This procedure must be done even if the maintenance work is being conducted to restore the service of the equipment as explained in the previous chapters.

6.05 Port of Mombasa and Maintenance.

The port of Mombasa is at times referred to as the gate way to Kenya. Its geographical location is shown in the map of East Africa shown in the annex It can be seen that it is across latitude 4.00 degrees South and 38 degrees longitude East.

The requirement of opening up and the consequence of development of the hinterland of East Africa had given the port of Mombasa the credibility it deserved in the in the maritime industry. All the ports in Kenya are under the Kenya Ports Authority. The Authority is a government parastatal organization which is under the Ministry of Transport. There are five ports in all. These are:

(I) Mombasa port which comprises Kilindini and the Old port.

(II) Lamu in the North East of Kenya.

(III) Kwale in the South East of Kenya.

(IV) Malindi about 100 kilometers north of Mombasa.

Kilindini is the main sea port of Kenya. The facility includes modern cargo handling equipment which can handle any type of cargo. The facility available at the port of Mombasa are:

(I) Container terminal.

(II) Conventional cargo berths.

(III) Oil jetty for bulk and other oil carriers.

(V) Anchorage.

(IV) Railway line and shunting yard from the port to the inland transport.

(V) Workshops for the maintenance of the cargo equipment and marine crafts.

The port has 18 berths and the maintenance arrangement is strategically made into zones, A, B, C, D, and E. For each zone a deport is established manned by the foreman, mechanics, electrician and manual workers. The purpose of the labour force within the vicinity is to carry out maintenance work on a daily and routine basis on the cargo handling machinery and equipment on site. When major maintenance work is needed a central workshop to aid the deport labour force.

It is noticed the major area of the maintenance work is in the electrical side of the cranes and the forklifts. The reasons are:

(a) The motive power of the prime movers for the cranes is the direct current electricity. Direct current is most suitable for the crane operations because of the easy of speed controls, and the required movement of hoisting, lowering and slewing of the jibs cranes. Inherently problems of commutations, brush gear wear and controls are paramount.

(b) Excessive loading of the motor which accelerates the commutation failure.

Hence the routine maintenance work in this area will involve strict regular inspection on the brush and control gear conditions for the reliance on the equipment.

Critical situations to watch for problems and causes of failures with commutation in the direct current installation are:

(a) The commutator ring and the brush gear installation.

(b) Quality of the brushes, and the designed contact pressure on the brushes.

(c) Physical brush gear position relative to the magnetic neutral of the motors.

(d) Contact resistance between the brushes and the commutator.

(e) Air gap between the stator and the armature of the motors.

(f) Excessive brush dust at the commutator rings.

Workshops both for the electrical and mechanical discipline are available within the port facility. Thus facility for the skimming of the commutator, motor rewinding of direct and alternating current motors, growler test for the direct current armatures are available.

The snag with the maintenance programme is the procurement of the genuine spare parts for the equipment. This situation is accountable for the low availability of equipment in the port.

The mechanical side of the crane is under control because the problems can physically be seen and so easy to trouble shoot. The problems in the electrical section are as obscure as the electrical power itself. Couple with its danger highly skilled labour force can be eluded by the actual cause of the failures with electrical break down. The mechanical section of the cranes problems are around the following areas:

(a) Loss of effectiveness of braking components due to wear.

(b) Excessive loading and maloperation of the equipment by overiding the safety limits.

(c) Negligence in the lubrication of the moving parts of the machinery.

The port of Mombasa has enjoyed vessel traffic over the past decade. There is a determination for the other East African ports to capture the market in the hinterland of the Eastern Africa. In this respect there is room for improvement of the short failings in the maintenance behavior of the port to maintain the efficient performance in the port facility. The area of concern are the following:

(a) The spares procurement; the port should be given some autonomy to procure these spares from the international market with little delay in order services the equipment.

(b) The engineering department should be allocated responsibility to manage maintenance procedures at the best of their ability and resources.

(c) Development of the cost consciousnesses in the equipment utilization and management must be achieved in the port.

(d) As the port is the core of the maritime affairs of the nation it should influence the government to establish national maritime administration as a directorate or division within the ministry of transport. The objective and functions of the directorate will be to administer the national and international laws related to the national and international agreements and conventions within the Kenyan economic zone. The benefit of the maritime administration will be from the vessel inspections. These will invariably generate maintenance work for the benefit of the nation.

7.00 CHAPTER SEVEN, DEEP SEA MAINTENANCE.

7.01 Maintenance on Sea Going Vessels.

Maintenance and operation on sea going vessels are conducted by the crew of the vessel at sea. The chief engineer through the second engineer organizes watch keeping duties and daily maintenance work for the engine room department. Thus the engine room crew will concentrate on the machinery.

This duty is split also into two sections. The watch keepers will concentrate on the running machinery e.g. The main propulsion machinery, auxiliary engine and the ancillary systems. Recording the performances of the machinery in the official log book will be part of operation and maintenance procedure in every watch.

The other section deals with day workers. This duty will involve also the electrician with any extra engineer or the ratings who will be required to perform extra work as in overtime basis after watch keeping.

Equipment that is not used for propulsion will be inspected for normal services of oiling, greasing, and cleanliness. The standby machinery will be maintained in the working mode all the time. The deck equipment that requires electrical attention will be carried out by the engine room crew, as it will be explained later.

The captain through the chief officer will organize the deck crew for the deck maintenance work. This will involve mainly inspection of the ship gear for cargo work and mooring the vessel. The deck will have to be inspected for any development of rust for removal and painting.

Smooth operation and maintenance of the vessel will be achieved when there is cooperation between the deck and engine room departments.

The maintenance work however can be resolved into four major sector for the sea going vessel:

(I) Vessel preparation for the sea passage.
(II) Maintenance tasks on passage.
(III) Arrival preparation for maneuvering and standby.
(IV) Port overhaul as for the survey inspection and defects in the voyage that could not be attended while the machinery is running.

Preparation

Once the time of departure is known the vessel will have to be prepared for the deep sea voyage. To prepare the vessel depends on the size of the vessel and the period of the voyage. Adequate notice is given to both departments for the preparation to commence. One hours notice before sailing may be enough for the preparation.

Engine Room and Deck Department.

Both main engine and auxiliary engines will be inspected. Warming up of the main engine by the use of jacket cooling water from the generator circulation through the main engine jacket spaces and pistons to gradually raise their temperatures to the working level. This process will avoid high temperature gradient which can develop into high thermal stresses at the start of the machinery. All the ancillary systems will be purged of air, e.g. fuel oil, lubricating, fresh water, to maintain steady state condition as at deep sea. The main engine turning gear will be engaged to give a few revolution of the engine in forward and stern directions. Then the turning gear is disconnected before standby is given.

Testing gears is a procedure which comprises checking of the steering, telegraph, engine room and bridge communication system and the steering compartment. This procedure is conducted by both the engine room and deck departments.

The other areas of preparation on deck involve the navigational aids and emergency rigging of the hoisting rope for oil lamp for the main mass light, in case it burns out at night of rough sea.

All the spare parts and stores will be kept at convenient space for quick retrieval during a break down.

The procedures for the gear testing prior to sailing must be entered into the official log book for both departments. Preparation and trials give indication of malfunction in time for the proper attention and accidents can be avoided.

Maintenance Tasks on Sea Passage.

Little or no maintenance tasks should be expected if the preventive maintenance tasks have been adequately conducted. The maintenance on passage should only be on routine work of replenishing of the fuel oil tanks, lubrication, filtration and maintaining the machinery parameters at the working levels at various sea weather condition.

Regular watch keeping with the engine power diagnosis by indicator cards or computer aid and maintaining cleanliness in the machinery spaces is ideal for operation and maintenance tasks on passage.

However another area of utmost importance is the regular tests of the safety and life saving equipment. These will consists of the following equipment:

(a) Stand by plants like the auxiliary generators, emergency fire pump, steering gear, battery unit.

(b) Life boat engines, life boat davit winch.

Weekly trials of the stand by machinery will ensure it is kept in the ready mode condition.

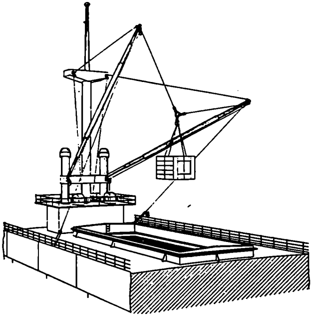
Cargo equipment on passage.

Deep sea provides the best opportunity for maintenance tasks on items which are not directly involved with the propulsion of the vessel. Hence inspection, testing and repair on the cargo winches and hatch opening devices must be done on passage.

Considering conventional cargo ship an average of 16 to 20 winches will be idle at sea passage. The electrician and one day worker can carry out the maintenance work for all the prime movers of all the cargo winches, cranes of the holds before arrival in port. Provided the weather condition is good maintenance work on deck machinery will commence with physical identification of all the prime movers and their control stations for respective holds. This is a safety procedure to prevent accidental operation while repairs are being done. Figure 7.00 (II) illustrates a sketch of a hold with respective position of the prime movers, e.g. Winch No. X, aft of cargo hold, port and starboard in union purchase

Figure 7.00C (II) Identification of the Cargo Equipment on Deck.

Union Purchase Rig.



Source: Marine Engineering Practice Vol. 2, part, 16.
Ships Gear: A review of Deck Machinery. By D. H. Beattie et al.

Electrical prime movers will be discussed as they form majority of the prime movers on conventional cargo carriers. The maintenance procedure will constitute the following steps

(I) Identification and isolation of the main and control power supplies to the respective winch. This may apply to any type of prime mover.

(II) Prove that the power circuits are dead before work commences, by a good reliable measuring instrument.

(III) Insulation resistance of the line and motor windings is taken before and after the work.

(IV) Open the covers for testing and visual inspection of the winding, brush gear and all the electrical items. Test for continuity, open circuit conditions and insulation resistance of all the items. This process will reveal any developing failures that may be hidden. Brush off any carbon dust at the commutator and winnings. Ensure the air gap between the armature and the stator is maintained to the required size. Otherwise inspect the bearings for greasing, oil lubrication and damage. Ensure effective sealing of the end covers of the motors is maintained to prevent any moisture into the electrical components.

Another item of importance is the cargo lighting in the holds and cluster light for the portable and shipside lighting during the cargo work.

Failure in the ships cargo gear is very crucial matter where the cargo work is done by the ships gear. This will constitute lost time in port, delay and disruption on the farther movement of ship to other port.

On the other hand availability of equipment will ensure also some free time for the maintenance workers while the vessel is in port.

 Chp6

End of passage is recorded in the log book. The vessel speed is reduced and stand by machinery is operated.
These will be the following machinery:
(I) The auxiliary generator, standby air compressor, and the steering gear.

The chief engineer will compile the voyage report and plan out the port maintenance work order for the ships and shore requirement. This is normally discussed between the chief engineer and the second engineer. Immediately after finished with engine the propulsion machinery is gradually cooled. Inspection of the following items in the engine room is then done:

(I) Crank case inspection of the main engine for any defects that may have developed during the passage.

(II) Engine mountings and any loose connections, glands and joints are made good to reduce leakage.

(III) External area of the machinery will then be cleaned while the machinery is still warm.

The chief engineer will then issue the list of the repair work for the ship and shore staff if there is need for the shore repairs.

The repair list will involve crank shaft deflection and the bearing clearances will recorded.

An overhaul of a machinery unit or ancillary equipment for the classification society will normally part of the items.

Port Overhaul.

At port the maintenance work will involve minor defects that could not be attended on line on the propulsion machinery; or scheduled work on the main engine, items that require survey and ancillary equipment lubrication pump, cooling pump and any defect on the piping system.

Over haul procedures have been discussed in the previous chapter, (chapter four, direct maintenance). The important consideration as far as port overhaul is concerned is planning of the work must take into account, the time factor. It should not exceed the vessel stay in port. All the spares and tools required are made available in time, as well as maintenance manuals so that the maintenance work can proceed without delay.

7.02 Minimum Ships Standards and Maintenance.

Maritime industry is an international trade. Hence the vessel, equipment, performance and the personnel must meet the required international minimum standards. It goes the same way with maintaining the vessel in the international trade. The purpose is to harmonize the maintenance work for the vessel wherever the vessel is in the world and comply with the requirement of the international rules and regulations of the industry.

The minimum standards of maintenance are related to the safety of the vessel, propulsion power, load carrying capacity and on the operators of the vessels. The need for the minimum standards is to enable various countries to participate in the industry.

International bodies like the International Maritime Organization, with assistance from the International Association of Classification Society and American Bureau of Shipping regulates the industry by setting the minimum regulations for the vessel.

The I.M.O. is the principal body which regulates all the maritime activities for the economic, scientific and economic development of the international community. Hence international conventions relating to the safety, capacity and environment play a major influence on the maintainability of the ocean going vessels. The major conventions are the following:

(I) International Convention on the Load Line....of

(II) International Conventional for the Safety of Life at Sea.

(III) International Convention on Marine Pollution.

(IV) International Convention on Tonnage Measurement.

(V) International Convention on Standard of Training Certification and Watch Keeping.

In all the above conventions the safety of the vessel and the equipment depend on well they are maintained.

The older the vessel the more stringent requirement are imposed on the vessel to meet the minimum standards by the classification societies and the insurance. The reason being that with age serious defects can develop on the vessel , which could not be easily diagonized during the normal inspections. Thus performance of maintenance tasks will bear the need to maintain minimum standards.

Maritime casualty and accident investigation procedures will always be interested to know the root cause of maritime accidents, e.g. Ship loss, marine pollution, grounding, stranding, foundered or collision. The attribution of the cause will be investigated to establish if the incident happened due to low standard of the vessel, lack of maintenance of the equipment, human error or act of God.

Mitigation of liability after maintenance performance followed by an accident is a factor maintenance organization should be concerned with. Hence after any major or minor maintenance on a vessel consideration on achieving above minimum ships standards is important to absolve the maintenance organization of the legal consequences.

In port facility shippers and other organization related to the port would have to sue the port facility for the services that donot meet the minimum standards.

7.03 Declining of the Fleet in the Developing Nations.

In the developing nations the merchant fleet is owned normally by the government. The government delegates a private agency for a high fee to run the shipping company. It has been observed over the time there is a dwindling in the shipping fleet.

There are a variety of reasons for this state of affairs. The following will be high lighted as they are related to the maintenance of the vessels.

(I) Second hand procurement of the vessels can be viewed as one of the reasons because from the bath tub characteristics the age of the vessel will cause it to have escalating maintenance expenses. These costs will make the shipping company unable to realize any profit margin to sustain the trade. Thus after a short period the fleet is laying off most of the vessels due to the high maintenance costs.

(II) The priority in the commercial shipping in the developing countries is such that it is overshadowed by the other political and social departments. Little incentive and investment is allocated to the commercial shipping sector.

(III) Scarcity of senior technically experienced personnel with genuine commitment in the shipping activities. Hence the operation is rampant with mismanagement and abnormalities which unfortunately affect the operation and maintenance of the vessels and disappointment to the sea going personnel for the loss of employment and at times their employment benefits.

As a result of the above where the shipping company requires maintenance it is normally deferred for next voyage because of lack of planning and inability to maintain the schedule. Breakdown in the equipment will follow one another and eventually collapse of the shipping company is inevitable.

It is the desire of the author to see the revival of the national shipping lines for the developing nations. The capital input is always cited as the main constraint for individual nation. Regional ownership as the case was with the defunct Eastern African National Line by the 1960s (1960-1980) is a sad example for the East African seafarers community.

The man power resource is abundant. The fiscal capacity of regional countries is adequate where there is good will in the respective administrations. The management structure on the regional basis has improved tremendously. It is the writers wish that such a venture is taken up again in the near future by the Eastern African respective administrations

8.00 CHAPTER EIGHT. REGIONAL MAINTENANCE STATUS.

8.01 OBSERVATION OF REGIONAL MAINTENANCE.

(a) The Port of Mombasa

On a research visit in Kenya and Tanzania ports a few observations were madè in relation to the maintenance infrastructure of marine vessels and port facilities. The purpose was to correlate the research of the dissertation with own experience, information from maintenance literature and on site observation of the maintenance procedures.

It is noteworthy to say that East Africa has a long history record of the maritime trade. Right from the era of the Arab dhows (sail ships with wooden hull) to the present day of the steel ships the sea trade has been thriving along the central east coast of Africa and the Arab and Indian coasts for centuries. The ports of Mombasa, Dar es Salam and Zanzibar became the main ports in the region. Nontheless the concepts of the maintenance in the maritime infrastructure has yet to develop into a modern status of institutional, administrative and management of the marine vessels and port facility. The lack of ship ownership and ship repair activities may have precipitated this status of affair. There has been a reliance on the foreign expertise on the port and ship operations. From the early sixties the national governments in the region intensify maritime training in all the sectors of the industry. The training has not yet produced adequate skilled manpower needed in the technical and non-technical fields.

The volume of maintenance work depends on the vessel traffic to a port, existing fixed and mobile equipment on the quayside like the cranes and forklifts. The equipment transfer cargo from the ship to the cargo yard, and eventually to the wagon and the consignee. The floating vessels, like the tug boats, floating cranes play an important role in the cargo handling operation. It provides the function of berthing and un-berthing of the ships for the cargo handling at berth or at the anchorage.

As for the observation of maintenance activities of the port of Mombasa a brief description had been given in the sub chapter 6.05. Farther information is in the annex. Additional observation need to be made as the following:

(a) The maintenance infrastructure does exist at the port.

(b) The cargo handling equipment is however over-stretched. This is evidenced by the persistent breakdowns; between 30%-40% of the forklifts are laid off due to the lack of spares and cannibalization of some equipment to keep the other equipment operative.

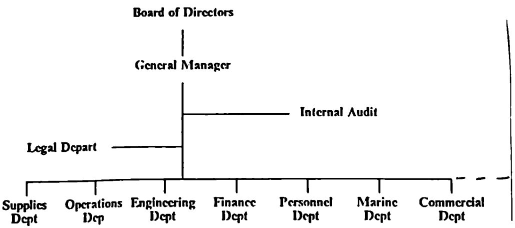
(c) The procurement of the spares poses as one of the major constraints for the planning of effective maintenance.

With the above short fallings the productivity of the cargo operation may not be the optimum target.

(b) The Port of Dar es Salam

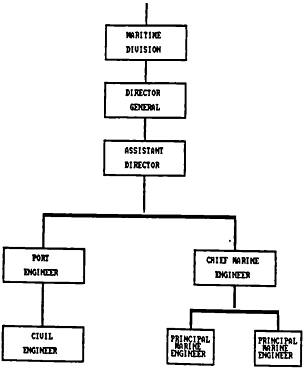
Tanzania has the highest number of sea ports in the region. These are Dar es Salam, Tanga, Lindi, Mtwara, Mafia and Zanzibar. Except Zanzibar the ports are under the Tanzania Port Authority which is a parastatal organization of the ministry of transport. Marine transportation is vital in the national economy. The main port is Dar es Salam. The organization structure is shown in the figure 8.01.

Figure 8.01 Organization chart of port of Dar es Salaam.



Source: Port equipment: Policy Management and Maintenance I. P. P. 3, series. (Seminar), (Untacd) 1990.

MARITIME ADMINISTRATION



Source: Own.

It can be seen that Tanzania has taken the initial step in the establishment of the National Maritime Administration with the creation of the Director General in the maritime matters. Apart from the international requirements the reasons for this important step are:

(a) There is intensive potential in maritime transportation for both cargo and passenger services.

(b) The need for continuity of the passenger services to the main and minor ports on the coastal port has a political, social and economical obligation.

(c) Transportation of the agricultural, commercial, and other commodities to all the coastal towns is given a high priority.

(d) Under-development of the roadway transport make marine transport more viable and economical than the roadways.

So it is imperative for the state to establish a directorate in the ministry to ensure proper regulation of the national and international maritime transport.

It is noted as well that the state has established a maritime institute as an independent parastatal body. The institute comprises:

(a) The ministry for administration, control and issue of certificates.

(b) Board of examiners, who approve and supervise the examination.

(d) The institute which offers the maritime educational requirement according to the national interpretation of the international convention on the Standards of Training Certification and Watch Keeping. The rules and regulation of the convention have been interpreted to suit the national requirements. Thus the manpower to man the coastal transportation is available at the local level. The institute offers upto class three certificate for the seafarers.

The maintenance capability is however at low key. This is evidenced by the lack of maintenance facilities which causes dependency on foreign maintenance centers for their own tugs and other crafts. With the revival in maintenance facilities at the dockyard a thriving repair industry will generate economical benefits for the region.

Meanwhile maritime maintenance is largely on small scale on the coastal vessels. Major maintenance work on larger vessels have to be conducted at the port of Mombasa, Madagascar or Japan.

(c) The Port of Zanzibar

The port of Zanzibar comprises two major ports. These are Pemba and Zanzibar. The ports are under the ministry of ports, commerce and transport. The maintenance infrastructure has not developed to be a large scale because of the dependency of foreign maintenance centers. However the awareness of the maritime requirement is very high because of the fact that Zanzibar is an island. The government has therefore given a lot of priority in this direction. By December 1992 extensive refurbishment of the quayside berths was under construction. Other facility are as shown in the annex

6.02 INFERENCE FROM THE VISIT.

From the above background of the short regional maritime history it is considered most essential for the region to establish the followings institutions:

(a) National regulatory bodies e.g. maritime administration which will formulate national policies for the national and international purposes of the maritime industry.

(b) Interpretation of the international agreement and conventions relating to the maritime industry for implementation and execution.

(c) Establishment of the modern concepts in the cultural, social, economical and technical philosophy in the operation and maintenance of the maritime affairs.

(d) Creation of sense of responsibility and accountability in the work performance at all levels of the labour force. Thus definition of the job description, objectives and expectations of the labour force must be made simple and clear to enhance productivity at all levels of the labour force.

(e) To establish cost consciousnesses in all maintenance procedures in terms of cost analysis of all the maintenance options, e.g. cost of part replacement, cost of time to perform the maintenance, loss of earnings, cost of hire and cost of energy in order for the best option to be followed as the maintenance policy.

8.03 FUTURE TRENDS IN MAINTENANCE.

The future trends in the maintenance of the maritime industry is geared towards the following goals:

(a) Durability in the vessels and the machinery so that the mean time between the overhauls can be extended.

(b) Full automation in the sea going vessels in order to reduce the crew.

(c) Energy saving in the plant from design to operation and maintenance for total economy.

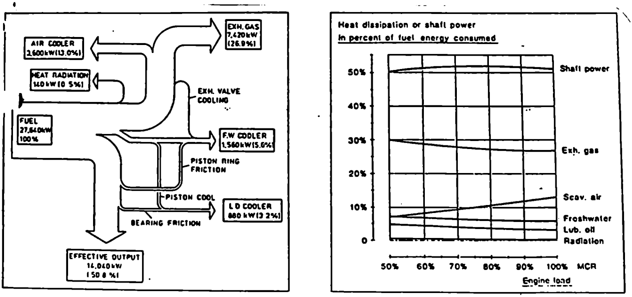
(d) Multi modal transportation of cargo from source to the customer for efficient cargo transportation.

In order to achieve the above goals for both the vessel and machinery the role of maintenance will focused on condition monitoring and preventive maintenance systems. Thus investment in this sector will realize the following:

(a) A high level of the availability and durability in the sophisticated automatic monitoring and control systems to extend the time between the overhauls as suggested by the classification societies.

(b) Utilization of the total energy input must be optimized so that heat losses can be minimized; as the leakages in steam, electrical and hydraulic power losses. prevention of these will enhance the thermal efficiency of a plant. Heat recovery from the exhaust gases and cooling systems can be used as thermal power to run the turbo generators and provide for low temperature heating. Figure 8.03 shows the heat balance of a diesel plant. By the same token the excess power from the main engine shafts can be geared to an auxiliary generator for useful and suitable power utilization.

Figure 8.03 Heat Balance of Diesel Plant.



Source: Lecture Notes, by visiting professor, Dr. Listewnik.

The aim of the above is to cut down the costs of operation and maintenance of the vessel or port facility.

In the future maintenance means money saved or lost. Hence conservation of energy from various leakages of energy can be equated to indicate losses of revenue. A means of power utilization of the wasted power for auxiliary power take off, waste heat exhaust boiler, distillation plant and turbo charger is viewed as an appreciation of cost values of the fuel economy. This will in turn improve the efficiency of the plant in its variety of forms.

The conditions to fulfil the above requirements will need the following criteria:

(a) Highly rated machinery for the port facility and the vessels. This will raise the levels of the reliability and durability of the equipment to a relatively high level so that to extend the mean time between overhauls.

(b) Sea going vessels will have to be equipped with automatic variable injection devices so that optimization of the specific fuel oil consumption at varying loads and speeds can be achieved and reduction in failure of the injection systems will reduce. It is acknowledged that over 70% of the engine breakdowns is caused by the injection system. This is due to the temptation of the operators to make random adjustment on the injection system with no due consideration of the rise in peak pressures and loading of the machinery components. This results premature failure of the machinery items.

(c) Efficient means of bottom inspection and cleaning of the hull while the vessel is still afloat so that as the drydock period is extended saving on the energy cost may also be realized.

(d) Installation of sophisticated computer equipment to aid the operators to maintain the fine requirement of the machinery parameters.

(e) Highly skilled ship operators and maintenance workers will be required. They will have specialized training in all the modes of control systems and simulation training in both bridge and engine room.

The purpose of the complexity in the modern equipment is due to the manufactures requirement of fine control of the major items like the cylinder liners, bearings and the crankshafts. For example a temperature rise of 2 degrees will produce damaging thermal stress. The controller in this respect must efficient enough to maintain the parameter at within the required limits. The same with the maximum pressures for the combustion. A slight increase in the may result in enormous pressure rise which can be harmful to the bearings and other components. It is therefore needful for the sophisticated controllers to be installed in the machinery of the modern vessel to safe guard against the failures.

9.00 CHAPTER NINE, CONCLUSION AND RECOMMENDATION.

The analysis of the problems in general maintenance and steps to take have been explained in the dissertation. It will emphasize the need to adopt the modern concepts in the in marine trade, viz: Terotechnology. This is defined as, " A combination of management, financial, engineering and other practices applied to physical assets in pursuit of economic life cycle costs." (A. Kelly, in Maintenance Planning and Control, 1987.)"

The complexity of the port facilities and vessels demand a great deal of determination on the maintenance sectors to achieve the goals. From the dissertation it will be clear reliability will depend on the control of the level of failures in the plant by effective preventive maintenance. In this respect the following procedure will benefit the maintenance sector:

(a) Keeping a proper data and information collection system of failure for easy decision making.

(b) Planning in line or of line maintenance work schedule.

(c) Implimentation of corrective maintenance from history record, feedback information and data of failure analysis.

(d) Keeping a good storage and spares system for quick replacement. The rate of spares usage will also indicate failure pattern.

Following the above procedure planning of the preventive maintenance work schedule can be instituted by a time frame or certain criterion from the experience gained in the operation.

Considering maintenance at all angles it will be seen that maintenance means saving in costs by the following methods:

(a) Conservation of energy through power losses leakages, hull resistance and corrosion.

(b) Optimization of appropriate functions and systems for power utilization to improve the machinery efficiency.

(c) Maintenance is also part and parcel in the safety and security assurance for the environmental concern. This will ensure the available resources within the environment will be available for the future generation.

It is strongly recommended in this dissertation for establishment of the following institutions:

(a) An effective maritime administration infrastructure for all the developing maritime nations, especially in Eastern Africa regions to implement the international agreement and maritime conventions on maritime affairs.

(b) A maritime academy in the Eastern Africa region preferably in Kenya for training seafarers. The existing Bandari college in Mombasa, Kenya is within suitable surroundings for the purpose.

(c) Creation of the awareness, in the national administration of the essence of the maritime affairs as a priority in the national policies. This will improve employment opportunity for the region and improve the regional economy.

10.00 ANNEX. PORT OF MOMBASA.

The annex will consist of statistical extracts of the operation and performance of the port of Mombasa. The information therein refers only to the port of Mombasa as provided by the kind permission of the office of the Managing Director, Kenya Ports Authority.

A.1. Inception of the Kenya Ports Authority.

The port of Mombasa is administered by the Kenya Ports Authority which officially came into being by the act of Parliament on January 20th, 1978.

A.2. Port Facilities 2(a), (b), and (c)

A.3. Transit Cargo,

A.4. Average Tonnage per ship.

A.5. Idle Time Analysis, 1988.

A.6. Availability of Floating Crafts.

A.7. Standard Maintenance Procedure of the K. P. A. Dockyard.

A.8. Slipway at the K. P. A. Dockyard.

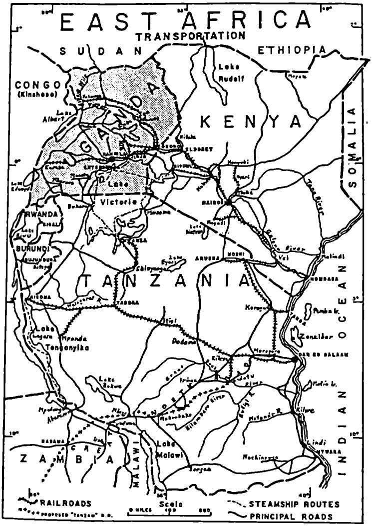
A.9. Maintenance Feed Record.

A.10. Plans of Tanks of the K. P. A. Berthing Tugs.

A.1

Location

Port of Mombasa.



MOMBASA PORT (Showing the location of Bandari College)

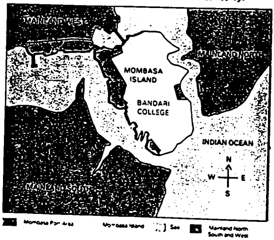


Table 31(a)

PORT FACILITIES — 1988
Berths, Wharves & Jetties

1. DEEP-WATER BERTHS:	
(i) Number	16
(ii) Total Length (m)	3044.00
(iii) Draft (m)	10
2. BULK OIL JETTIES (Tanker Berths):	
(i) Number	2
(ii) Draft (i) SOT (m)	9.75
(ii) KOT (m)	13.40
3. CASED OIL JETTY:	
(i) Number	1
(ii) Draft (m)	4.30
4. CONTAINER BERTHS*	
(i) Number	3
(ii) Length (m)	596.06
5. BULK CEMENT BERTHS:	
(i) Number	2
(ii) Total Length (m)	315.00
(iii) Number of Silos	3
(iv) Capacity per Silo (tons)	6000.00
6. LIGHTERAGE & DHOW WHARVES:	
(i) Number	2
(ii) Total Length (m)	412.00
(iii) Handling points (number)	9
7. EXPLOSIVES JETTY (Handling Lighters) No.	1
8. DHOW JETTIES (Old Port)	2

*Length and number included in 1 above.

Source: Engineering Department.

A. 2. (b)

SHEDS/STACKING GROUNDS — 1988

Table 31(b)

1. Main Quay Transit Sheds:	
(i) Number*	14
(ii) Total floor area (m^2)	106,281
2. Back of Port Transit Sheds:	
(i) Number	6
(ii) Total floor area (m^2)	43,625
3. Passenger & Baggage Hall & Sheds:	
(i) Number	1
(ii) Total floor area (m^2)	1,222
4. Cold Storage:	
(i) Number	1
(ii) Total floor area (m^2)	1,247
(iii) Capacity (m^3)	4,562
(iv) Total Number of Chambers	6
5. Lighterage Area Transit Sheds:	
(i) Number	1
(ii) Total floor area (m^2)	16,250
6. Customs Warehouses:	
(i) Number	1
(ii) Total floor area (m^2)	4,002
7. Old Port Godowns:	
(i) Number	4
(ii) Total floor area (m^2)	895
8. Stacking Grounds:	
Total floor area (main port area (m^2)	114,117

*A unit transit shed is taken as part of the whole of a shed allocated for one berth.

Source: Engineering Depatment.

A. 2. (c)

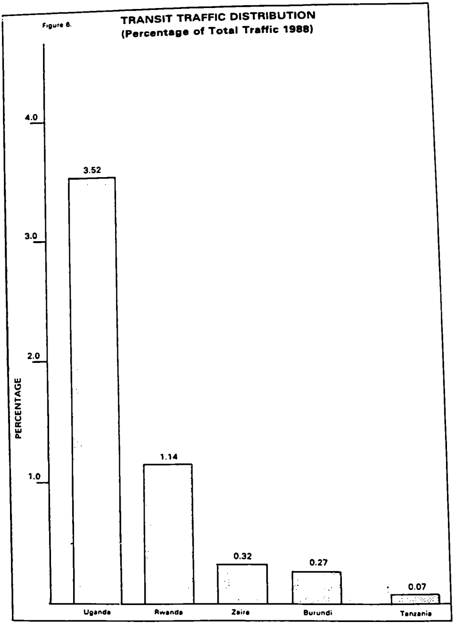
Table 31(c) **HANDLING APPLIANCES — 1988**

TYPE OF APPPLIANCES	TOTAL IN USE AS AT 31-12-87	No. WITH-DRAWN in 1988	No. PUT IN SERVICE IN 1988	No. IN USE AS AT 31-12-88
1. Portal Electric Travelling Cranes				
3 Tonne Cranes	1	–	–	1
5 Tonne Cranes	29	–	–	29
7 Tonne Cranes	8	–	–	8
10 Tonne Cranes	3	–	–	3
15 Tonne Cranes	9	-	–	9
20/7 Tonne Cranes	2	–	–	2
2. Portal Electric Fixed Cranes:				
2 Tonne Cranes	2	–	–	2
3 Tonne Cranes	5	–	–	5
5 Tonne Cranes	–	–	–	–
10 Tonne Cranes	–	–	–	–
3. Electric Overhead Travelling Cranes:				
2 Tonne Cranes	1	–	–	1
3 Tonne Cranes	2	–	–	2
10 Tonne Cranes	2	–	–	2
4. Mobile Cranes:				
5 Tonne Cranes	8	–	–	8
6 Tonne Cranes	14	3	–	11
10 Tone Cranes	2	–	–	2
11 Tonne Cranes	14	–	–	14
15 Tonne Cranes	1	–	–	1
25 Tonne Cranes	2	–	–	2
35 Tonne Cranes	1	–	–	1
40 Tonne Cranes	1	–	–	1
5. Gantry Container Handling Cranes:				
40 Tonne Kone Container Crane	1	–	–	1
40 Tonne Ship to Shore Cranes	3	–	–	3
40 Tonne Rubber Yard Container Cranes	17	–	–	17
40 Tonne Rail Mounted Container Yard Cranes	2	–	–	2
6. Under Hung Jib Cranes:				
1 Tonne Cranes	6	–	–	6
1½ Tonne Cranes	6	–	–	6
Wall Bracket Cranes	5	–	–	5
7. Floating Cranes:				
60 Tonne Jumbo Floating Crane	1	–	–	1
8. Overhead Belt Conveyer Cranes:	2	–	–	2
9. Tractors & Trailers:				
Tractors	80	15	–	65
Trailers	247	75	–	172
10. Forklift Trucks:	240	102	1	139
11. Goosenecks & Stands:				
Goosenecks	18	–	–	18
Goosenecks Stands	10	–	–	10
12. Side Loader:	1	–	–	1

INLAND CONTAINER DEPOT - NAIROBI

1. Cargo Shed .... 1 No.
2. Hardstanding Area .... 99,000 sq. m.
3. The number of Tractor, Trailer & Forklift trucks are included in item No. 9 & 10.

Figure 6.


TRANSIT TRAFFIC DISTRIBUTION
(Percentage of Total Traffic 1988)
PERCENTAGE
4.0
3.0
2.0
1.0
3.52
1.14
0.32
0.27
0.07
Uganda
Rwanda
Zaire
Burundi
Tanzania

A.4.

Table 15. **AVERAGE TONNAGE PER SHIP WORKING DAY**

MONTH / YEAR	1984	1985	1986	1987	1988
January	802	945	850	870	953
February	816	1,099	904	848	822
March	869	959	1,149	815	908
April	905	1,106	1,074	919	952
May	820	1,188	744	979	864
June	879	999	843	1,020	1,019
July	888	1,171	635	1,056	1,342
August	836	1,141	1,000	891	1,355
September	1,145	1,268	1,051	800	917
October	1,337	955	715	982	880
November	1,151	1,017	1,015	1,163	871
December	1,125	690	776	1,124	835
AVERAGE	964	1,045	896	956	954

Source: Monthly Review of Port Working.

Table 16. **TONS OF DRY CARGO HANDLED PER SHIP WORKING HOUR**

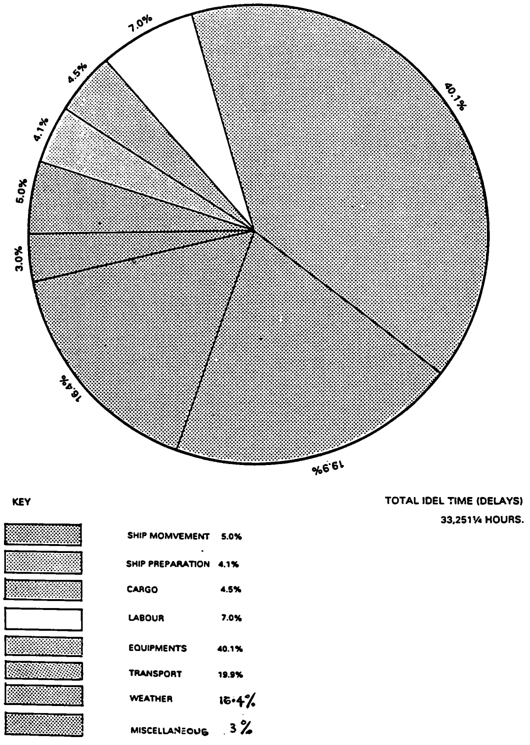
MONTH / YEAR	1984	1985	1986	1987	1988
January	50.13	59.07	53.13	54.38	59.56
February	51.00	68.69	56.50	53.00	51.38
March	54.30	59.94	71.81	50.94	56.75
April	56.56	69.13	67.13	57.44	59.50
May	51.25	74.25	46.50	61.19	54.00
June	54.94	62.44	52.69	63.75	63.69
July	55.50	73.19	39.69	66.00	83.88
August	52.31	47.38	62.50	55.69	84.69
September	71.58	79.25	65.69	50.00	57.31
October	83.56	59.69	44.69	61.38	55.00
November	71.94	63.57	63.44	72.69	54.44
December	70.31	43.13	48.50	70.25	52.19
AVERAGE	60.00	65.31	56.00	59.00	59.63

Source: Monthly Review of Port Working

A.5.

Figure 12.

IDLE TIME ANALYSIS (%) 1988



TOTAL IDEL TIME (DELAYS)
33,251¼ HOURS.

A.6.

KENYA PORTS AUTHORITY

AVAILABILITY OF FLOATING CRAFT

Date: 8th January, 1992

VESSEL	TYPE	STATUS	REMARKS
CHUI	TUG	IN SERVICE	ATTENDING SHIPPING MOV.
NGUVU II	TUG	IN SERVICE	ATTENDING SHIPPING MOV.
SIMBA II	TUG	OUT OF SERVICE	UNDER REPAIR
DUMA	TUG	OUT OF SERVICE	UNDER REPAIR
FARU	TUG	IN SERVICE	ATTENDING SHIPPING MOV.
KIBOKO	TUG	OUT OF SERVICE	ON SLIP - WAY
TEWA	TUG	OUT OF SERVICE	WAITING DISPOSAL SURVEY
EL-LAMY	TUG	IN SERVICE	ATTENDING SHIPPING MOV.
NAHODHA	PILOT	OUT OF SERVICE	GOVERNOR FEED AND DRAIN PIPE NO. READY
BAHARIA	PILOT	IN SERVICE	ATTENDING SHIPPING MOV.
TANGULIZI	PILOT	IN SERVICE	ATTENDING SHIPPING MOV.
KIONGOZI	PILOT	OUT OF SERVICE	UNDER TRIAL
KMB 1	MOORS	IN SERVICE	ATTENDING SHIPPING MOV.
KMB 2	MOORS	IN SERVICE	ATTENDING SHIPPING MOV.
KMB 3	MOORS	OUT OF SERVICE.	ENGINE HULL REPAIR
KMB 4	MOORS	IN SERVICE	STAND BY AT DOCKYARD
MTUMISHI	LAUNCH	OUT OF SERVICE	WAITING PRESSURE GAUGES
PELELEZI	LAUNCH	IN SERVICE	ON H/M. SERVICES
KORONGO	WORKBOAT	IN SERVICE	ATTENDING SHIPPING MOV.
MKIZI	VISITORS	OUT OF SERVICE	AT AFRICAN MARINE
JUMBO	CRANE	IN SERVICE	STAND BY AT NO: 75
MLINZI	POLICE	OUT OF SERVICE	UNDER REPAIR
MCHUNGUZI	POLICE	OUT OF SERVICE	WAITING GRINDING OF GRINDING OF CRANK-SHAFT
TIDDLER	TOWING TUG	IN SERVICE	UNDER REPAIR
TWENDE	TOWING TUG	OUT OF SERVICE	RETAINED FOR REHABILITATION
MAFUTA	POLLUTION	OUT OF SERVICE	WAITING DISPOSAL SURVEY
LB. 2	LABOUR BOAT	LAID UP	-
TOROKA	TOWING TUG	LAID UP	-

KENYA PORTS AUTHORITY

STANDARD MAINTENANCE PROCEDURES

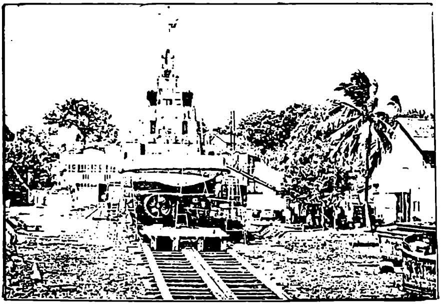
VESSEL:- NGUVU II

EID NO:- RUSXXX VESSEL NO:- KPA561

S.M.P.	DESCRIPTION	HOURS
AAA001	LUBRICATE GOVERNOR AND FUEL EXTERNAL LINK	50
AAA002	LUBRICATE AND TEST OVERSPEED TRIP	50
AAA003	CHECK TURBOCHARGER OIL CHAMBER BREATHER	150
AAA004	CLEAN AIR FILTER ELEMENT	150
AAA005	CHANGE PRIMARY FUEL FILTERS	150
AAA006	CHECK L.O SUPPLY TO VALVE GEAR	200
AAA007	WATER CLEAN TURBOCHARGER	200
AAA008	CLEAN AND EXAMINE L.O. FILTER	250
AAA009	EXAMINE CRANKCASE BREATHER	250
AAA010	CLEAN AIR CONTROL FILTER	250
AAA011	DISMANTLE AND CLEAN CHARGER AIR COOLER	250
AAA012	RENEW SECONDARY FUEL FILTERS	250
AAA013	CHECK CRANKSHAFT ALIGNMENT AT FLYWHEEL	750
AAA014	CHECK HOLSET FLEXIBLE COUPLING	750
AAA015	CHECK CAMSHAFT GEAR L.O SUPPLY	750
AAA016	CHECK AND ADJUST VALVE CLEARANCE	750
AAA017	SERVICE FUEL INJECTORS	750
AAA018	CHANGE L.O. AND L.O. FILTERS	750
AAA019	CLEAN F.W. COOLER	750
AAA020	CLEAN L.O. COOLER	750
AAA021	CHECK L.O. AND F.W. THERMOSTATIC VALVES	750
AAA022	CLEAN AND GRIND IN AIR START VALVES	750
AAA023	CHECK CRANKSHAFT ALIGNMENT	1500
AAA024	CLEAN AND EXAMINE EXPLOSION RELIEF VALVE	1500
AAA025	CHECK BACKLSH AND L.O. SUPPLY TO AUX.GEARS	1500
AAA026	STRIP AND CLEAN TURBOCHARGER	1500
AAA027	CHECK TURBOCHARGER CLEARANCES	1500
AAA028	EXAMINE CRANKPINS	10000
AAA029	EXAMINE BALANCE GEAR COMPONENTS	10000
AAA030	OVERHAUL CYLINDER HEADS	10000
AAA031	REMOVE AND CHECK PISTON RINGS.	10000
AAA032	EXAMINE LINERS	10000
AAA033	OVERHAUL FUEL INJECTION PUMPS	10000
AAA034	EXAMINE PINS AND BUSHES FOR LINKAGE	10000
AAA035	DISMANTLE AND REBUILD L.O.PUMP	10000
AAA036	DISMANTLE AND INSPECT L.O. REDUCING VALVE	10000
AAA037	DISMANTLE AND INSPECT L.O. RELIEF VALVE	10000
AAA038	RENEW CYLINDER HEAD WATER CONNECTIONS	10000
AAA039	DISMANTLE AND OVERHAUL F.W. & S.W. PUMPS	10000
AAA040	CHECK CONNECTING ROD ALIGNMENT	10000
AAA041	OVERHAUL F.O. TRANSFER PUMP	10000
AAA042	RENEW HIGH PRESSURE F.O. LINES	10000
AAA043	MAJOR OVERHAUL	10000

A. 8.

SLPWAY at K.P.A.
DOCKYARD.



Tug on the slipway

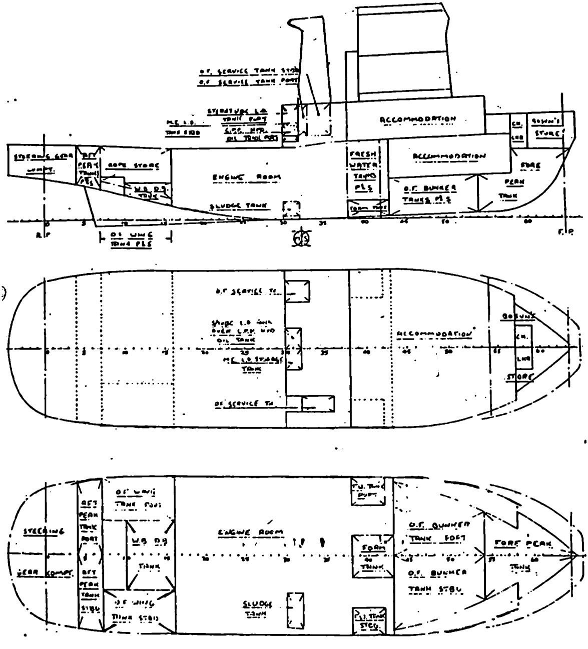
Kenya Ports Authority.

MAINTENANCE FEEDBACK REPORT.

VESSEL :- NGUVU II
VESSEL NO.:- KPA 561
MONTH :- APRIL/MAY

Maintenance Work Order.	Equipment Identification Number.	Sample Maintenance Procedure.	DATE ACCOMPLISHED	HOURS ACCOMPLISHED	REMARKS
5610001	RUS003	AAA001	170591	008474	XX
5610002	RUS003	AAA002	170591	008474	XX
5610003	RUS003	AAA003	170591	008474	XX
5610004	RUS003	AAA004	170591	008474	XX
5610005	RUS003	AAA005	170591	008474	2 ELEMENTS
PT. _ No 1	1-P441	/1059/	1 USED	XX	
5610006	RUS003	AAA006	170591	008474	XX
5610007	RUS003	AAA007	No.	EQUIPMENT	XX
5610008	RUS003	AAA008	170591	008474	XX
5610009	RUS003	AAA009	170591	008474	XX
5610010	RUS003	AAA010	170591	008474	XX
5610011	RUS003	AAA011	170591	008474	XX
5610012	RUS003	AAA012	170591	008474	2 ELEMENTS
USED X X					
5610013	RUS003	AAA013	170591	008474	XX
5610014	RUS003	AAA014	170591	008474	XX
5610015	RUS003	AAA015	170591	008474	XX
5610016	RUS003	AAA016	170591	008474	XX
5610017	RUS003	AAA017	170591	008474	XX
5610018	RUS003	AAA018	170591	008474	4 ELEMENTS

A.10.



PLAN OF TANKS

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