Marine automation and its impact on the fleets of developing countries such as Bangladesh

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MARINE AUTOMATION AND ITS IMPACT ON THE FLEETS OF DEVELOPING COUNTRIES SUCH AS BANGLADESH.

By

Khondoker Nazmul Ahsan
People's Republic of Bangladesh

A dissertation submitted to the faculty of World Maritime University as one of the requirements for the award of a

MASTER OF SCIENCE DEGREE

in

MARITIME EDUCATION AND TRAINING
(Marine Engineering)

Year of Graduation
1993
DECLARATION

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

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

Khondoker Nazmul Ahsan
MET(E)93
World Maritime University.

Supervised By:
LCOR. S. J. Ohnstad,
Lecturer, Department of Maritime
Education and training (Marine Engineering), World Maritime University, Date

Assessed By:
Associate Professor Kenji Ishida, Ph.D.
Head of the Department of Maritime
Education and Training (Marine Engineering), World Maritime University, Date

Co-assessed By:
Prof. Dr. Ing. F. Richert,
Head of the department of Marine Automation, Flensburg Ship Research Institute, Germany.
First of all I would like to express my heartfelt gratitude and sincere thanks to all those who provided me with abundant encouragement and help without which I am sure it would not have been possible for me here at this unique place, "The World Maritime University".

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I am also grateful to a number of persons and institutes who have contributed to the completion of this study:

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ABSTRACT.

Automation is the control of automated processes where human beings can be replaced, to some extent, by a machine. It is the operation of process and procedure by means of a self-regulating mechanism. Control is the heart of automation.

The concept of the shipboard control system is not new. It dates back to the early years of iron man and wooden ships when control was carried out through a relatively simple communication protocol; as the beat of the drum was heard, the oar was expected to make a positive stroke. The speed of the vessel was controlled by the frequency of the drum beat, with a little encouragement from the lash. From there, shipboard automation has developed to a stage where the crewless vessel has been tried. The modern era of electronics has ushered in a second industrial revolution and its impact on society, industry, as well as on the maritime industry, could be even greater than that of the original industrial revolution. Having substantial resources and less manpower, shipowners in developed countries have taken full advantage out of that by introducing the use of a very high level of automation in their fleets. However, developing countries with a surplus of cheap manpower, lack of technical knowhow, maintenance, repair and servicing facilities and finally financial resources should make a careful evaluation and analysis before installing such a high capital intensive venture.
This project studies fleet position, manning structure, ship-repair facilities, level of automation on vessels and socio-technical environment of developing countries like Bangladesh. It also deals with the fundamental principles of automation to give access to the described classification societies’ requirements on automated vessels, the present level of marine automation being used by the developed countries and its cost and the impact, reliability and safety of automated vessels.

Finally, all the above data and information have been analyzed to evolve guidelines for the level and mode of shipboard automation for the oceangoing vessels of Bangladesh. Also, to run and maintain that level efficiently and successfully, further guidelines to establish our crew levels, train our ships’ personnel, improve shore repair facilities at the home port and reorganize a support system from the shore office. The author has the firm belief that the above will guide Bangladeshi flagged vessels towards a way of economic and efficient ship-operation to sustain in the present tough economic competition.
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Chapter - I

INTRODUCTION

1.1 Marine Automation and its Development:-

To a housewife automation may be the automatic dish washer, to the marine engineer it may be unattended machinery, to the shipowner it could be the difference between profit and loss. In the broadest sense automation is the control of automated processes where human beings can be replaced to some extent by a machine. Automation is the operation of a process and performance by means of self-regulating mechanisms.

Originally ship automation systems were unlike those of an electrical base, they were pneumatic, hydraulic or purely mechanical based control systems. With the introduction of an electrical control system, relays were used widely. Even today many control systems are based on relay logic.

Electronics has changed dramatically over the last three decades in the marine field. With the invention of semiconductor devices, control valves, such as triodes, were replaced by transistors. The rapid development of solid state electronics, from transistors to the advent of the integrated circuit (IC) in the early 1960’s and microprocessor in the early 1970’s, the amount of intelligence that could be built in to a machine at a reasonable cost took a giant leap forward. The number of complex shipboard machine-tasks that could be automated has increased several fold. Electronic control systems which were
not feasible even just five years before because of cost, have become obsolete today. With the advancement of micro electronics technology, today a micro processor chip on a piece of silicon 5 mm by 5 mm, consumes nominal power, costs less than USD 50 and approaches more than one million calculations per second.

The modern era of electronics has ushered in a second industrial revolution and its impact on the society, industry, as well as on the marine industry could be even greater than that of the original industrial revolution. Now, the microprocessors used in marine automation systems have become tiny in size, less expensive, more reliable, flexible, safer, and have reduced shipboard workloads, manning levels and operating costs. Developed countries' shipowners, having substantial resources and less manpower, have taken full advantage of this by installing a very high level of automation on their fleets. But, developing countries with a surplus of cheap manpower and a lack of technical know how, maintenance, repair and servicing facilities and financial resources, should make careful evaluation and analysis before installing such a high capital intensive venture.

1.2 Purpose and objectives of the paper:-

It has been experienced that when procuring a vessel developing countries, do not consider the level and mode of shipboard automation and whether or not they are in a position to maintain and run the vessel successfully and economically. Sometimes circumstances do not allow them to consider this because of political or other reasons.
In developed countries, to a shipowner the main reason for introducing automation in a vessel is to curtail expensive shipboard manpower. But, manpower in developing countries, especially in Bangladesh, is comparatively cheap, therefore it is very difficult to justify, from the technical and economical point of view, the utility and merits of a very sophisticated full automation system on ships having a large compliment.

It is not only the initial investment of fitting automation systems on board a vessel that is required, but also the proper running, maintenance with repairs and servicing facilities, especially at home ports to keep the system operational. Besides the system also requires maintenance by skilled manpower in order to run smoothly and efficiently.

It has been experienced that during the breakdown or malfunctioning of highly automated equipment, shipboard personnel try to fix it by replacing components one by one using the trial and error method. This not only destroys/consumes the stock of spares and defecated spare parts budgets but also impairs the ships’ schedules and the company’s reputation, resulting in financial loss.

In the context of the above I have written my dissertation on the topic with a view to design fleet automation recommendations/guidelines for my country as well as other developing countries having similar fleets and manpower structures. For our survival in the present competitive shipping economy and to run the organization profitably, my objectives in this dissertation are to:

- recommend guidelines on the level and mode of
shipboard automation for our-ocean going vessels which may also be followed during vessel procurement. 
- recommend guidelines to impart training on the shipboard personnel to run and maintain the automation successfully and efficiently and also to give access to employment on foreign flag vessels.
- advise on guidelines to establish a safe crew level for the vessels, considering the country's techno-socio-economic condition.
- develop requirements for shore based backup facilities at home ports for maintaining and servicing the recommended automation systems.
- recommend the adaptation of new policy for modernizing and rearranging the ship operator's office to give full support to the ship's staff for operating and maintaining automation systems and to run the organization efficiently from the technical and commercial point of view.

Other objectives of the dissertation to conclude a vessels' automation specification are to:
- specify the present development of marine automation;
- discuss classification societies' requirements on automated vessels;
- study the reliability of automation equipment;
- work out the impact of automation on manning and safety.

1.3 Area of focus:

(a). Fleet position, manning structure, level of automation on vessels and socio-technical environment of the developing countries.

(b). Basic principles of marine automation.
(c). Present level of marine automation and automation expected to be introduced in the fleets of developed countries.
(d). Classification societies' requirements on automated vessels.
(e). Reliability investigation of marine automation equipment.
(f). Impact of automation on shipboard operation.
(g). Cost benefit analysis of an automated vessel.
(h). Requirements to maintain and run an automated vessel.

1.4 Methodology:

The basic idea transmitted by the professors, visiting professors, lecturers of the World Maritime University, field trips to different developed countries, industrial tours in Sweden and practical course on marine automation at Flensburg, Ship Operation Research Institute, Germany were used as guidelines. My own experience at sea as an Electrical/Senior Electrical Engineer, dealing with automation problems and later as Deputy General Manager in the Ship Repair Department and General Manager (Acting) in the Marine Workshop of Bangladesh Shipping Corporation, allowed me to choose the broad outline of the subject. All these ideas and tools would have been futile and useless without the critical path adopted at different stages of this dissertation.

I have asked different ship operators about their fleet positions, manning structures and levels of automation of the fleets. The present level of marine automation used by developed countries is
Control Diagram of the Dissertation,

METHODOLOGY
already known and I have also received detailed product specifications of the automated equipment in use and coming into the vessels in the near future from major reputed automation equipment manufacturers. The requirements of automated vessels and unattended machinery spaces are already mentioned in the rules and regulations of different classification societies. I have procured reliability investigation and survey reports on shipboard automation equipment from different ship-research institutes and classification societies.

Analyzing all the above information in the light of my own experience on marine automation I have tried to compromise between manning structure and level of automation on the vessels. From here I have recommended shipboard machinery specifications, upgrading of shipboard personnel training and marine repair facilities suitably giving importance to the techno-socio-economic condition of the country.

1.5 Design of the paper:

The dissertation contains 10 chapters. The first is an introduction to the research / study design and process. The second is the background of the country under discussion. Chapter III provides an overview of the automation control fundamentals to understand the behavior of the equipment mentioned in Chapter-IV. Chapter IV outlines the current state of technical development in the field of marine automation. In this chapter I tried to view a picture of present levels of marine automation used by the developed countries and leading to the automation likely to be introduced within near future which may
be helpful in selecting equipment. Chapter V focuses on the requirements of automated vessels. Here I have tried to mention the requirements from the classification societies' point of view. Chapter VI contains a reliability investigation of automated equipment used on the vessels. Chapter VII is the impact of automation on shipboard operation. In this chapter I have mentioned how manning has been reduced gradually in the marine field and its effect on shipboard operations. In Chapter VIII I have analyzed all the above information and data and pointed out the cost benefits of the additional investment for automation. I have also analyzed the level and mode of automation we should have and other requirements to maintain the automation. Chapter IX is the conclusion and recommendations where a specification on automation is given and other recommendations to improve our manning skills, home port repair facilities and re-organizing shore supporting system to maintain the level of automation successfully.
2.1 Bangladesh in brief:-

Bangladesh is a country of 115 million people and has an area of 1,43,998 square kilometer. It is bounded by India on the East, West and north, also there is a small south-east boundary with Burma. The Bay of Bengal ties in the south. The country has a coast line of 1,500 Km, which runs along the northern most tip of Bay of Bengal. A total of about 24,000 Km of rivers, streams and canals criss-cross the country. The river network of about 8,500 Km has a great influence on the economy of the country.

Bangladesh has two sea ports, one is at Chittagong, on the river Karnaphuly and the other is at Chalna, on the river Poshur, known as Mongla. Chittagong is the biggest port of the country, handles mainly import and part export of the country. Mongla port mainly handles export and part import and also large volume of cargo of land locked neighboring country Nepal.

The economy of the country is predominantly agricultural and its major exports are products such
as jute, jute-goods, tea, leather, and leather goods, ready made garments, frozen foods and so on. The major imports are food-grains, cement, coal, sulphur, iron scraps, machineries, general cargo, raw cotton, edible and crude oil. This calls for a cheapest mode of transportation for movement of above commodities between Bangladesh and other countries of the world in the foreign trade and collection/distribution to and fro from the two sea ports to the inland sector to survive in the competitive market. The water borne transport is the only answer for Bangladesh. Therefore, the country should have an efficient and cost effective shipping, an essential instrument for over all national development strategy. The government being well aware of it and seeks to promote steady development of the national fleet in nationalized and private sectors. The future target in ship-acquisition program to a ultimate goal to carry the cargo as per provision of UNCTAD, that is 40:40:20; on its own bottoms. In a study under taken by Bangladesh transport survey, it was recommended to increase the fleet requirement of about 100 ocean going vessels of total tonnage of over 1.5 million DWT. At present merchant fleet of 40 vessels with a total capacity of about 600,000 DWT carrying only 20% of the combined volume of imports and exports on its own bottoms.

2.2.1 The Bangladesh Shipping Corporation :

Bangladesh Shipping Corporation (BSC) was established in the public sector on 5th February 1972 under the presidential order no.10 of 1972 that is soon after the liberation of the country in 1971.
It’s aim was to provide an efficient and modern ocean transportation system with a view to develop necessary self reliant infrastructure for carrying home-based export and import commodities of the country. Today BSC is the largest shipping company of the country. Without having any ships of its own, the corporation started functioning as agency house on behalf of foreign shipping lines in the home ports. At the same time, launched the drive of ship owning. Despite inadequacy of resources and financial constrains BSC acquired the first vessel in June 1972 and initiated the first liner service to the UK and European continent. With the patronage of Government BSC acquired a mixed fleet of 26 vessels in the year 1987 and made a plan to build up a modern and balanced fleet of 31 vessels with a combined DWT capacity of 580,000 tones by the year 1990 in order to be able to cover about 30% of the seaborne trade of the country. But, unfortunately this could not be materialized due to non-availability of foreign assistance/loans at low/acceptable rates of interests and grants from developing partner countries/agencies under bilateral agreement.

At present BSC has a mixed fleet of 18 vessels containing 4 general cargo, 1 container, 11 multipurpose cargo vessels and 2 crude oil tankers with a total capacity of 267,019 DWT with an average age of approximately 12 years.

Presently BSC operates in three regular liner routes which are as follows:-
1. Bangladesh and UK continent
2. Bangladesh and Far East/Japan
Bangladesh and Colombo/Pakistan/West Asia Gulf service. During the financial year July 1991 to June 1992 BSC has carried 1,653,487 tones of import and 1,435,569 tones of export cargo representing about 18.1% and 12% of the country's total import and export cargoes respectively.

2.2.2 Organization of BSC:

There are 7 members in the board of Directors. Minister of Ministry of Shipping himself is the Chairman of the Board. The Managing Director and three Executive Directors of BSC are members of the board by virtue of their rank, other two members are Secretary of Shipping and Joint Secretary of Finance of Bangladesh government. The Managing Director and three other Executive Directors of the corporation are appointed by the Government. The Managing Director is free to select the other employees and managers but it has to be within the Government approved chart and this appointments have to be approved by Ministry. BSC has 830 permanent shore employees and 500 afloat officers. Ships ratings are employed on rotational basis as and when required from the ratings registered with BSC. Organizational chart of the corporation is shown in Table-2.1.

2.2.3 Ship Acquisition Plan of BSC:

During the third five year plan (1985-90), BSC had a plan to build up a mixed fleet of 31 ships including 19 ships to be acquired with combined dead weight capacity of 586,000 tons. The plan kept
Organizational Chart of Bangladesh Shipping Corporation

BOARD OF DIRECTORS

MANAGING DIRECTOR

EX. DIRECTOR (Finance)
- EXP. CONT.
- BUDGET
- ACCOUNTS
- F.R. CELL

EX. DIRECTOR (Commercial)
- CONTAINER
- DHAKA OFFICE
- FE. & WAG.
- UK / USA
- CARGO OPER.
- CHARTERING
- INS. & CLAIM
- REG.OFF.KHULNA
- REG.OFF.LONDON

EX. DIRECTOR (Technical)
- SHIP REPAIR
- SHIP PERSONNEL
- SHIP STR.MANG.
- BUNK. & BILLS
- TANKER CELL
- MARINE WORKSHOP
- GRAIN CONV.W/S.

ADMIN. & ESTABLISHMENT
- PR.COMM.PROTOCOL

SECRETARIAT
- SHIP PLANNING
- AUDIT

Table - 2.1
provision for procurement of different types/sizes of vessels for balancing and modernization of the present fleet of BSC; but it has not been possible to fulfill the procurement target envisaged under the plan. However, BSC has been able to acquire six ships during the plan period. BSC has proposed to acquire total 13 ships of different sizes including one mother tanker during the 4th five year plan (1990-95).

2.3 Private Merchant Fleets of Bangladesh:

Private investment in Bangladesh is very shy and it is more so in shipping industry due to high economic competition and prolonged world wide recession in shipping. Since 1977 the ship-ownership is no longer nationalized in Bangladesh. Since then, it is the policy of the government to encourage private investment in shipping in order to develop private shipping side by side with the national line. At present, private ship-ownership is gradually increasing despite the set back suffered by shipping due to unprecedented recession all over the world and an obvious fear prevailing in the mind of private investors due to political instability that has prevailed in the country. At present total shipping capacity in the private sector is about 120,000 DWT. It is hoped that a sizable merchant fleet under private sector will develop soon and will help meet the country's sea-borne transportation requirements simultaneously with the national line. This will surely, enhance commercial capability of all the shipping lines in Bangladesh.

The future of shipping in the private sector is quite promising in Bangladesh, manning is one of the
cheapest in the world. The Bangladesh Flag Protection Ordinance stipulates certain criteria for two way sea-borne trade and BSC’s inability of carrying full share of our national trade are a few of the advantages which will encourage the private enterprises to invest in shipping. However, a rapid growth of this capital intensive industry can not be expected without state assistance.

The role of private shipping in developing countries like Bangladesh in protecting county’s interest is very important. This will act as a competitor of the national line and national line will be compelled to improve its performance. The trade is expected to receive a better service from the shipping lines under competition for commercial gain.

2.4 Ship Repair Facilities in Bangladesh:

Bangladesh Shipping Corporation’s own workshop BSC Marine Workshop and Chittagong Dry Dock Limited provides main ship repair facilities to the ocean going vessels. Besides these, there are few small scale marine workshops are there. None of them is experienced with the repair and maintenance of sophisticated automation equipment. The present ship repair facilities of the country for ocean going vessels are not commensurate to the requirements.

2.4.1 BSC Marine Workshop:

The workshop is located in Chittagong with road and water way connections, from the port area made the location most suitable for attending ships in port.
It comprises an area of approximately 11,000 square meter with the facilities of machine shop, bench fitting shop, fabrication shop, black smith shop, foundry shop, carpentry shop, electric shop, refrigeration and air conditioning shop and automobile shop. The workshop is manned by around 200 permanent employees and depending on work load another 150 to 200 temporary workers.

The workshop undertakes the job of milling, drilling, shaping, boring, of different shipboard machineries and manufacturing spare parts in a limited scale; grinding of crankshafts; dismantling, overhauling and assembling of various types of valves, pumps, gears, and other ship board machinery; overhauling and rewinding of electrical motors, generators and other electrical equipment; casting pump body, impellers, rings, valves of ferrous and non-ferrous metal; repair and maintenance of shipboard refrigeration and air-conditioning plants; fabricating/repairing hatch covers, air ducts, ladders and other steel plate and structure works of the vessel; repairing/renewal of piping systems. The outdoor operation department of the workshop is engaged, as the name implies, for carrying out repair and maintenance works on board ships. Major jobs are handled by them, indoor section gives back-up facilities to the out-door section. The workshop also has another wing named "Grain Conveyer Workshop" which deals with operation, repair and maintenance of food grain conveyor machines.

90% of the repair of BSC fleet are carried out by this workshop. The workshop also undertakes repair
and maintenance works on other private owned domestic and foreign flag vessels.

2.4.2 Chittagong Dry Dock Ltd:-

The Chittagong dry dock is the only yard in the country with docking facilities for ocean-going vessels. It is situated on the south bank of the river Karnaphuli, about three miles up the river from Bay of Bengal.

The main functions of the yard are firstly, to repair ocean-going vessels including docking. Secondly, to manufacture steel structure such as trusses and members of buildings, power transmission towers, pressure vessels, tubular pipes, railway wagons, belle bridges etc. and lastly, ship-braking to meet the requirements of scrap for Chittagong Steel Mill Ltd. and others.

The physical facilities of the dock are graving dock for dry docking of vessels, outfit quay for afloat repair of vessels, workshop complex as backup facilities for dry docking and afloat of vessels in the outfit quay. The maximum size of the ship that can be docked is 174 meter in length, 24.5 meter in breadth and maximum DWT of 16,800 tones. The present manpower of the yard is about 400. It is a standard practice for a shipyard to have servicing /repairing facilities of specialized items such as turbochargers, fuel pumps, governors, hydraulic hatch covers handling equipment, electronic and automation equipment by the makers' service engineers or by makers' authorized service stations who are readily
available on short notice. But, in Bangladesh these services are not readily available either due to lack of suitable infrastructure due to the lengthy official procedure of bringing the technicians from abroad.

2.4.3 Ship Repair Facilities in Private Sectors:

No large scale marine workshops have so far been established in private sectors for catering repair/dry docking of ocean-going ships in the country. Small scale workshops of about 25 / 30 in the private sector are engaged in repair and maintenance works on board ocean-going vessels. These workshops are scattered in Chittagong, Khulna and Mongla/Chalna area.

These workshops can undertake plate renewal works, fabrication jobs, overhauling and rewinding of up to medium size electrical motors and alternators, overhauling and maintenance works of main engine components, pumps, valves and so on, renewal/repair of pipes, machining of small parts, casting of up to medium size white metal bearings and machine parts, machining of parts and components of smaller sizes.

2.5 Importance of Merchant Fleet in Developing Countries:

The following socio-economic considerations promote developing countries to build her merchant fleet commensurate with the growth of the external trade:

- To save foreign exchange in the form of freight payment to the overseas shipping companies.
- To earn foreign exchange as freight through crosstrading.
- To create employment opportunities for the surplus man power of the country.
- To reduce dependance on foreign shipping lines.
  Since, shipping being a strategic industry, total dependance on foreign shipping could be a disaster at the time of national emergencies.
- To have control on freight.
- To help the country in the field of trade promotion services by opening new shipping routes and offering competitive freight especially for non-traditional commodities.
- To ensure the timely despatch of commodities to meet national export target / international obligations and import targets for maintaining steady supply in the local market and smooth development activities.
- To facilitate national ship building and related industries.
- To develop technical skill and know-how in maritime industry.
- To fly the national flag all over the world.
- To fulfill greater national objective of self reliance in all spheres of the national economy.

2.6 Maritime Institute in Bangladesh:

Chittagong Marine Academy is the only maritime training institute for training merchant navy officers. It is situated on the eastern bank of river Karnaphuli. To insure a steady supply of well trained and qualified manpower for our merchant fleet, allied industries and related administration, Bangladesh
recommissioned its Marine Academy in the year 1973. The academy was established in the year 1962 and since then has been giving pre-sea training to both nautical and engineering cadets. The academy conducts two years training and on successfully completion awards Bachelor of Science degree. Besides pre-sea training academy conducts post-sea training also.
3.1 Automation:

Automation is the control of automated process where human being can be replaced to some extend by a machine. Automation is the operation of process and the procedure by means of self regulating mechanism. Control is the heart of automation. Automation in a process is dependent on the ability to control the process with little or no help from humans. What has to be controlled depends on the process, but generally control involves starting, stopping and regulating the movement, position or flow of each of the components of the process. The ability to control, in turn, usually depends on the ability to monitor or measure variables in the process that needs to be controlled to ensure that the final output is as desired. This depends, in turn, the ability to compare the actual product to the desired product and make adjustments in the process if the error exceeds some predetermined threshold. A system that has all these abilities is called a control system.

Automation is dependent on the ability to control a process. Controls are defined as variously designed devices provided to direct, govern or influence the operation of machines. The control device is therefore
Human operated liquid-level control system of earlier vessels and its block diagram.

With the introduction of automation, level control system took place to the above block diagram.

Figure: 3.1
the interconnection / interface between man and the machine. Technical developments have permitted this interface to become more and more automated control from the basic machine.

In a manual control system, control action is only when man recognizes a deviation from the desired condition and activates the control mechanism. The system is dependent on man and his limitation and therefore the degree of control obtained depends on the individual's ability to recognize and respond the off-normal condition as detected by the instruments. Man's ability to sense and response to a deviation is generally poor. It is not possible for a human being to become continuously alert, which effects the effectiveness for manual operation. Figure-3.1 shows liquid level control system of unautomated and automated vessels.

3.2 Components of Control System:-

Control systems are the heart of an automation system. Major components of a control system are measuring element, controller, actuator and process.

3.2.1 Measuring element:-

The ability of a control system process depends on first of all the ability to sense what is happening. This has been and continues to be a major obstacle in the automation of tasks now performed by the human, especially those involving the eyes. Sensors are a type of transducer which convert physical information such as temperature, pressure, flow rate, position and so on into electrical signals. The electric signals are related
to the physical variable in a known way so that the
electrical signal can be used to monitor and control a
process.

Sensors are usually categorized by what they
measure. For continuous process, one or more of these
are often needed:
1. Temperature
2. Pressure
3. Flow
4. Velocity
5. Acceleration.

For batch processing, it may be one or more of these
quantities:
1. Weight
2. Volume
3. Level
4. Composition
5. Tension
6. Compression
7. Dimension
8. Position

For discrete parts manufacturing, the sensors primarily
measure on/off condition. The ideal sensor would be
small in size, durable and reliable and hence infinite
resolution and accuracy. Its output would not drift
due to temperature or any other environmental factors
and of course, it would be easy to make and low in cost.
Despite the fact that many sensors are available today,
there continues to be a need for better and more
accurate sensors, especially as the availability of low-
cost reliable controllers makes the automation more and
more feasible.

The basic sensor types are related to the physical
properties needed to describe the world around us. The
ability to measure these properties accurately is a
necessary requirement in automating a process. There
are many variables of input sensors, from very simple
switch contacts to very elaborate atomic particle
detectors, all of which find applications in various
system.

Measuring temperature, pressure, and flow now-a-
days marine automation system often needed:

1. Temperature sensors
   a. Thermocouple: A temperature sensor based on the principle that two joined, dissimilar metals generate a voltage when heated.
   b. Thermistor: A heat sensor that measures the temperature by the change in a semiconductor's resistivity.
   c. RTD: Resistance temperature devices, operate on the principles that the resistivity of a metal changes when heated. It has a linear change of resistivity with temperature.

2. Pressure sensors
   a. Aneroid Barometer: In an aneroid barometer, change in pressure are converted to electrical signals by a moving diaphragm stretched over a sealed vacuum chamber.
   b. Capacitive Pressure Sensors: The plates on each side of an evacuated chamber form the capacitive pressure sensor. Changes in pressure deflect the plates and change the capacitance.
   c. Solid State Strain Gauge Pressure Sensor: A piezoresistor bonded directly on to a diaphragm is the heart of a solid-state strain gauge pressure sensor. It provides smaller size, better reliability and lower cost, than mechanical sensors.

3. Flow sensors:
   a. Venture: The difference in pressures at the point of constriction and upstream from the construction is the basis on which venture flow sensors operate.
   b. Turbine: An impeller is placed in a tube through which the material flows. The turbine output shaft drives a generator which provides a voltage output proportional to the speed, that is flow.

4. Position sensors:
Mechanically activated limit switch is the simplest position sensors, widely used today. Closing or opening of its contacts indicates position, but this type of switch requires physical contact with something to actuate it. In lot of cases physical contact is not required or desirable.

a. Light sensor switch: Position sensors using light are of two types. One interrupts a direct beam another a reflected light beam, they are light emitting diode (LED) and photo transistors.

b. Capacitive switch: It is used for sensing a metallic object. When detecting metal objects, the metal object can be used to form one plate of a capacitor and the change in capacitance generates an electric signal.

c. Hall-effect switch: Hall-effect switches are made of semiconductor material and generate voltage when current is passing through the device and the device is placed in a magnetic field. They are used to sense position or shaft rotation.

3.2.2 Controller:

Controller is the brain of a control system. It receives information (input) about a process via sensors and external devices and performs mathematical calculations and logical comparisons and makes a decision, performs some action on the actuators and monitors the result.

Several technologies have been developed to perform the controller function over the years but the basic concept remains same. In marine control system pneumatic control and relay logic are the oldest system and they are still in widespread use. Relay logic control finds application in automation of sequential
type machines while pneumatic control usually is found in automation of proportional control of a continuous process. Both the above processes now-a-days in marine automation are handled by programmable electronic controllers based on solid state programmable processors. They are of low cost, reliable and of very small size. Solid state electronic components and processors have made the electronic programmable controller the emerging leader in marine automation. Programmable controllers are "soft ware" based. Instructions are stored in the memory, and they can be changed easily. A control hardware diagram is shown in Figure-3.2.

The quality of an automated system's performance is determined by measuring the system's stability, sensitivity, responsiveness, and other such parameters affecting the desired output. There are four different types of controllers commonly used for process control of continuous and batch systems:–

1. Proportional
2. Proportional plus integral
3. Proportional plus derivative
4. Proportional plus integral plus derivative

In a proportional (P) control system, the output signal to change the controlled variable is proportional to the error signal. As a result, as the error correction gets closer to the set point, the smaller the correcting signal becomes, and therefore at equilibrium there will be a small constant error to provide a constant control signal.

Proportional-Integral (PI) controller is used in a situation requiring significant changes in the set-point due to large amount of change in load.
Control Hardware Diagram

Figure - 3.2
Proportional-Derivative (PD) controls is not widely used in automation control applications since it does not eliminate the off-set error of the proportional control mode. They can be useful in systems where rapid changes in the load are likely to occur.

Overall, the most flexible process control is the Proportional-Integral-Derivatives (PID) controller. This type of controllers can be used in almost all control systems, although it is difficult to setup.

In a perfect control system the output is always the same as the set point irrespective of changes in load and disturbance. A control system is chosen depending on the objective. When controlling hot water geyser temperature, it can be set maximum and minimum values of the temperature. With in these limits oscillations are permitted and also time necessary to reach the set point can be rather long. When controlling the rpm of a diesel generator, there should not be any oscillation, but even rather big deviations of short duration may be allowed.

### 3.2.3 Actuator:

Actuators give the required physical action by converting the electrical signal to a mechanical motion. In marine automation, this might be a solenoid, relay or electric motors.

a. Solenoid:– The solenoid is an electro magnetic device that produces a straight line mechanical force for pulling or pushing and is useful as an actuator. They are widely used in marine automation as valve actuator and fire protection.

b. Relay:– The relay is similar in operation to the solenoid. It's moveable armature is attached to fixed
core and has a flexible strips with electrical contacts attached to it. Relays make and break these contacts when they operate.

c. Electric motors:- Electric motors are the most suitable among all actuators. Low cost solid state electronic for control has resulted in many proportional actuators based on electric motor. D.C servomotor, a.c synchronous motor, universal motor and stepper motor are commonly used as actuators.

D.C servomotor:- The d.c servo motor utilizes a variable d.c voltage for speed control. A tachometer driven by the motor provides speed feedback to a control system called a servo loop and a rotational position servo provides feedback to form a self-contained positioning system. These motors are used where precise position control is necessary along with high-speed operation.

A.C synchronous:- In an a.c synchronous motor, current flows in the armature in the correct direction all the time and the rotation is caused by a rotating magnetic field provided by an a.c voltage. It requires very little control circuitry and is less expensive and smaller than an equivalent d.c motor, but is also limited in its flexibility.

Universal D.C motor:- The universal D.C motor operates either an A.C or D.C voltage. This motor has poor speed control, thus, it is usually used where speed is not critical. Sometimes it is used with a gear train or a clutch-break mechanism.

Stepper motor:- Stepper motors, unlike conventional d.c motors, do not provide a smooth continuous motion. The out shaft of a stepper motor rotates by incrementing in discrete steps, but motor speed can be varied. External circuitry is required to drive this type of motor, but the operation leads itself to direct digital control.
Since it provides precise position control movement, it is widely used with machines that use index movement.

3.2.4 Process:

The Merriam-Webster Dictionary defines a process to be a natural, progressively continuing operation or development marked by a series of gradual changes that succeed one another in a relatively fixed way and lead toward a particular result or end; or an artificial or voluntary, progressively continuing operation that consists of a series of controlled action or movements systematically directed toward a particular result or end. In terms of kind of operation, process can be grouped into three general areas:

1. Continuous,
2. Batch,
3. Discrete Items.

In a continuous process materials move continuously from raw material to finished product. In batch processing, a given quantity of material is processed through its manufacturing steps as a unit, each step being completed before the unit passes on to the next step.

In discrete processing each item to be manufactured is processed at each step as a separate, individual item. It is the most common processing system.

3.3 Classification of Control System:

Automation control systems may be classified in many different ways according to their performance. They are described below. Any one control system
obviously will relate to several of the categories listed.

3.3.1 Classification by Type

Open loop - Closed loop system:

In an open-loop control system output has no effect on the control action. That is, in an open-loop control system no information is fed back from the output and hence input settings determine the output and depending on the system response, can result in large output errors.

A practical example is a washing machine. Soaking, washing and rinsing is done on a time basis. The machine does not measure the cleanliness of the cloths, that is the output signal.

A closed-loop control system is one in which the output signal has a direct effect on the control action. That is, actual output of the process is measured and compared to the desired output. Adjustments are made by the control system until the difference between the desired and actual output is as small as required.

A true automatic electric washing machine should have the means of checking the cleanliness of the cloths being washed continuously and turn itself off when the desired degree cleanliness is reached. Then we can say the system as closed-loop system.

Generally speaking, advantages of an open loop control system are: Relatively simple, resulting in cost, reliability and maintainability advantages, inherently stable. Disadvantages are: Relatively slow in response to determined changes, inaccurate, due to
lack of corrective action for error.

Generally speaking, advantages of a closed-loop system are: Relatively fast in response to demanded changes, relatively accurate in matching, accurate to desired value. Disadvantages are: Relatively complex, potentially unstable under fault condition.

3.3.2 Classification by Type of Process Variable being Controlled:

Normally in a control process velocity, acceleration, force, torque, tension, temperature, pressure, liquid and gas flow rate, mass, liquid level, humidity, chemical composition, pH, voltage, current, frequency, neutron flux density, air speed and so on are controlled.

In a closed loop system transducers (sensors) are provided to sense above process variable and send signal to the controller. So, a closed loop system is only as good as its transducers. The accuracy of control cannot be better than the accuracy of the transducers.

3.3.3 Classification by Type of Plant being Controlled:

In marine automation main engine control, auxiliary engine control, main engine auxiliaries controls, boiler controls and so on are the plants being controlled.

3.3.4 Servomechanisms versus Regulators:

A servomechanism is filled in a process where plant output is mechanical in nature; the function of
the system is to cause the actual value to track as accurately as possible changes in the desired value. Position control system is the example.

The function of a regulator in a closed loop system is to hold the actual value at a constant level, determined by set point in the presence of fluctuating operational conditions. Automatic voltage and frequency control system in auxiliary engines, temperature and liquid level control systems are regulator based.

3.3.5 Classification by Type of Control Signal being Employed:

The system is defined by the nature of the signals involved in the process. A process can be controlled by electrical, mechanical, hydraulic, pneumatic or combination of them.

3.3.6 Analog, Digital and Hybrid Control Elements:

An analog signal varies in a continuous wave-like fashion over a given period of time, and has an infinite number of values between its maximum and minimum limits. Usually such signals vary repetitively at some frequency. Most electrical elements and virtually all non electrical elements are inherently analog. Most sensors generate analog signals and are easing attached to an analog controller.

Digital signals operate in a binary mode that is, only two signal 1 and 0. Like analog signal digital signal have a period and frequency but the period measured differently. Period is the time the level is at that of one digit (bit). A grouping of bits represents a codes. A common grouping is a byte which
is of 8 bits.
Since, digital signals used in control system have only
two levels, they are called binary signals.

Most sensors and actuators in control systems are of
the analog type. When a digital controller needs a
digital signal, it is necessary to condition an analog-
to-digital signal between sensors and controllers by A/D
converter and digital-to-analog signal between
controller and actuator by D/A converter.

Hybrid systems contain some analog and some
digital elements, are referred to as Sampled Data
control systems. Since almost all plant processes are
inherently analog, it follows that any continuous
control system using digital control elements is a
sampled data system.

3.3.7 Single Versus Multiple loop Continuous Control
System :-

In marine automation many control systems have
more than one feedback loop, that is, multiple feedback
loops. These feedback loops are often placed around
individual system elements. Marine boiler water level
control system is an example of multiple loop control
system. There is shrinkage and swell characteristics of
feed water in the boiler drum and also level of water as
indicated by the gauge glass is not a true
identification of water level or quantity of water
whilst steam is being generated. When there is
increased steam demand, pressure in to boiler will tend
to fall, causing the release of large quantity of steam
bubbles at the heating surfaces. These bubbles force
their way through the water in the generator tubes to
the steam space in the drum and in doing so water level
rises in the boiler drum above the previously indicated
by the gauge glass. Instantaneously therefore, the water level appears to rise in the boiler drum, although the actual input of feed water is less than the output of steam from the boiler.

Therefore any control system based on solely upon the measurement of level that is, one feed water loop will function incorrectly in this condition. In two loop feed water control systems, additional control loop sensing steam flow, inflow of feed water can be controlled. In three loop control systems, basic control is carried out by a comparison of steam flow and water inflow by two control loops in addition to 3rd loop consisting of measurement of boiler water level.

3.4 Electronics Fundamentals :-

The rapid development of solid-state electronics from transistors to the integrated circuit has changed and continues to change the approach and technique used for automatic control systems. Digital logic, microprocessors, and micro computers for decision making; analog amplifiers for amplification; and analog to digital converters and digital to analog converters for signal conditioning are a few of the basic elements in integrated circuit form.

3.4.1 Integrated Circuits:-

These are tiny circuits, multiple members of interconnected transistors, diodes, and resistors manufactured on the surface of a small piece of pure silicon and the finished circuit is located in a plastic package with connecting pins. This new device was called an integrated circuit. Today the piece of
silicon out of which the circuit is made often is called simply a "chip".

They are classified as small scale integration (SSI), medium scale integrated (MSI), large scale integrated (LSI) and very large scale integrated (VLSI) according to the number of components on the silicon chip. There are thousands of different integrated circuits (IC) in the market and they have dedicated function.

3.4.2 The Micro Processor:

Most micro computers are made with a micro processor. A micro processor is a LSI circuit, but it is not a dedicated device like normal IC as it can be programmed to function to suit particular application. It contains most of the digital logic circuitry usually associated with a digital computer. That is, digital computer that incorporate a micro processor are said to be microprocessor-based. Microprocessors are small, cheap and reliable that is why more and more control and monitoring applications are being taken over by them. Above all these characters they are programmable that they can be used in any control function that is universal controller rather than, as stated earlier, dedicated controllers for specific applications. The same microprocessor could be used in an automatic washing machine, a children's toy or a computer. Figure 3.3 is the 6502 microprocessor used in a typical micro computer.

The microprocessor is a digital device and works on two different states of signals, value "0" represents no signal and "1" represents a signal or a
voltage. So, on each of the 40 pins the micro processor will have either a "0" or a "1".

3.4.3 Memory:

The memory stores data and instructions in binary form. They are of two types Read Only Memory (ROM) and Random Access Memory (RAM).

Often data should be stored temporarily for later retrieval and use, then after use, the data is changed. The data may originate from input device, sensors, or may be intermediate results of calculation. The data also could be results of an analysis that will be sent to output devices. This type of data is stored in RAM.

Static and dynamic are the two type of semiconductor RAM. They are made of metal-oxide silicon field-effect transistor (MOSFET). Flip-flop is the basic static memory. Dynamic memory cells are basically a capacitor of MOSFET or bi-polar type.

Data is built in to ROM initially when it is manufactured. The second kind of ROM is programmed after it is manufactured. It is programmable ROM or PROM. It can be programmed only once after manufacture. If there is mistake in programming a ROM it must be discarded. Since programming errors are common, another kind, an erasable PROM or EPROM was developed. The EPROM can be erased and reprogrammed with the help of a programmer so that user has the flexibility of writing and storing his own program and data. Reprogramming can be done by using ultraviolet light. The disadvantage is that the entire PROM must be erased. The electronically alterable ROM or EAROM allows only selected portions of the ROM to be changed electronically.
Hierarchy of semiconductor memories.

Figure - 3.4
All types of ROM retain their contents even when the computer is switched off. RAM, on the other hand, loses the information stored in it when the computer is switched off. The hierarchy of semiconductor memories is shown in Figure-3.4.

3.4.4 Central Processing Unit (CPU) :-

Most microprocessors are Central Processing Units of a computer. The CPU is the combination of Arithmetic - Logic Unit (ALU) and control unit. Arithmetic unit carries out many of the functions that are specified by the instructions. This carries out arithmetic operation such as addition and substraction, and logic operations such as AND, OR, or complement. For example, if an "add" instruction is stored in memory, the control unit will fetch it, interpret it, and send signals to the ALU that cause two numbers to be added. If the CPU is contained on integrated circuit, this IC is called a microprocessor. The first microprocessor was developed in 1971.

A complete micro-computer is formed when memory and input/output circuits are added to a microprocessor or MPU. These circuits are often external to the single MPU IC. A micro computer is a computer whose CPU is a microprocessor. Solid state technology has developed to the extent that it becomes possible to put CPU, memory, and input/output (I/O) on one integrated circuit. These type of devices are called single-chip microcomputers. A functional block diagram of CPU is shown in Figure-3.5.

3.5 Computer Control System :-

A control system can be classified with five
criteria as a computer control system.

1. The system should have an input so that data, instruction can be entered through it.
2. The system should have a memory to store data, instruction and result.
3. The system should have capability of making calculations using arithmetic operations.
4. The system should have decision making capability using logical and relational operations so that it can select alternative courses of action using the input data and previous calculations.
5. The system should have capability to give an output in order to actuate or transit the results of its operations.

The majority of sensors used in the control system produce analogue output signal and these are the input to a digital computer. A conversion of the signal from analogue to digital is made in an Analogue to digital converter (ADC) before putting to the input of the computer. The decision of the control system that is the output is again digital and it is converted from digital to analog by digital analogue converter (DAC) before putting the signal to the actuator.

The block diagram of a digital control system is shown in Figure-3.6. Four basic components CPU, memory, and input, output device will satisfy above five criteria of a computer control system.

The input block is of one or more input channels to feed the CPU. A particular input is selected by its address being placed on the address bus by the CPU. Depending on the design, data are transferred either 4, 8, 16, 32 bits in parallel to the CPU via the input data bus. Memory receives data from the CPU in binary code.
Central Processing Unit

Figure - 3.5

Typical block diagram of a computer control system.

Figure - 3.6
in write operation and provides CPU in the same way from the memory location up on receiving command from the CPU. Memory location is selected by the CPU using the address bus, the data is transferred via the bi-directional data bus. The memory is of semiconductor ROM or RAM or magnetic storage or a combination of these. Most of the micro-computer has got semiconductor RAM and ROM with magnetic disk or diskette for external mass storage.

A computer can be used in the automation system in a supervisory role or to provide direct control. In computer supervisory control (C.S.C) systems, actual measured values from the various process sensors are input to the computer and the various desired values are outputs from computer to controllers. The individual control loops then operate their control loops as independent systems. The program or instruction inside the computer with display information from where the change of desired value in the individual controllers will ensure optimum operation and the logging of data. In this system the computer is acting in a supervisory capacity and in the event of a computer failure, process controllers can have desired values set by the hand. This system is expensive because individual controllers are provided in addition to the computer, but it can be an element of redundancy since the computer and controllers are working in parallel.

Direct digital Control (DDC) is achieved when computer is working directly as controller unlike CSC system where computer is working in parallel with the controllers.

3.5.1 Analogue Computer:
Analogue computers work on analogue parameters,
which continuously vary in amplitude. It is made up of a number of amplifiers, an input function generator, an output display unit suitably connected using a patch panel. Additional elements are provided for doing mathematical functions. Various non-linear units, stabilized d.c supplies and a number of potentiometer completes the system.

Previously analogue computers have served as a valuable aid for the design and analysis of control systems, but it has been rapidly replaced by digital computers because they take less space, are cheaper and are more reliable and faster.
Chapter IV

Development of Marine Automation

4.1 Introduction

The concept of a shipboard control system is not new, it dates back to the early years of iron man and wooden ships. During those early days, control was carried out through a relatively simple communication protocol; as the beat of the drum was heard, the oar was expected to make a positive stroke. The speed of the vessel was controlled by the frequency of the drum beat, with a little encouragement from the lash. Since then automation has developed to a stage where a crewless vessel has been tried.

In this chapter attempts has been made to describe present level of automation which are being used for shipboard automation. These will be useful in determining level of automation and selecting equipment for our vessels.

4.2.1 Main Propulsion Plant Control:

In most oceangoing ships one or two diesel engines each mechanically connected to a fixed pitch, or controllable pitch propeller, with or without reduction gearing. Propulsion direction controlled by changing direction of rotation of engine, propeller system; relation between engine power and speed depends on the propeller characteristics. These engines are
turbocharged in order to provide a higher unit output. In some cases mechanically driven scavenge pumps, or electrically drive auxiliary blowers are provided in addition, to ensure adequate air supply at low load, operating automatically as a function of engine speed.

The normal method of starting a direct coupled engine is to rotate the engine by compressed air to a speed sufficiently high speed to ensure compression ignition of the fuel. The sequence in which engine rotates is controlled by air distributors, one for ahead rotation and another for astern rotation.

In addition to selecting the head or astern starting air distributor, it is of course necessary to arrange the appropriate sequence and phasing of fuel pump cams, valve gear etc, which is normally achieved by rotating the camshaft relative to the crankshaft by sliding the camshaft axially relative to the value and fuel pump mechanism, thus bringing into operation the appropriate sets of cams.

Power required to operate control elements like engine reversing gears, starting air valves, revering gear box operation, propeller pitch operation, clutch operation etc is too high for convenient manual effort. To operate all above components power assistance is required and to in most of the cases compressed air and oil. In spite of this power supply assistance, control arrangements which are mounted on, or immediately adjacent to, the engine installation and operated by levers, handwheels, etc, are normally referred to as "manual" controls. In centralized control systems, controls are located at some distance from the engine/engines and to introduce automatic features, mechanical transmission by such levers etc, becomes awkward to arrange, and transmission of the signals and
sometimes the power, necessary to operate the actual control elements on the engine installation is more usually accomplished pneumatically, hydraulically, or electrically. More complicated control systems frequently use more than one of these media.

These types of simple engine systems imply manipulation in the appropriate manner of:
- the reversing mechanism;
- the starting mechanism;
- the governors speed setting and/or fuel pump control rods.

Propulsion plants may be controlled by very simple mechanical controls or by very complicated and sophisticated control systems, or by a variety of intermediate possibilities. The main distinctions are to be found in:

a) the way in which the control elements on the engine are operated, e.g. by manually-operated levers, by fluid powers, by electric actuators etc;

b) the extent to which automatic features are incorporated, for instance to control the sequence and timing of the various functions; and

c) the location of the normal control position, e.g. adjacent to the engine, at a central control position in the engine room, or outside the engine room - most usually on the navigation bridge.

The choice of possible features and permutations thereof is extremely large and the major decisions regarding the control system to be adopted for any particular installation depend, among other things, on:

- type of installation;
- type of engine;
- type and operation of the ship;
- need to safeguard the ship, and particularly
the machinery installation against the consequences of human error or ignorance;
- manning policy pursued;
- pursuit of efficiency, both in the operational and the thermodynamic sense;
- desirability of minimizing maintenance;
- requirements imposed by government and international legislation and by the Classification Societies;
- economic consideration.

As I have mentioned earlier, because of cost factor and proven reliability micro processor based control systems are becoming popular day by day. In fact now a days automation in the modern vessel can't be thought without micro processor based control system. Numerous remote control systems for main propulsion are available and selection depends on the number of control stand and mode of control. A modern (microprocessor based) propulsion control system perform the following functions including basic functions for which it has been designed like starting/shutdown, reversing, run up and run down.
- Engine start and programmed loading
- Engine stop
- Automatic quick transition in the critical speed range
- Thermal limiter insures a slow running up if cold engine.
- Run up program prevents too rapid from set point variation.
- Attendance of propulsion plant operation, fault alarms and automatic reduction in load or stop of the engine in case critical parameters like drop in
pressure of lubricating oil jacket/piston water exhaust temperature, cylinder liner temperature fuel limit occur etc.

- **Shut down protection/ emergency run/ engine step / crash stop function in case of critical condition if the vessel.**

- **Start failure function** protects the start air from being blown out in case of missed starts or other failures.

- **Start program functions** in two levels, normal and heavy, to ensure a safe start without unnecessarily stresses.

- **Ensure proper operation of engine with other main propulsion plant elements such as CPP and gear boxes.**

- **Over load limiter (fuel limiter)** protects the main engine from too high of torque

- **Manifold pressure limiter (fuel limiter)** protects the main engine against sooting.

- **Emergency stop makes it possible to stop the engine,** even if the bridge control system has failed

- **Manual upon adjustment covers 75-100% of full speed.**

- **Monitors the control system operation which includes passive control of the safety system.**

A typical black diagram of main propulsion control system (SIMORCS 51) designed by SIEMENS is shown in figure:-4.1. It enables remote control if the main propulsion engine (engines) including the speed control, controllable-pitch propeller including the pitch control from the bridge and/or engine control room and satisfies all the requirements of UMS class.

The control system is made up of components from programmable logic controller systems. Four input function generators provided to serve different tasks.
System design of Main Engine remote control system (SIMOS RCS 51)

SOURCE - SIEMENS

Figure - 4.1
for "Sea" or "Manoeuvre" operations of the diesel engine remote control system. The speed set value(s) are fed analogy in to the operating panels and transferred in series to the central station via the ET-bus. If the change of a set value is greater than a programmable limiting value, a short acoustic alarm sounds on the ECR-control panel. This changing impulse is active only when the bridge is on control. The active set value is displayed on the operating panels in 1/10 rpm. On the bridge panel a digital fine adjustment setting for a range of e.g. +/- 5.0 rpm is filled. Speed limit can be set on the ECR or bridge panel. A maximum fuel injection limit can be set digitally on the ECR panel with digital speed controller (SPC).

Any critical speed range is blocked in the ahead and astern direction or passed through the maximum rate-of-change. During run-down and run-up a special program ensures that the critical speed range is passed through more quickly e.g. cutting off the fuel supply until the critical speed range has been passed; respectively by measuring, if there is enough power output for the acceleration through the critical speed range. The parameters for the limit values, changeover points and set values can be assigned by the operator panel (OP).

The actual values of the system like engine speed, fuel rack setting, change air are detected through the control processor. The processor converts the detected values to dimensioned variables and presents them to the CPU.

The digital speed controller (SPC) measures the speed via fast acting angular rotation (incremental) sensors. That achieves direction of actual values e.g. between two ignitions, and also of the speed mean value.

The plan actual values can be displayed on the
bridge and ECR control panels by pressing push buttons or can be interrogated via the operator panel. All of the actual values are checked for min./max. and changes.

When operating in the automatic mode the main engine is controlled directly with the engine telegraph levers and all the necessary starting and reversing sequences and initiated automatically.

Starting and reversing are initiated semi automatically during electric-manual operation. The function of the engine control system depends on the type of control of the particular engine involved.

Up to three start attempts are made to start the engine. The first attempt is determined by the parameters of the set point value of speed start ahead or set point value of speed start astern, cut off speed for start air (ignition speed), maximum time for start air release and speed controller for giving booster injection during the start and stabilizing phase. Parameters like start-air interval between the start attempts, minimum shaft speed below which the engine cannot run, increased start set value (speed), increased cut-off speed for start air (ignition speed) and lifting charge air pressure characteristic curve can be set for the second and third start attempt.

Moving the telegraph from the stop position to ahead or astern triggers the appropriate solenoid valves and, if necessary, reversing the camshaft. The starting air supply is enabled as soon as reversing has been effected and the governor receives a preset "Starting set value" at the same time. The starting set value is then given a preset "Start stabilizing time" that is separately adjustable for ahead and astern which is followed by enabling of the ramp function generator.

Stepping is determined by the parameters rate-of-
charge, at which rpm is reduced at high speed and speed, below which fuel admission is immediately reduced to zero.

When the engine is running at nominal speed and the telegraph lever is moved to the "manoeuvre full" position, the engine speed can able a programmable speed, be reduced to that value with two selectable rates of change by means of the slowdown-program. Below the programmable speed set value (fuel index) is set to zero immediately.

The speeds and rates of change/break points of the program are also programmable.

When operating in the automatic mode the main engine is controlled directly with the engine telegraph levers and all the necessary starting and reversing sequences are initiated automatically. Reversing of the shaft rotation is determined by reversing speed for normal manoeuvering/crash manoeuvering. The permitted times are monitored for reversing of the camshaft and start air until speed passes through zero.

If a command is issued with the telegraph lever to reverse the engine while it is running, the program first sets the speed set value or fuel rack setting to zero, in the same way as for "stop" command. The reversing system is achieved as soon as the propeller speed falls below the present limit "reversing speed 1". When the reversing sequence has been completed, the engine is brought to reset with starting air and then started in the opposite direction. When reversing in the "emergency manoeuvre" mode, the sequence is activated using "reversing speed 2". Reversing speed and monitoring times can be programmed by the operator panel (OP).

Three run-up programs are available for ahead and
astern, which can be adapted to suit the individual requirements of the ship and main engine.
- Standard program, 3 separately adjustable rates of rise for run-up and run-down mode
- Emergency manoeuvre program, 2 separate adjustable rates of rise.
- Program for thermal run up: considering the temperature status of the engine, the lowest speed of the normal start program is moved towards rates of rise i.e. with warmed up engine faster rates of rise also at higher speed ranges are possible without thermally overloading of the engine.

The digital speed controller measures the speed via fast acting angular sensors. That achieves detection of actual values e.g. between two ignitions, and also of the speed mean value and facilities for instance controller action in the operating range of one cylinder. This speed controller concept works with two parallel controllers. A very fast P-controller acts at a parameterizable set value/actual value differential. The second P1 controller takes control during normal operation, thus changing fuel injection as little as little as possible respectively as much as necessary only. If an over speed occurs for half a revolution the emergency stop cylinder will be energized via a relay contact. This "op-over speed" detection is in addition to that provided by the safety system. The speed controller contains a function generator. Programmed into the function generator are loaded and charge air curves. The load curve is stored by a 3-segment-function generator and the charge air curve by a 7-segment-function generator. In the event of an "Emergency manoeuvre" both curves are offset. The magnitude of the offset are programmable. Misfiring detection system
notices misfiring if any and reduces engine speed without waiting for the increased exhaust gas deviation alarm. Automatic change-over at sea operation from speed control to fuel control is possible by preselecting on the operation panel, when weather condition should make that necessary. Thus continuous positioning of the fuel linkage is avoided and fuel is saved. Manual change-over speed control/fuel control is possible on the operation panel. In maneuvering mode the speed control is always activated. The engine is also protected against overload.

In the control system a Variable Injection Timing (VIT) function curve can be parameterized. The VIT-function can be integrated via a positioning controller to the pneumatic actuator. Positioning will be automatic depending on fuel injection.

Advantages of the automatic propulsion control system are:
- Proper selection of the system can simplify the installation
- High system availability
- Minimum maintenance
- Optimum maneuverability with low fuel consumption.
- Minimum start air consumption
- Maximum maneuverability in emergencies.
- Simple fault diagnosis.

4.2.2- Electrical Power Generating Plant Control:-

Electrical power requirements for modern motorships are generally met by three or four alternators having a combined power output of between 100 kw and 1.5 mw according to the size and service of the ship. The requirements for UMS operation requires automatic
The automatic provision of electrical power to meet varying load demands can be achieved by performing the following functions automatically.

1. Prime mover start-up;
2. Synchronizing of incoming machine with bus-bars;
3. Load sharing between alternators;
4. Safety and operational checks on power supply and equipment in operation;
5. Unloading, stopping and returning to standby of surplus machines;
6. Preferential tripping of non-essential loads under emergency conditions and their reliability when acceptable.

One such system capable of all these functions is shown in figure-4.2, the system is designed by NORCONTROL.

Each generator unit is connected with a Power Management Unit PMU. The PMUs are connected to a remote supervisory system, which allows the operator to initiate the same monitoring and control functions that can be performed locally. Communication between the supervisory system and each PMU is carried at an redundant serial lines. Interactive colour graphics mimic diagrams and a dedicated functional keyboard with roller ball in the remote operative station are used for remote monitoring and control.

Functional Description:

Automatic synchronizing is performed by the power management system. It selects which generator that shall be synchronized to the net. Then the appropriate PMU takes care of the speed control, checks that the voltage
A typical Power Management Configuration
and frequency deviation between generator and net is acceptable and finally gives the breaker a close signal when the phase is equal between the generator and the net. If synchronizing of any generator exceeds an adjustable limit, e.g. 1 minute, a synchronizing time-out alarm is given and the engine will be stopped. If there is another stand-by generator in the system, this will be started, synchronized and connected to the net.

4.2.3- Auxiliary Equipment Control System:

A diesel prime mover requires to be supplied with air, fuel, cooling and lubrication and, if it is to operate satisfactorily, the quantity, pressure and temperature levels of these must be maintained within limits prescribed by the engine design. These are called auxiliaries.

A large portion of routine watchkeeping tasks are concentrated with auxiliary machinery, and in terms of reducing work load, automation if auxiliaries is equally important. As requirement for unattended machinery space operation, these equipments operation has to be automated.

NORCONTROL has designed Data Chief Process Control Unit (PCU), a multipurpose computer unit for control and monitoring of different kinds of auxiliaries like:

- Single pumps and stand-by pumps
- Value control
- general purpose PID controller
- Compressor controller
- Purifier controller
- Boiler control
- Viscosity control
located in the propulsion plant.

Each PCU is an independent, self, controlled micro-
processor system which can function as a stand-alone unit or as an integrated subsystem of a larger system. It maintains a local database with the necessary parameters and channel-configuration for all the controllable units (valves, pumps, etc).

4.2.3.1- Auxiliary Boiler Control

An auxiliary boiler on a diesel engine vessel to cut-in to assist a waste heat boiler when the vessel is at sea or may operate alone when the vessel is in port. Steam demand may vary considerably and on occasion perhaps be zero. The boiler may then be arranged to dump steam or the burner management system may shut down the boiler.

Basic common operation of an automated boiler are lighting-up sequence and flame monitoring. When light-up is required, detected low steam pressure causes the fuel oil pump and heater of the boiler system to energize. High-temperature cut out will disconnect the heater circuit as soon as oil temperature reaches to the required temperature. When the fuel oil reaches a suitable temperature the low temperature cut-out will close the circuit and provide a supply to the forced draught fan. After a period of purging the boiler with air, the delay switch will operate to close the circuit and provide a supply to the solenoid-operated changeover valve. Fuel oil will be supplied to the burner and simultaneously a spark will be created at the burner ignitor. The timer in this circuit will disconnect the spark after a reasonable time and the light-up procedure will then have to be repeated. If a flame is established, however, this is sensed by a solenoid-operated switch. A photo-electric cell will de-energize the changeover valve solenoid in the event of flame failure. A number of safety trips are also provided
which operate to step the forced draught fan and change over the fuel to circulating. These are flame or combustion air failure, high steam pressure and low water level. A time delay exists in the flame failure shut-down circuit to enable initial lighting-up of the boiler.

4.3.3.2- Lubricating Oil System:

In the case of different engine components, the required cooling flow, and in the case if lubricating oil, the pressure required for correct bearing conditions is dependent in a continuous supply from the independently driven pumps. If the pressure in the system falls below a certain figure an alarm is essential and the stand-by pump should be started automatically. The system temperature must also be controlled. The amount of energy removed as heat from the jackets, pistons, valves and other designed components of the engine is of the order of 30% of the mechanical output, and the temperature can change very rapidly in these two cases, it is desirable to maintain a constant temperature at outlet from the engine, either by controlling the amount of seawater passing through the cooler. In order to ensure an adequately fast response to changes in engine power and to maintain stability, a "cascade" system is sometimes used whereby a detecting device in the engine outlet is used to reset a temperature controller in the cooler outlet so that the required constant engine outlet temperature is maintained. For start-up conditions most engines demand preheating. Steam heating are normally provided, control of which is automatic and integrated with the cooling control system using a split-range controller.
4.2.3.3- Compressor Operation:

Compressed air must always be available for the starting of main and auxiliary diesels, operating whistles, pneumatic control devices, etc. Its provision, usually by two or three compressors, can be ensured by two methods of machine operation. These are on-off pressure control and continuous running with loading and unloading. In each case the machine must be fitted with automatic unloader to ensure that it starts up unloaded, i.e. no air is delivered. Once running at speed the machine will "load" and begin to produce compressed air. An automatic drain must also be fitted to ensure the removal of moisture from the stage coolers. A non-return valve is usually fitted as close as possible to the discharge valve of the compressor to prevent return of airflow. It is an essential fitting when unloaders are used.

4.2.3.4- Control of Fuel Oil Systems:

To maintain a continuous supply of fuel to a ship's main engines involves a series of operations which are ideal for the application of automatic control. The usual sequence of operation is as follows. Oil is first drawn from the ship's bunkers to a dirty settling tank, where some of the impurities settle by gravity. Oil from the tank is taken as required for treatment in the fuel oil separator, after which it is passed to a clean oil settling tank. The clean oil is then drawn-off by the engine fuel pumps, being first passed through viscosity control equipment. The transfer of oil from bunkers to the dirty oil settling tank is a relatively infrequent requirement, depending of course on the tank capacity and the engine fuel consumption. It is usual to provide
the engine fuel consumption. It is usual to provide simple remote manual controls for the valves and transfer pump, so that the operation can be accomplished from the control room when necessary.

4.2.3.5- Fuel Oil Separator:

Operation of fuel oil separating plants have, in the past, called for much manual control and frequent shut-down to clean machines and remove accumulated study. In most of the ships built after 1975 the equipment is entirely automatic in operation. Control systems vary in detail according to the design of separator to which they are applied, but a typical fully automatic system would include sequential starting and stepping of the separators, automatic discharging of sludge, an internal alarm system, and clean oil tank level control.

4.2.3.6- Fuel Oil Viscosity Control:

For many years it has been customary practice to heat oil fuel by steam or electrical means, to maintain temperature for efficient fuel injection. It has been usual to supply the fuel to the engine at a fixed temperature, but the heart of the problem is the viscosity of the oil rather than its temperature. With the very heavy oils now used in diesel engines, the relationship between temperature and viscosity varies to some extent, and most operations now employ controllers which regulate fuel temperature according to direct measurement at viscosity.
4.3 Navigation/Bridge Control:

Navigation depends primarily on knowing the position of own ship. Associated with this is the requirement to know the position of fixed and moving hazards that may affect the planned movements of the ship.

One of the oldest automatic devices on the bridge is the automatic helmsman. From the original electromechanical system it has progressed to a form of microprocessor based control. Provision is made to insert ship condition, sea and weather quantities and these are computed to determine the most economic use of the rudder required to maintain the chosen course. The basis of each set of integrated navigation equipment are the sensors. These include:

- the gyro compass,
- the rate gyro,
- the magnetic compass,
- the ship's log,
- the radar,
- the navigation receivers.

They provide the information:

- heading (magnetic north or geographical north)
- the ship's rate-of-turn
- the ship's speed
- the position - and distance information of the objects in the current sea region, relative to the ship's position,
- the ship's position in latitude and longitude.

The gyro compass is a heading sensor. In the north, indicating system compass, two gyro compasses are coupled together and located in a closed sphere. This
The rate gyro equipment is an important navigational aid. It measures the rate-of-turn of ships if all sizes already in the beginning stages if an initiated manoeuvre. In inland navigation the rate-of-turn indicator equipment, in conjunction with the radar equipment, is required because it indicates heading changes under poor visibility conditions.

Global Positioning System (GPS) is a highly accurate satellite navigation receiver supplies the required position data of the ship all over the world, independent of the weather and round the clock.

In most automated vessel this has been integrated in the navigation and steering control system. GPS receiver computes many navigational data which are relevant for the ship for precision position finding, track control suitability.

The automatic plotting table is an important component of an integrated navigation system on a modern bridge. It relieves the navigator from the very time-consuming task of continuously transferring the ship's position from the latitude and longitude values determined by the position receiver into the sea chart. A microprocessor computes the current position of a light-spot from the position data. Controlled by actuators, it thus shows the current ship's on the sea chart. Up to 200 sea charts can be called up out of its working memory with their most important identification characteristics. If the automatic plotting table is combined with an adaptive course and track controller, it can be used as track planning system. In this function, it is a planning - and storage unit. Few
selected routes and ways points planning according to the design of the system, stored in the working memory and called up as needed. A functional diagram of an automatic chart table designed by ANSCHUTZ is shown in the figure: - 4.3.

In Navigation - and steering control system, if the skill of the helmsman together with the experience of the navigator are in the spotlight in and manual steering of a ship, in automatic steering, intelligent steering components take over much of the optimizing if the steering process. To do this, all the sensor data is taken up and processed in a microcomputer for the following units: -
- Digital autopilot
- Adoptive (self adjustable) autopilot
- Track controller
- Automatic plotting table
- Heading managing reference system
- Steering control system
- Navigation information system

The conventional steering control of the ship takes place with the manual steering elements. These include the:
- non-follow-up steering elements handwheel, tiller, push-buttons, etc.
- follow-up steering elements of the same construction, in conjunction with follow-up steering amplifiers,
- take-over systems for linking all around steering positions on the ship. The priority rating of the different steering positions is programmed in a remote steering selection, so that authority cannot be granted unintentionally.
Functional diagram of an automatic chart table designed by: ANSCHUTZ

Figure - 4.3
- Override system, so as to be able to intervene manually in the automatic steering process.

Digital autopilot and adaptive autopilot are the main components in the automatic steering. Digital autopilot is also a semiadaptive digital autopilot and gives following functions of a conventional autopilot.
- Heading control with gyro compass heading signal,
- Adjustment to the ship-and rudder-specific circumstances if the ship,
- Rudder limit setting,
- Monitoring of the heading reference signal against a second (redundant) heading sensor (e.g. magnetic compass).

According to today's requirements, it also does the following standard operating functions:
- Adjustment to the current ship's speed,
- Steering of the ship with rate-of-turn controls,
- Incorporation of the magnetic compass course,
- Upgrading of the digital autopilot to track controller,
- Connection of several digital autopilot operator units.

The adaptive autopilot contains a stored ship's model as well as the resulting optimal steering characteristics of the ship. The ship-specific data such as ship's length, tonnage, normal speed, etc., are set when the autopilot is set in operation. Variable parameters such as load conditions, draught, etc., are entered by hand. Microprocessor based adaptive autopilot continuously determines the deviations from ideal condition, checks whether the desired results are
achieved and corrects the commands to the steering control equipment automatically. In doing this it takes all set parameters into account. Besides all basic and extension functions which are carried out by the digital autopilot, it offers, in addition to the "Rate of turn" steering mode, the steering mode "Radius", i.e. a radius can be entered in sea miles and thus a precise circle can be steered. The software module makes the adaptive autopilot into an "adaptive course-and track controller", with which track control between 3 way points is possible.

Together with the attached sensors, heading reference managing system combines the following important performance characteristics in one system:

- Selection of the heading reference sensors gyro compass/magnetic compass,
- Correction of the speed error of the gyro compass,
- Correction of the magnetic variation and the deviation,
- Transmission of the corrected sensor data to the connected repeater units,
- Continuous digital indication of the magnetic compass course,
- Monitoring of two connected heading sensors according to given tolerance,
- Automatic synchronization of the heading receivers in case of switching to different heading reference,
- Central synchronization of all connected repeater units is the operator unit,
- Automatic or manual input if the speed,
- Optical and audible signalling of error messages,
- Output of the valid course and the ship's speed via a serial interface.
- Connection of heading reference (torque) receivers.
The above equipment can be extended redundantly in various stages of development. In the most simple stage as magnetic compass/gyro compass equipment it is possible to switch between the gyro compass course and the corrected magnetic compass course at any time.

Navigation information/Nautical display system is the central navigation work place of modern bridge system. It gives comprehensive information, essential requirements of the navigation. Representation of the navigation - and manoeuver - technical data takes place on a high - resolution graphic colour display in analogy and digital form. The information for course control, track control, trend representation, engine data, propetter data, battery data, fuel level indicator, etc according to the design can be called up via a separate operator tableau arranged according to operating factors. In addition, warning - and alarm messages are given by the connected sensors.

One such system capable of all above mentioned modern integrated bridge system designed by ANSCHUTZ is shown in figure: - 4.4.

4.4 Integrated Control ship /Ship of the Future / one Man Bridge Ship:

If the definition of the "Bridge" is defined as "the position in a ship from where the command of operations is performed", then it can be accepted that its function in merchant vessels has remained unaltered since its inception. What has changed is the extent to which the actual performance of the total command operation is controlled from that one position. The advent of modern electronic microprocessor technology and increased economic competition within international shipping, in combination with high bunker and crew cost
Integrated Bridge System
Source - ANSCHUTZ

Figure - 4.4
has integrated and correlated various ship-operational functions on the bridge.

In the mind of many naval architects, shipowners and electronics manufacturers the idea of the integrated ship control system was taking shape some 30 years ago. A step in this direction was taken in 1967 when 20,000 GRT bulk carrier "Sugar Crystal" was fitted with bridge console in a configuration. The vessel console was more of congregation than of integration and was still an assembly of discrete units. But in the same year, 1967, Norcontrol of Norway, in collaboration with the Norwegian Ship Research Institute, Det norske Veritas, and some influential shipowner, embarked on a study into how the then burgeoning computer technology could be employed to correlate data derived from a number of individual navails and thus present the bridge watchkeeper with a summarized but complete picture of voyage progress. Trails on the cargo ship "Taimyr" were followed in 1970 by the first commercial installation of what later became Norcontrol's highly successful Databridge system, abroad the tanker "Thorshard". Since then integration has become the watchword of the maritime industry, and today the concept has gathered such momentum that little else seems to occupy the pages of the technical press or the minds of ship designers. The aim of the pioneers was to harness computer technology to make navigation more accurate and safer. At the same time, they helped to ease pressure on the watchkeeping officer and reduce vessel operating costs by boosting fuel efficiency and reducing voyage duration. Today, the fundamental principle remained the same but horizons are broader and ambitions much grander.

Today, an integrated ship is not simply of
integrated navigation, but of integrated ship control systems, in which the functions of
- navigation,
- machinery monitoring and control
- cargo operations,
- ballasting and trimming,
- communication and
- all other ship-operational systems, are combined in a single area/bridge.

Various countries have used the above technology according to their techno-socio-economic condition and named the project as "Ship of the future", "Pioneer ship", "Efficient Ship", "Integrated ship" with a goal of "One man bridge". The concept of the one man bridge operating twenty four hours a day at sea is still in the experimental stage. IMO in its circular no MSC/566 of 2nd July 1991 authorised trials on one man bridge operations 24 hours a day under certain strict guidelines. Historical background on the trials of one man bridge system is given in Appendix:1.

Generally speaking there are four sub-systems making up the Integrated Control system
1- Bridge automation system.
2- Propulsion and Engineroom automation system.
3- Cargo handling system.
4- Ship Administration system.

An integration system allows information exchange between different computer-based monitoring and control system on board sea-going vessels. Information can be passed between any of the operating areas by a direct connection or a local area network (LAN). This enables the coordination of data for processing of available
Data is displayed on video display units at workstations which are appropriately located around the ship. All available data can be accessed and data may be input at any workstation.

A typical Integrated Ship Control system designed by NORCONTROL is shown in figure:-4.5.

Where all systems are connected in a LAN. Internal and external data transfer to administrative computer on LAN. Each system in the network can get access to data from another system through special communication programs installed in every station interfaced to the net. The network allows for point to point connection and broadcasting of information to several nodes or groups of nodes.

In the configuration, there are three level of signal processing and information.
1. Basic signal processing in Local Processing Station.
2. Intelligent signal processing, information distribution and not communication in Master Control Units (MCU)

Flexible system configuration including integration to the ship's administrative PC network.

Individual sub-system are shown in the figure:-4.6. The system complies fully with the NCA Integrated Ship Control System with data exchange on LAN. Communication with other systems with LAN - Ethernet with TCP/IP protocols.

Following functions are done by the integrated navigation system:
- Presentation of Radar signals
- Arpa functions
Ship Administration System
Integrated Navigation System

Local Area Network

Engine Room Automation System
Cargo Handling System

Main Systems Connected to NCA LAN

Integrated Ship control system
Source: NORCONTROL
Figure: 4.5

Dual Net Solution

Individual sub-system
Source: NORCONTROL
Figure: 4.6
- Presentation of navigation information
- Position Estimator
- Rate Planning/Chart editing
- Course/Speed Control
- Conning Display
- Tracking function
- Reports on printer and/or display
- Interface to fulfill requirement for total integrated ship control system.
- Stand-alone and integrated configuration.

Engine room automation function:
- Remote monitoring of temperature, pressure, flows, levels and other process variables.
- Remote monitoring and control of power plant including power management.
- Remote monitoring and control of stand-by pumps, valves, regulators, fuel transfer system and bilge pumps.
- Operation through mimic pictures with direct addressing of process variables with tracker ball.
- Functional operator panel with direct addressing to functions.
- Reports on printer and/on display.
- Possibilities for both centralized and/or local operation.
- Interface to fulfill requirement for total integrated ship control system.
- Engineers watch calling system and navigators safety system.

The Level Gauging and Cargo Handling System does following function:
- Control of pumps, valves and sequences with special logic.
- Start/stop and cavitation control of cargo pumps, ballast pumps and COW pumps.
- Alarm and monitoring with log functions.
- Automation discharge and stripping programs.
- On-line load calculator.
- Operation through mimic pictures with direct addressing of process variables with trackball.
- Function control panel with direct addressing to functions.
- Reports on printer and/or display.
- Input from cargo and ballast levels.
- Interface to tank radar sensors from several manufacturers.
- Possibilities for both centralized and/or distributed operation.
- Interface to fulfill requirements for total integrated ship control system.

Ship Management System:

It's a very new and modern concept in ship operation. The system computer permits direct and fast information access between ship, shipping company and agents for efficient planning, organization and implementation of strategic and technical ship's operation. The communication module permits data to be exchanged in protected mode, at high transmission speeds and, thus, at lower cost than conventional system. It permits following information for example to be extracted or transmitted directly via satellite and PTT network:
- Complete cargo configuration.
- Order transactions resulting from the servicing and maintenance modules.
- data of the ship's log stored via electronic log management.

In this system access to the databases of the ship, shipping company or agents is protected against access by unauthorized persons. It is also possible to issue communication jobs or check pending jobs directly via the communication module provided in the standard operator interface.

In general shipboard management computer is a microcomputer system based on the MS DOS/C DOS operating systems in use throughout the work and can be performed following internal and external jobs:
- SATCOM communications.
- General housekeeping on board
- Maintenance program
- Spareparts management
- Loading calculations
- Operating system.
- Navigation support/Deck log-book
- Engineering support/Engine log-book
- Process application/Trend program
- PC application/work processing program languages.

The German government, in collaboration with shipowner, shipyards, institutes, universities, industry, model tank establishments, classification societies and trade union took up a project "Schiff der Zukunft" (sdz- ship of the future) to increase economic ship operation through reduction of operating costs. German shipbuilder HDW provided the project management for the total project. First vessel of the project "Sdz "Norasia Samantha" was launched successfully in 1985.

The results of the project is shown in figure:-

4.7. Aims of the project are:
- reduction in fuel costs
- reduction in personnel cost
- increased safety is shown by introducing different technology and equipment.

(a) Reduction of fuel costs:

This was achieved by taking different technical measures in the ship and machinery plant (figure-4.7).

Symbol 1 - Asymmetrical aft body
Symbol 2 - Large propeller diameter
Symbol 3 - Wake distribution nozzle
Symbol 4 - Fuel saving diesel engine
Symbol 5 - Shaft generator
Symbol 6 - Scoop cooling system
Symbol 7 - Centralized bunker system
Symbol 8 - Advanced fuel preparation
Symbol 9 - Sludge oil burning
Symbol 10 - Fuel analysis.

Combination of asymmetrical aft body, screwed propeller of large diameter and wake distributed nozzle fitted on a vessel gives large power savings to the propulsion engine and initiates no propeller vibration. Due to the power saving measures at the ship's aft body a substantial derating main engine (lowering the mean effective pressure while the ignition pressure is kept on a high level) down to a very economical point is possible. Since the engine is derated it can give only one to two grams of fuel saving per horsepower if an Eta booster or a turbo compact system (TCS) is fitted, which cannot pay back the necessary high investment. Therefore, the more effective turbocharging system is the solution. Proper main engine arrangement from right aft of the main engine for container stowage. With this
Prototype "Ship of the Future"
Applying the Results of the Research Project "Schiff der Zukunft" (SDZ)

1-10 Fuel Saving Measures
11-20 Crew Reduction
21-23 Increased Safety

MS "NORASIA SAMANTHA" and MS "NORASIA SUSAN"

Ship of the Future
Source - HDW
Figure - 4.7
arrangement slow running long stroke modern engine for low propeller revolutions can be fitted.

There are three economical modes of electric power generation. They are:
- Diesel engines driven by heavy fuel
- Shaft generator
- Turbo generator driven by steam from the exhaust gas boilers.

For the installation of a turbo-generator the power of the main engine on these ships can be too low. Therefore the only decision is to choose between heavy fuel auxiliary diesel engines and a shaft generator. The difference of the overall operating costs between heavy oil driven diesel generators and a shaft generator is not very large. Considering maintenance saving shaft generator is the best solution. This also can be possible to run the vessel as a one-fuel ship during sea service.

Another remarkable item is the scoop type cooler. With this cooler it is possible, in connection with a central fresh water cooling system, to re-cool the whole fresh water cooling without operation of the main sea water cooling pump. The speed of the ship draws the sea water through the scoop cooler. A small amount of energy propulsion energy can be spend for this, but it is negligible if inlet and outlet are placed in the right positions. Except manoeuvering no electrical power is for sea water cooling pump and naturally there is less maintenance work.

If the fuel is stored in double-bottom tanks, the amount of available steam is not sufficient for heating purpose as because increased efficiency of diesel engines today has led to much lower exhaust gas temperature and thus to a decrease in the performance of
the exhaust gas boilers. Expensive fuel has to be burnt in the oil-fired boiler to balance the shortage steam. However, if the fuel tanks are installed in a central position in the ship, forming block tanks with a relatively small area in contact with the sea, even the low amount of steam produced by the exhaust gas boiler is enough to heat the fuel.

Approximately 2 to 3 percent of the bunkered fuel oil will accrue as sludge during necessary cleaning process. This sludge includes a large amount of water which is not possible to segregate by gravity. There are two legal possibilities to get rid of this sludge - either by pumping it ashore or by burning it in the boiler. Because of the water content in the sludge a lot of expensive diesel fuel has to be burned in addition for burning sludge oil. HDW developed a plant and installed in these vessels which evaporates the water from the sludge. So, on one hand no additional fuel oil is necessary to burn the sludge and on the other hand heat energy can be gained during burning. The vessel is also equipped with most modern fuel treatment plant.

All above measures has reduced fuel consumption by 25 percent as compared to a conventional vessel.

2 Manning Reduction:

The plant and equipment arranged in these vessels in such a manner that number of crew could be reduced in these vessels substantially without increasing workload and compromising with safety. Some of the examples are:

Symbol 11 - Communication Center
Symbol 12 - Ship Operation Center (SOC)
Symbol 13 - Board Management Center (BMC)
Symbol 14 - Computerized Monitoring Plant
Symbol 15 - Board Computer
Ship Operating Center (SOC):

To run the ship with one-man watch operation, the conventional bridge is modified into a ship operation center (SOC). A high grade of automation and the installation of newly operational concept opened up the possibility to run the vessel from pier to pier with only one man on watch. All monitoring and control tasks is focused on the single watch watchkeeper. The control and monitoring of the engine plant is also transferred to SOC. The tasks to be performed in the SOC are assigned to particular sites on the basis of time and motion studies. This led to the arrangement of each working space for:
- Command
- Engineering and
- Planning

From the command position, one man is in charge of all operational and monitoring functions. Due to the all-round view design of the SOC this man can watch the surrounding sea without leaving his seat. All necessary information displays and operating instructions are graphed around him in the latest ergonomical layout.

Special equipment is also developed during research work for the SOC and filled on board. This includes:
- radar equipment with constant digital display and daylight visibility.
- course controller for automatic ship steering along a pre-selected course.
- determination of the required course by the integrated navigation system that provides the necessary information for the automatic pilot.
- position monitoring by the integrated navigation system that shows the ship's exact position on the chart plotting table by a running light point.
- computerized information and monitoring system treating all arising alarms in a way which allows non-technical persons to react properly.
- navigation display showing graphically the most important environmental conditions such as wind direction and force, etc, and
- heavy weather damage avoidance system which judges the additional strain put on the hull by heavy seas.

Board Management Center (BMC):

In these ships, the engine control room no longer exists, as all monitoring and control for engine plant has moved to the SOC. But, the SOC is unmanned in the harbor. So, creating a BMC in the common entrance area of the deckhouse and the engine room provided an almost optimum solution for all requirements. All information about the systems total ship is available here either from the information and monitoring systems or from the manuals. Maintenance crews and visitors can be received here without disturbing ships operation. Manpower saving aspect of the BMC is greater.

The distribution of tasks between the SOC and BOC is shown in the figure-4.8.

Automation:

The major position in the labor saving concept is
taken by the high degree of automation. This is mainly achieved by a highly intelligent computerized information and monitoring system. The "brain" of the system is two separate, redundant computers communicating with a number of sub-station and colour displays. All data processed by the alarm is displayed in columns, diagrams, curves, etc, for easy understand. All alarms are supplemented by decision aids in clear wording. This system allows the monitoring of all auxiliaries on the screens and, the operation of a number of pumps, valves, etc, which can be actuated via the displays. This means that the engineer can choose the respective system from a menu on the screen and then initiate the necessary operation of a pump or a valve by touching the respective unit with a light pen. The flow of the medium in the system is shown in changing colours.

Besides this system, a special computer is installed for onboard administrative work, such as loading calculations etc, as well as for maintenance programs.

Maintenance Saving Engine room Layout:-

The over all layout of the engine room and the arrangement of all equipment arranged in such a manner that even with a reduced crew a large amount of maintenance and repair work can be carried out by the crew itself. According to the newly developed transport concept, most important items in the engine room are the clear transport ways leading around every deck of the vessel. To avoid the manpower-absorbing the often dangerous way of hoisting parts in the engine room by tackling or pull lifts, a crane is able to reach nearly
Ship Operation Center
Source - HDW
Figure - 4.8

NAVIGATION
ENGINEERING
EXTERNAL COMMUNICATIONS
OFFICIAL DOCUMENTATION

SHIP OPERATIONS IN HARBOUR
FAILURE ANALYSIS
MAINTENANCE
BOARD ORGANISATION CARGO
ADMINISTRATION
EXTERNAL COMMUNICATIONS IN HARBOUR

DIVISION OF TASKS SDC - BMC
every part of the engine room. A lift is installed for the vertical transport of the trolley with its load. This allows movement of parts from the foremost corner of the double-bottom in to the workshop by one man.

Crew accommodation:-

The vessel is designed to reduce the influence of the negative environmental factors on the crew as far as possible by a new layout of the living quarters: narrow corridors have given way to open spaces allowing freedom of movement, and a neutral leisure area with communication center is intended to prevent tensions arising among crew members. An extensive sports area is also provided.

(c) Safety:

Sdz type vessels are designed to carry a free-fall lifeboat. This is a closed boat easily accessible from the accommodation and launched in free fall from a ramp equipped with a newly developed radio station able to transmit position data by an integrated navigation memory system. Distress signals are automatically transmitted on shipping and air distress frequently.

With all measures mentioned above, "sdz" type vessel can be operated by 12-man crew. It is obvious that a vessel with such advanced technology must be more expensive than a conventional one with a crew of 24 men. According to Mr. K.H. Paetow of HDW, on the basis of today's fuel oil costs and the wage cost currently valid for the crew of ships flying the German flag, the additional money spent in the higher investment will be amortized within four years.
4.5 Condition Monitoring and Knowledge Based System/Expert System:

Reliability and availability are the key points for the economic ship operation. A high level of availability of an equipment depends upon its condition being known at all times in order to take necessary action for maintenance.

Corrective maintenance is carried out after a serious defect or sudden failure has occurred. Preventive maintenance is done with the extension of reducing the probability of reaching the limit. Preventive maintenance can be separated into:
- Scheduled maintenance, based on statistically pre-determined intervals (meantime between failure)
- Condition-based maintenance carried out when qualified pre-described criteria (condition parameter) reach limiting values.

On one hand corrective maintenance may be the intended maintenance strategy, the greatest part of all maintenance on a marine equipment is directed towards the prevention of failure. On the other hand, within the limits of safe operation, unnecessary preventive maintenance should be reduced or avoided. The need for a better and more cost-effective maintenance strategy
has led to the development of condition-based maintenance systems.

The decision on when to carry out maintenance is based on measured quantitative information (condition parameter) on the deterioration of components during normal running equipment/engine. The condition analysis need to contain following elements:

- Evaluation of the present condition and if the change since previous analysis,
- Finding the cause of this change (diagnostic)
- Estimating the future condition (trend analysis)
- Evaluate the consequences of continued deguration
- Decide on process control actions to be performed to kill irregularities and failure development
- Predict improvements which could be obtained by maintenance work.

Condition monitoring can be obtained from the parameters of the main engine:
- Thermal load monitoring (exhaust valve, cylinder cover and liner)
- Combustion monitoring (fuel oil quality, fuel oil pre-heating temperature, fuel oil impurities-water, condition of injection equipment)
- Cylinder Pressure Measurements
- Piston Ring Monitoring
- Air/Exhaust Gas System (efficiency of turbo change turbine, efficiency of turbocharger compressor, pressure drop across cooler)
- Bearing monitoring

Condition Monitoring of Turbocharger:-

Turbocharger efficiency is important. Reduced efficiency gives less air throughput. This leads to
higher thermal load on exhaust valves, cylinder cover, piston and liner. It was observed that there is a correlation between its RPM and efficiency. The fouling of the air and exhaust system (in pipes, diffusor, nozzles and compressor and turbine rotor) reduces both the turbine and the compressor efficiency. The RPM is reduced simultaneously. Therefore the deviation between actual RPM and reference RPM as condition parameter can be used. Accordingly a mathematical model/program can be developed.

Cylinder Pressure Measurement:

The cylinder pressure measurements have to be synchronized with the crank position. Thus a crank angle maker has to be used. An optical angle maker has to be used. An optical angular position encoder is chosen. A special coupling that is torsionally stiff but literally flexible is made to link the coder to the crankshaft. The encoder is mounted at the end of the engine.

The encoder has two output lines. One gives a pulse train with one square-wave pulse every $\frac{1}{2}$ degree; the other gives one square-wave pulse per revolution. The "one per revolution" pulse is used to mark TDC position of each cylinder.

The pressure sensors used are designed for continued measurements. The signals from the sensors are digitalized in a very fast analogy to digital converter (ADC).

Knowledge based or "Expert based" system provides ship operators with a valuable tool for achieving maximum operating efficiency with minimum down time and minimum
maintenance and repair cost. It is suitable for shipboard as well as shoreside application and provides facilities which ensure smooth and trouble free operation of main diesel engines.

The economic operation of a ship depends on numerous factors, the most important of which are the operating reliability and availability of the main engine. A high level of availability depends upon the engine condition being known at all times, so that any necessary maintenance and repair work can be carried out at the most suitable time in accordance with the ship's sailing schedule. Due to the wide variety of parameters which determine the loads and stresses to which an engine is subjected, routine maintenance and repair intervals based on statistical methods are today no longer the best solution, particularly in view of the costs involved.

Normally a personal computer is introduced as a diagnostic tool for the monitoring and maintaining of the engine. Basically, it provides automation of the performance evaluation and general operation procedures documented in the engine operational manuals. With the implant of the know-how of an expert operation appraisal engineer, it thereby forms an expert system.

It is a performance analysis software program and can be used in a PC with MS-DOS or PC-DOS operating system normally it required 2 to 2MB hard disk space according to the program. The program is matched with the make and type of the engine. MAN B&W has developed such a software program for their turbocharged diesel engines and named as Computer Aided Performance Analysis (CAPA) performance. It gives full menu control effected by means of a main menu, and pull down and pop-up menus, where the requested functions, kept in plain text, are
selected by means of a highlighted letter or by positioning a selection bar via the keyboard. An electronic system manual is clued, and full support is provided by on-line help pop-up windows. In this way the CAPA performance programme can perform at considerably higher levels of expertise. The CAPA program works as an off-line system. The engine performance values required for diagnosis are read off the engine's normal monitoring system, and are thereafter entered into the computer for subsequent computation and analysis. The program generates a set of calculated performance parameters corrected to the standard ambient conditions. The corrected values are compared to reference curves, and deviations from the reference curves are calculated. From the data, the expert system extracts and shows those parameters which exceed their maximum limits of variation. Furthermore, through fault and matching pattern procedures, the expert system generates maintenance advice about the components most likely to cause problems, and gives recommendations as to corrective measures to be taken.

4.6 Marine Simulator:-

Due to extreme economic competition in shipping and at the same time technological development, new complex equipment and ship types are constantly being introduced. Artificial intelligence has been introduced and is going on board ships, Harbor turnarounds are now counted by hours rather than days, and at the same time reduced manning levels put greater responsibility on those left onboard. Tight international conventions and strong competition demand greater know how and efficiency from everyone involved. Public awareness in matters of
environmental protection leave little room for error of judgement, adding more strain to an already stressful situation.

These new trends drastically increase the need for training. Refresher courses, certificate renewal and customer designed programs for the maritime industry is keeping schools and training centers busy. At the same time new technology has made it possible to simulate all aspects of ship operation. Visual systems technology has made realistic out of the window views available. Better hydrodynamic models recreate all the complex behavior of ships. Smaller space requirements and efficient implementation of new cost effective technology make these systems available to most users. Simulators meet all above criteria. A simulator can compress years of experience in to week. Mathematical models of physical systems can be solved by using differential equations. The use of electrical analogues enables the representation of the equations and their analysis without actually solving the mathematics. Simulation is usually considered to be representation of individual physical items in a system by computing elements. The inter connection of the computing elements is the same as in the simulated system. A feedback control system can then be examined with respect to the effects of varying any individual parameter. An initial attempt at system simulation might deal with a heat exchanger system such as that for a jacket or piston water cooling on a diesel engine. The techniques of simulation have now progressed to the extent that every single item in a ship's machinery space can be simulated. These systems can further be made to interact with another to produce, in every respect, the complete range of activities that may occur
during an engine room watchkeeping period. The physical equipment used for the operation and control of the ship's machinery is identical to the real thing. Only the engine, its associated systems and auxiliaries are modelled in an engine room simulator. The control room therefore is life-like and realistic, even to the point of having introduced the appropriate noises.

Simulator training has over the past years proved to be an effective training method, especially where an error of judgement can endanger life, environment and property. Ship simulators can be of Bridge simulator, Engine room simulator, Cargo handling simulator. A bridge simulator can offer a complete line of:
- ARPA training
- Radar Navigation simulator
- Ship Handling simulator
- Vessel Traffic simulator
- Instrument simulator
- Multi Bridge Visual simulator.

Cargo handling simulators can improve knowledge on cargo pumps, gear and lines, tank cleaning, crude oil washing, ballasting, pollution control system, intert gas system, vapour emission control, hull cleaning etc.

An engine room simulator normally comprises an engine control room, a machinery space and instructor's room. A digital computer forms the heart of the unit and various dynamic models describe the various process within the plant. These models can be interconnected in many ways and can be adjusted to vary the plant conditions.

The machinery control room houses the main switchboard and the control console. The main switchboard contains the generator synchronizing equipment to simulate power generation and distribution. The control
console has two separate sections, which house the alarm displays and the remote control system. The instructor's room is separate but has a view through windows of the control room. A communicating console is provided to enable inputs to the control room equipment. The engine room is another separate space which contains panels or boxes to represent the simulated units. These panels provide indication, can be reset if the unit is considered to have a simulated failure, may be "repaired", or provide some manual operating features. The trainee is required to visit the engine room at intervals to undertake these various tests according to the simulated condition requirements. Mimic panel displays are provided in the control room and engine room to give process details and fault indications. Engine room simulator can give training to fulfill following needs:

1. Maintenance training
   - supervision
   - procedures
   - handling

2. Operator training
   - principles of operation
   - control the process
   - rule based sequences

3. Team training
   - co-operation training
   - form a perfect team

4. Decision training
   - give a total overview
   - implement actions to reach a defined goal
   - make correct decision.

The different training can be implemented on different training levels:
Basic operator training
- Preparation for getting underway.
- Manoeuvring to open sea.
- Steady steaming.
- Manoeuvring in to harbour.
- Finishing with engine.
- Operation of auxiliary boiler and cargo turbines.
- Responding effectively to abnormal and emergency situations.

Advanced operational training
- How will an engineer react when faced with serious problems.
- How will a crew operate together when an abnormal situation develops.
- How can errors within the system be traced and corrected.
- How can the engine room system be restored to normal operation.

Economic and optimising studies:
- How to judge the performance of various components.
- How to differentiate between external and internal causes of a deterioration occurs on a given component, how much will this affect the overall fuel economy.

Besides these, it can also be used for research, investigation, ship design and other various marine uses. Simulator training is now recognised by IMO and the regulatory authorities and usually results in exemption from some period of sea-time. In some countries it is also used a tool for skills competency judgement.
4.7 Programmable Controller:

In automation there are two types of controllers are used:
- wired
- memory programmed controller.

In wired controller switching elements are solidly connected. They are also called relay logic. In this type of controller every change of function has to be done by rewiring the controller and switching elements.

In programmable controller (PC) the function of the controller is stored in memory and depends not on the connections of hardware (switches, relays, contacts etc.). The hardware is connected to the inputs and outputs of the programmable controller. The input and output signals are combined by the program stored in the controller. Whenever a change of function has to be done, only the program has to be changed.

Before a programmable controller is able to control a process a program has to be written in a special language and entered in to the controller. This program is written by programmer in a computer with a special software package. The software supplies the user with a powerful tool to enter his program in a convenient way and convert it to controller's understandable language.

It is a digitally operating electronic apparatus which uses a programmable memory for the internal storage of instructions for implementing specific functions such as logic, sequencing, timing counting and arithmetic to control through digital or analog input/output modules, various types of machines or process. PCs have been available for over 20 years, but the advent of the microprocessor provided both the
incentive and the means for development of a new series of PCs with added capability.

Working principle:

The programmable controller works basically as a sequencer when used to automate a shipboard plant. It first senses the input conditions of interest, then solves the logic equations programmed by the user based on the current input conditions. It then sets the required output actuators to provide action as dictated by the solution of the logic equations. The block diagram of a PC in Figure:-4.9 shows the four main functional blocks.

Input:

The input block allows the sequencer to sense the machine input parameters. These may consist of operator switches used to set up and select modes of machine operation and for starting and stopping the machine operation, limit switches used to sense position or presence of a part, and other sensors or switches used for safety or fault monitoring. In short, any external parameter which must be provided to the controller from it to make the proper decision when running a machine is provided through the input block.

Sequencer:

The sequencer block performs the operations of timing, latching, and control that hardware logic does, except the operations are done with programmable solid-state logic rather than with discrete hardware components. The sequence logic is basically digital codes using the digital logic signals.

Programmer:

The sequencer is controlled by a user-defined program that contains the steps necessary to execute the task from the ladder diagram ( or any other mode of
Functional blocks of PC

Figure -4.9
entering the program) which is equivalent to the relay logic. The user program is entered through the programmer. The sequencer itself has its own operating program—sometimes referred to as a microprogram—which causes the sequencer hardware to step through the user program and execute it according to the predefined rules of the system.

Output:

In the output block, the output points are turned on or off according to the results of the ladder logic based on inputs at any particular time. The state of output is stored in the memory therefore the on or off state of these outputs can be used with in other logic equations simply by the program examining the contents of the appropriate memory location. If hardware relays were used, each logic equation would require using a separate set of contacts for a particular output.

Advantages of PC:

The PC has grown exponentially in popularity as because:

1. High flexibility: modular construction in both software and hardware, customer configured, expansible and even rebuildable.
2. Ease of programming: relay ladder logic diagram language, other symbolic and high level languages specially designed for control purposes.
3. Specially designed tolerance: for application in harsh environment
4. Cost effective: hardware costs are reduced, owing to mass production for the huge market and standardized modular construction. The initial cost can be very low for the PC user who can introduce a system with the minimum of modules and then expand it when the need arises. Software development costs are cut by their
unique user friendly real-time multi-tasks programming
language. It is experienced that using relay ladder
logic, programming time can be cut to 10%.

5. Reliability:

(1) Protection of software and data:

For normal use of PC, power failure may cause loss
of user program and data in RAM, and also in case of
unauthorized alteration, which may introduce errors and
omission. All these may damage the controlled process.
All these protection approaches have been considered in
PC design. Initially, the users programs were stored in
battery retain RAM or EEPROM (non-volatile) and many
users would like to fix them into reliable EPROM using
a ROM writer, after field testing, as a backup copy.
The transient data are normally stored in RAM, but
important data, such as the status of some flags which
may affect the operation after the power failure, is
locked in a special ram area retained by battery when
programming. The protection from unauthorized
alteration is achieved by hardware key switches or
software pass words. In many PCs both approaches are
applied to ensure that every alteration is valid. To
avoid errors being introduced during alteration, most PC
systems provide a hardware timer/counter set point unit,
where only a few necessary set points can be altered and
there ranges can be easily limited in the user program.

(2) Environmental tolerance:

Well known PCs fulfil classification societies
regulation for harsh marine environment like:
- Ambient temperature, humidity.
- Mechanical vibration, shock and inclination.
- Electromagnetic interference.

(3) Redundancy:

Because of their modular design and network
ability, PC systems are easily constructed in a distributed configuration which simply restricts the function area affected by a single fault. The recent innovation of middle and large size PCs is the hot back-up system with dual or even triple redundant CPU modules requested in critical applications. This greatly increases in MTBF, and a calculated MTBF for one of these PCs has reached several hundred years.

(4) Maintenance and service:

It is beyond the reach of engineer's on board to shoot and repair faulty components of printed circuit cards of micro electronic system. But the PC system provides a new opportunity for internal self checking facilities which automatically locates hardware fault for replacement. PCs are constructed by modules with LEDs and clearly indicates the status of the module and every I/O point on the surface. Therefore identification for replacement is easy and does not require skilled personnel and special test equipment. I/O terminals of some new PC are on bus plates which does not require even a second or a tool like screw driver.

(5) Reduction of spares stock:

The versatility of PC systems enables some type of hardware to be utilized for several functions on the same ship. Therefore, one set of spares/modules can serve several systems. Additionally, PC system spares, which are just modules, are usually much cheaper than the spare cards required for special purpose computer systems.

(6) Security of procuring spares:

It has been observed that the rapid development of microelectronic technology is making previous generation
obsolete in a short time. But, it is not as easy to stop large scale production of a major PC. Furthermore, the innovation of PC products are mainly based on modules. The new modules are normally compatible with the old one and at the same time it offers some new features. Therefore the user does not suffer.
5.1 Introduction:

Practically every ocean-going ship is registered with a Classification Society and is therefore required to comply with the rules of the relevant society. These differ slightly in technical and also in survey requirements keeping the basic guideline same. In this chapter different shipboard machinery/equipment, design has been explained considering level of automation complied from the Classification Societies point of view to give an idea of an automated vessel.

5.2.1 Automated vessel:

A ship whose machinery spaces are intended to be periodically unattended in all sailing condition including manoeuvering and automated installations are designed to achieve maximum guarantee of safe operation, at least equal to the non automated installation, operated by watch keeping personnel are accepted by the Classification Societies as Automated Vessel or Automated Installations.
5.2.2 Application:

Classification Society's requirements on automatic or remote control of machinery and equipment of a vessel applies to control following:

(1) Main propulsion.
(2) Controllable pitch propeller.
(3) Steam raising plant (boilers and their ancillary equipments).
(4) Electric generating plant.
(5) Auxiliary machinery associated with machinery and equipment.
(6) Fuel oil system.
(7) Bilge system.
(8) Deck machinery.

5.3 Design of automated installations

5.3.1 System design:

Control systems, alarm system and safety systems in shipboard automated installations are so designed that one fault does not result in another fault. They are designed on the "fail to safe" principle and sufficiently reliable under service condition.

5.3.2 Control means:

(1) Electric power -

Electric power required for the control, alarm and monitoring systems are not branch offs from the power and lighting circuit. Normally individual machinery and equipment has same power supply for operation, control,
safety and alarm system. Alarm and safety power for electric generating sets are supplied from an accumulator battery.

(2) Hydraulic oil -

The supply of control oil pressure and quantity are stable. Pressure relief valves are fitted on the delivery side of the hydraulic oil pump. To control main propulsion machinery and main shafting, two or more independent sets of hydraulic oil pressure pumps are fitted. They are so arranged that one is kept as a stand by pump and starts automatically in case of oil pressure failure.

(3) Pneumatic pressure -

Control air is supplied from two or more sets of control air compressors and an air reservoir of capacity of supplying air to control devices at least for 5/10 minutes in the event of the failure of the control air compressor. Each control air compressor can supply the full requirement for control air. Control air is also taken from main propulsion or generating diesel engine starting air reservoir through pressure reducing valves and normally they are duplicated. Control air supply is independent of general service air and starting air.

5.3.3 Marine Environmental Conditions:

Marine automated equipment is capable of operating satisfactorily in the marine environment and the ships operating conditions. In addition to the forward motion of a vessel, vessel encounters three linear motions, such as surge, sway and heave motion and three rotational motions named as rolling, pitching and yawing motion. The vessel also faces severe mist, rain, snow, hail, storm, wind, fog, vibration and so on. Automated
equipment should withstand above severe marine environmental conditions.

To get type approval certificate of the equipment from the classification societies, the equipment must undergo environmental tests like vibration test, dry temperature test, heat and humidity test, salt fog test, and performance test, dielectric test surge voltage test and so on.

5.3.4 Control System Requirements :-

Control systems of main propulsion engines and their auxiliaries and boilers, electric generating sets are independent of each other. In case of more than one main propulsion engine, electric generating sets or important auxiliaries which are designed to operate simultaneously under the same condition, interconnecting devices are provided between the control devices for each unit.

Automatic control and remote control devices have control characteristics in conformity with the dynamic properties of the equipment they serve and do not malfunction or hunt due to disturbance.

Control devices are provided with suitable interlocking arrangements in order to prevent damages to the machinery and equipment due to anticipated malfunctions and misoperation of the machinery and equipment.

Main engines and auxiliary machinery, boilers, electric generating sets also have manual starting mechanism so that they can be manually started, operated and controlled in case of automation failure. Automatic control functions of equipment can be stopped manually. The function of remote control devices can be cancelled manually. If the machinery and equipment have more than
one control station then each control station will indicate which one is in operation and also at a time control can not be possible from more than one station.

5.3.5 Alarm System :-

In case of abnormal condition of machinery, alarm systems give visible and audible alarms. Alarm systems give indication at the same time in case of more than one fault. Alarm signals are clearly separated from the other audible signalling devices such as general alarm, telephone, fire, carbondioxide flooding alarm and so on. An alarm sequence is included at least for a warning phase with general audible signal and individual flushing luminous signal corresponding to the activated channel or channel group. In the acknowledgement phase, the above luminous signals become steady after the acoustic signal has been switched off. If an alarm has been acknowledged and a second fault occurs before the first is rectified then audible and visual signal operates again, except where justified alarm system is independent from control and safety system.

Failure of the normal supply and the alarm system is also indicated by an alarm. Visual alarms are such that each abnormal condition of the machinery is readily distinguishable and so arranged that acknowledgement is clearly noticeable. Alarm systems are capable of being tested during normal machinery operation.

5.3.6 Control and Monitoring Station's Communication :-

A central monitoring and control station is arranged, which is included control devices and instruments necessary for the execution of the
operations intended to be carried out from this station.

Telecommunication systems are provided for interconnecting various monitoring and control stations and for calling the personnel on duty.

5.3.7 Safety System :-

Safety systems are designed as far as practicable to operate independently of the control and alarm system. In the system a failure or malfunction will not prevent the safety system from operation. Safety systems for different items of the equipment are arranged so that failure of the safety system in one part of the plant is not interfered with the operation of the safety system in another part of the plant.

When a safety system is activated, an audible and visual alarm is initiated to indicate the cause of the safety action. The safety system is provided with a manual reset. Visual indication is given at the relevant control stations of the machinery and equipment where an overriding safety system is in operation. The overriding arrangements are such that inadvertent operation is prevented.

5.3.8 Micro Processing System :-

Micro-processor based control systems, alarm systems and safety systems for the machinery and equipment are arranged in such a way that a single failure or malfunction of the electronic equipment will not effect more than one of these functions. The reliability and maintainability of the computer based control system are not to be inferior to those of the conventional control system that is at least as reliable.
as a hard-wired system. Central processing units and important associated apparatus are designed with self monitoring facilities and any fault causing failure of the system to carry out its intended function is to initiate an audible and visual alarm. The location of a hardware fault is indicated to a level compatible with the equipment's designed repair/replacement policy. The system initiates an audio and visual alarm in case of any power supply failure to the system. At that time the system automatically changes over to an alternative power supply.

Important programs and data held in the system are protected from corruption by loss of power. Where any part of the program is stored in volatile memory a permanent copy of the program and the means to re-enter it are provided. The storage arrangements for the program copy are such that corruption will not occur due to environmental condition.

5.3.9 Local Area Networks (LANs) :-

A general purpose communication network that provides interconnection of a variety of data communicating devices within a small area is called Local Area Network.

Where a LAN is used to transfer alarm, control, safety and supervisory data between computers and data gathering equipment. The network topology is such that in the event of a failure between nodes, the system on the network continues to operate and data transmission between them is maintained.

The network is capable of transmitting maximum data transfer which could possibly arise without incurring an unacceptable data collisions.
Protocols are ensured the integrity of data flowing on the network in addition, the software in the computers sharing the network is designed to carry out limit checking on data values.

Means are provided to maintain the network operation in the event of a network controller failure. Means are provided to monitor the usage of the network, the occurrence of faults and other parameters necessary for assessing its performance. Audible and visual alarms are operated in the event of a network fault.

The arrangements for connecting or disconnecting nodes to and from the network are to be such that the network continues to operate with the minimum of interruption to other systems sharing the network. Voice communications and video signals are normally shared by the network. The network installation provides adequate protection against mechanical damage and electro-magnetic interference.

5.4 System Design for the Automation and Remote Control of Main Engine:

The main engine or if there is any controllable pitch propeller, can be controlled from the navigating bridge or main control station. The control devices of the control stations are referred as remote control devices for main propulsion machinery.

5.4.1 Remote Control of Main Engine:

Remote control arrangement of main engines is controlling the propeller speed and the direction of thrust. When main propulsion engines are controlled by governors; they are adjusted in such a manner that main
engine should not develop rpm more than 110 % of the maximum continuous power. Governors are capable of maintaining the safe minimum speed.

In case engine output is controlled by programmable controller, the program is designed in such a way that an increase or decrease of engine output does not develop excessive mechanical or thermal stress in any part of the engine.

The remote control and monitoring station of main engine is provided with propeller speed indication and direction of rotation in case of fixed propeller or pitch position in case of variable pitch propeller.

The remote control station is provided with main engine alarm devices. Remote control of the main engine is possible only from one station at a time, as such station interconnected control positions are permitted. At each station there is an indicator showing which station is in control of the main engine.

The transfer of control between the navigating bridge and machinery spaces is possible only from the machinery space or from the machinery control room. The system includes means to prevent the propelling thrust from altering significantly when transferring control from one location to another.

In the event of failure of remote control system of main engines, engine speed and direction of the propeller thrust are maintained until the control is in operation from the main control or local control station and the transfer of control to local or main control station can be done by a simple operation.

In case of main engine remote control failure main engine alarm device actuates, engine can be stopped from the independent emergency stopping devices and if necessary engine can be controlled from the local/manual
control station.

The number of automatic consecutive attempts which fail to start the main engine by the remote control device is normally limited by the classification society. A visual and audible alarm is issued at the relevant control station and the main control and monitoring station in the event of failure of main engine starting. An alarm is also initiated in case of low main engine starting air pressure when engine started by compressed air.

5.4.2 Bridge Control Device:

The remote control device provided on the bridge to control main engine under all sailing conditions, including manoeuvring, the speed, direction of the thrust, and if applicable, the pitch of the propeller is referred as bridge control devices. Bridge control devices are designed either with devices to pass automatically and rapidly through the critical speed range or with alarm devices which operate in case where the main engines operate exceeding a predetermined period in the critical speed range in order to prevent prolonged running of main engines in critical speed range.

5.4.3 Safety System :

Necessary interlockings are provided with the remote control devices for the main engine to prevent serious damage in case of misoperation. The main engine safety system is designed to stop engine automatically or capable of being stopped in case of failure of main
Electric supply when all the auxiliaries of main engine are driven by electric power and in that case engine is also designed not to restart automatically after restoring electric power. Emergency stopping devices for main engines are provided at the monitoring station.

Main engine safety devices will activate to shut off fuel or steam supply automatically except in cases which could lead complete breakdown, serious damage or explosion.

Remote control devices are designed so that starting of the main engine is only possible when it is confirmed that the camshaft is in the Ahead or Astern position and during cam reversing fuel is not injected.

Safety measures to the remote control devices for the multi engine coupled to a single propeller shaft is provided with an overload preventive device and each engine is not subjected to an abnormally unbalanced load.

Remote control devices for multiple engines coupled with clutches to a single shaft are designed to disengage the clutch when engine is stopped in an emergency. Engaging and disengaging the clutches is carried out below a predetermined value of the rpm of main engines.

Remote control devices for engines driving controllable pitch propeller are designed not to start the engines when their clutch is engaged and propeller blades are in a neutral position.

5.5 System Design for the Automatic and Remote Control of Electric Generating Sets:

When electric power required for main engine auxiliaries and steering gear can normally be maintained
by only one generator, then provision is kept in case of power failure to start automatically and operate a stand-by generator of sufficient power/capacity to ensure the supply of auxiliaries necessary for the propulsion and navigation as well as normal lighting.

Voltage from the stand-by generator is restored on the main switchboard(s) within 45 seconds following the power failure and then automatic re-start of the essential electric services is followed.

If the electrical power is normally supplied from more than one generator simultaneously in parallel operation, provision is made for load shedding and without overloading the other generators to permit propulsion, steering and safety of the vessel in case of loss of power failure of one of these generators. Electric generating set arranged to start automatically or remotely is provided with interlocking devices for safe operation. Their automatic starting arrangement is designed in such a way that the number of automatic consecutive attempts which fails to produce a start is limited to two times and is provided with an alarm device to operate at that event.

5.6 Automatic and Remote Control of Boilers:

Burners are controlled automatically to produce required amount of steam, steam pressure and temperature. The devices to control the fuel supply for the required load are capable of ensuring stable combustion in the controllable range of fuel supply. Combustion control is carried in such a way that upper limit of boiler steam pressure is set lower than the safety valve setting pressure.

The burner control devices for intermittent
operation are to comply with certain requirements.
Before ignition of the pilot burner/main burner, the
combustion chamber is purged by forced draught air. In
case of direct ignition, opening of the fuel valve is
not preceded the ignition spark and in case of indirect
ignition, opening of the fuel valve for pilot burner is
not preceded the ignition spark, and opening of the fuel
valve for main burner is not preceded the opening of
ignition fuel valve. Firing is carried out within the
set period. Main fuel valve is so designed as to close
after opening of the valve not exceeding certain time
setting in case of firing of main burner failure.
Firing of the main burner is carried out in the low
firing position. After closure of the main fuel valve,
purging is carried out for certain set time to ensure
adequate combustion air to burn remaining fuel oil
completely between the fuel oil valve and the burner
nozzle.

The burner control device for the control of the
number of burners firing are complied with certain
requirements. Each burner is fired and extinguished
according to the planned sequence. Sometimes, the base
burner may fire by manual operation and other burners
may fire by flame of other ignited burner(s). The
remaining fuel in the extinguished burner is
automatically burnt up for easy restarting. The burners
for main boilers are capable of firing and extinguishing
from the main control station, excepting for the firing
of base burner.

Boiler feed water is controlled automatically in
order to maintain the water level in the boilers within
a predetermined range. Main boilers are provided with
not less than three water level detectors used for feed
water control device, remote water level indicator, low
water level safety device and low water level alarm device.

Safety valves and relief valves, water level indicators, pressure and temperature measuring devices and safety devices in steam connections, feed water system, blow-off system, burning system, thermal oil heaters and alarm devices are provided.

5.7 Automatic and Remote Control of Auxiliary Machineries:

Automatic operation of air compressors, automatic starting and stopping of bilge pumping arrangements, automatic control of thermal oil installations, high temperature alarm for oil heaters, opening and closing devices for sea valves, liquid level alarm systems for fuel oil tanks, mooring arrangements, fuel oil filling arrangements and so on are fitted as part of the requirements of automatic and remote control systems.


5.8.1 Requirements for CMA-ships.

CMA-ships are provided with centralized monitoring and control station and it is so arranged that under all sailing conditions including manoeuvring, safety of the machinery operation will be equivalent to the sailing condition under direct supervision.
The centralized control station is provided with remote control devices and monitoring devices for main engines and for boilers.

Bilge wells in the spaces of main engines, propulsion shafting, boilers, electric power generating sets and propulsion auxiliaries are installed and large enough to accommodate normal operational drainage from the above. High liquid level alarm devices are provided at two or more places as to detect high level bilge at normal heel and trim condition. Bilge pumps are capable of being started and stopped automatically and take suction from the above mentioned bilge wells.

Fuel oil and lubricating oil piping system are properly protected/shielded in order to prevent scattering/leakage of oil. Leakage of oil from high pressure fuel oil pipes are collected in suitable tanks. Means are provided to prevent overflow/spillage in the case where fuel oil service tanks are filled automatically or by remote control means. Equipments related with flammable liquid like fuel oil, lubricant oil purifiers and their heaters are normally installed in a confined space. A high temperature alarm device is provided below the flush point in case where fuel oil service tanks or settling tanks are filled with heating arrangements. Appropriate fire detection and alarm systems are provided.

Control, alarm and safety devices are normally independent of each other. Safety systems for the operation of safety devices are in any case, independent of other systems. Means are provided for safety systems to investigate the case of the action of the safety systems.

Alarm systems are designed with self-monitoring properties and can be tested during normal machinery
operation and also means are provided at convenient and accessible positions to permit the sensors for testing without affecting the operation of the machinery. Computerized control system, alarm and safety systems are independent to each other. Alternative or backup means of alarm systems are provided when alarm systems are computer controlled.

5.8.1.1 Main Propulsion Diesel Engines:

Over-speed and lubricating oil pressure failure causes safety devices to actuate for automatic shut off of fuel oil supply to the main engines. Means are provided to reduce speed/load automatically of the main propulsion diesel engines in case of high temperature or scavenge fire, high oil mist density in the crank case or high bearing temperature, low pressure/flow of cylinder cooling water and piston cooling water/oil.

Means are provided with oil mist detectors or monitoring devices of bearing temperature to prevent crank case explosion.

Main engine auxiliaries stand by pumps are designed to start automatically or remotely from engine room/bridge centralized control station in case of delivery pressure or flow rate of the lubricating, cooling and fuel oil supply pumps in operation fails below a pre-set value.

Main propulsion diesel engine(s) is(are) provided with alarm devices to operate in the event of the abnormal condition given in Table 5.1.

5.8.1.2 Electrical Generating Sets:

Diesel driven generating sets are provided with
safety devices to shut off fuel oil supply to the engine automatically in case of over-speed, lubricating oil pressure failure, high temperature of the cooling water at the outlet.

Turbine driven generating sets are provided with safety devices to shut off steam supply automatically in case of over-speed, loss of lubricating oil pressure, high exhaust gas pressure or low condenser vacuum, abnormal vibration.

Electric generating sets are provided with alarm devices to operate in the event of the abnormal condition given in Table 5.2.

5.8.1.3 Main and Auxiliary Boilers:

Boilers are provided with safety devices as mentioned earlier in section 5.6. Main boiler feed water piping is provided with a self-closing valve to operate automatically in the event of abnormal rise of the main boiler water level. Low water level detectors actuate safety devices for low water level in the main boiler.

Stand by feed water and fuel injection pumps for operation of the main boilers and important auxiliary boilers are so arranged to start automatically or capable of being remotely started from the centralized control station immediately when the delivery pressure or flow rate of the pumps in operation fall below a preset value or when the pumps stops.

Alarm devices are provided to operate in the event of the abnormal conditions given in Table 5.3.

5.8.1.4 Controllable Pitch Propellers:

Stand by hydraulic pumps for controllable pitch
propellers are designed to start automatically or be capable of being remotely started from the centralized control station when delivery pressure or flow rate of the pumps in operation fall below a predetermined value or when the pump stops.

Controllable pitch propellers are to be provided with alarm devices to operate in the event of the abnormal conditions given in Table 5.4.

5.8.1.5 Other Auxiliaries:

Air compressors are designed to stop automatically in the event of loss of lubricating oil pressure.

Lubricating oil coolers, coolers for cylinder cooling water, coolers for piston cooling water/oil, fuel oil heaters, heaters for fuel oil purifiers and heaters for lubricating oil purifiers for main engines, main boilers, important auxiliary boilers, generators and prime movers driving auxiliaries for propulsion of ships are provided with temperature control devices in order to regulate the temperature of lubricating oil cooling water/oil and fuel oil in a pre-set range.

Air compressors and heat exchanger mentioned above are provided with alarm devices to operate in the event of abnormal conditions given in Table 5.5.

5.9 UMS-ships:

UMS-ships are designed and arranged to ensure the safety of the ship equivalent under all sailing conditions including manoeuvring to a ship operated with full time watch keeping personnel. The design and arrangement are to be capable of performing unmanned
### Table 1.1 Main Propulsion Diesel Engines

<table>
<thead>
<tr>
<th>Monitored variables</th>
<th>Alarms</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cyl. coolant outlet, each cyl.</td>
<td>H</td>
<td>not required when L.O. system is integrated with propulsion engine system</td>
</tr>
<tr>
<td>Piston coolant outlet, each cyl.</td>
<td>H</td>
<td></td>
</tr>
<tr>
<td>Fuel valve coolant outlet</td>
<td>H</td>
<td></td>
</tr>
<tr>
<td>L.O. inlet</td>
<td>H</td>
<td></td>
</tr>
<tr>
<td>Thrust bearing or L.O. outlet</td>
<td>H</td>
<td></td>
</tr>
<tr>
<td>Reduction gear L.O. inlet</td>
<td>H</td>
<td></td>
</tr>
<tr>
<td>F.O. injection pump inlet or viscosity</td>
<td>H L</td>
<td>applied when viscosity control of F.O. is performed</td>
</tr>
<tr>
<td>Exhaust gas outlet, each cyl. from average temperature</td>
<td>H</td>
<td></td>
</tr>
<tr>
<td>Scavenge air high temp. or fire</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td>Air cooler air outlet</td>
<td>H L</td>
<td>applied when automatic temperature control device is provided</td>
</tr>
<tr>
<td>Cyl. cooling water inlet</td>
<td>L</td>
<td></td>
</tr>
<tr>
<td>Piston cooling water inlet</td>
<td>L</td>
<td></td>
</tr>
<tr>
<td>Fuel valve coolant inlet</td>
<td>L</td>
<td></td>
</tr>
<tr>
<td>Piston cooling oil inlet</td>
<td>L</td>
<td>or flow, not required when L.O. for propulsion engine system is used</td>
</tr>
<tr>
<td>L.O. inlet</td>
<td>L</td>
<td></td>
</tr>
<tr>
<td>Pressure difference between inlet and outlet of L.O. strainer</td>
<td>H</td>
<td></td>
</tr>
<tr>
<td>Turbo charger L.O. inlet</td>
<td>L</td>
<td>not required when L.O. system is integrated with propulsion engine system</td>
</tr>
<tr>
<td>Reduction gear L.O. inlet</td>
<td>L</td>
<td></td>
</tr>
<tr>
<td>F.O. injection pump inlet</td>
<td>L</td>
<td></td>
</tr>
<tr>
<td>Starting air at engine inlet</td>
<td>L</td>
<td></td>
</tr>
<tr>
<td>Cooling sea water or flow</td>
<td>L</td>
<td></td>
</tr>
<tr>
<td>Flow in cyl. lubricator</td>
<td>L</td>
<td></td>
</tr>
<tr>
<td>Oil mist concentration in crankcase</td>
<td>H</td>
<td></td>
</tr>
<tr>
<td>Failure of engine starting</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td>Leakage from F.O. injection pipe</td>
<td>O</td>
<td></td>
</tr>
</tbody>
</table>

**NOTE:**

"H" and "L" mean high and low.

"O" means abnormal condition occurred. Same meaning is applied in Table

### Table 1.2 Controllable Pitch Propellers

<table>
<thead>
<tr>
<th>Monitored variables</th>
<th>Alarms</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydraulic oil</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tank, level</td>
<td>L</td>
<td></td>
</tr>
<tr>
<td>Pressure</td>
<td>L</td>
<td></td>
</tr>
</tbody>
</table>

**Source:** Korean Regestry of Shipping
### Table 3.3 Electric Generating Sets

<table>
<thead>
<tr>
<th>Monitored variables</th>
<th>Alarms</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>L.O. inlet</td>
<td>H</td>
<td></td>
</tr>
<tr>
<td>Coolant outlet</td>
<td>H</td>
<td>or low pressure/flow</td>
</tr>
<tr>
<td>Exhaust gas, turbo charger each inlet or cylinder each outlet</td>
<td>H</td>
<td></td>
</tr>
<tr>
<td>F.O. injection pump inlet or viscosity</td>
<td>H</td>
<td>L</td>
</tr>
<tr>
<td>L.O. inlet</td>
<td>L</td>
<td></td>
</tr>
<tr>
<td>Coolant outlet or flow</td>
<td>L</td>
<td></td>
</tr>
<tr>
<td>Leakage from F.O. injection pipe, level in leakage tank</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td>Oil mist concentration in crankcase</td>
<td>H</td>
<td>or bearing temp not required for small engines</td>
</tr>
<tr>
<td>Steam turbine for generator</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pressure, Temperature</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L.O. inlet</td>
<td>L</td>
<td></td>
</tr>
<tr>
<td>Steam inlet</td>
<td>L</td>
<td>For steam turbine ship, applied only where extracted steam is used.</td>
</tr>
<tr>
<td>Exhaust steam</td>
<td>H</td>
<td></td>
</tr>
<tr>
<td>Ampere</td>
<td>H</td>
<td>Sensors for controllers may be used</td>
</tr>
<tr>
<td>Voltage</td>
<td>H</td>
<td></td>
</tr>
<tr>
<td>Frequency or number of revolution</td>
<td>H</td>
<td></td>
</tr>
<tr>
<td>Current</td>
<td>H</td>
<td>Sensors for controllers may be used</td>
</tr>
<tr>
<td>Voltage</td>
<td>H</td>
<td></td>
</tr>
<tr>
<td>Frequency or rotational speed of generator in rpm</td>
<td>H</td>
<td></td>
</tr>
<tr>
<td>Bearing L.O. inlet</td>
<td>H</td>
<td>Applicable to the forced lubrication system</td>
</tr>
<tr>
<td>Stator winding or compensating pole winding</td>
<td>H</td>
<td>Applicable to 500 kW or more</td>
</tr>
<tr>
<td>Cooling air or cooling water outlet</td>
<td>H</td>
<td></td>
</tr>
<tr>
<td>Bearing L.O. inlet</td>
<td>L</td>
<td>Applicable to the forced lubrication system</td>
</tr>
</tbody>
</table>

### Table 5.4 Boilers

<table>
<thead>
<tr>
<th>Monitored variables</th>
<th>Alarms</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>F.O. to burners</td>
<td>L</td>
<td>or F.O. heater outlet for aux boiler.</td>
</tr>
<tr>
<td>Gas air heater or economizer outlet</td>
<td>H</td>
<td>applied to main boilers</td>
</tr>
<tr>
<td>Superheater steam outlet</td>
<td>H</td>
<td></td>
</tr>
<tr>
<td>Steam drum or superheater outlet</td>
<td>L</td>
<td></td>
</tr>
<tr>
<td>Forced draft</td>
<td>L</td>
<td>or stop of driving unit</td>
</tr>
<tr>
<td>F.O. to burners (atomizing press.)</td>
<td>L</td>
<td>applied to water tube boiler with max. working press exceeding 1 MPa not used for only heating and general use</td>
</tr>
<tr>
<td>Atomizing medium</td>
<td>L</td>
<td></td>
</tr>
<tr>
<td>Water level</td>
<td>H</td>
<td>L</td>
</tr>
<tr>
<td>Side of air preheater driving unit</td>
<td>O</td>
<td>applied to main boilers</td>
</tr>
<tr>
<td>Feed water pressure at feed water pump outlet</td>
<td>L</td>
<td>applied to water tube boiler with max. working press. exceeding 1 MPa.</td>
</tr>
<tr>
<td>Feed water pump outlet, salinity</td>
<td>H</td>
<td>applied to ships provided with steam turbine driving generator.</td>
</tr>
</tbody>
</table>

Source: Korean Registry of Shipping
<table>
<thead>
<tr>
<th>Monitored variables</th>
<th>Alarms</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distilling plant, salinity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Purifier, malfunction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F O or L O, heater outlet, temperature</td>
<td></td>
<td>or heater outlet, flow L, or stop of driving unit</td>
</tr>
<tr>
<td>Condensate pump outlet, pressure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Condensate pump outlet, salinity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drain pump outlet, salinity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>External desuperheater, steam temperature</td>
<td></td>
<td>L is required when the steam is used for the aux turbine relating to propulsion</td>
</tr>
<tr>
<td>Deaerator, level</td>
<td></td>
<td>H L</td>
</tr>
<tr>
<td>Sump tank, level</td>
<td></td>
<td>H L</td>
</tr>
<tr>
<td>Service tank, level</td>
<td></td>
<td>H L</td>
</tr>
<tr>
<td>Drain tank, level</td>
<td></td>
<td>H</td>
</tr>
<tr>
<td>Sludge tank, level</td>
<td></td>
<td>H</td>
</tr>
<tr>
<td>Sump tank, temperature</td>
<td></td>
<td>H L</td>
</tr>
<tr>
<td>Service tank, temperature</td>
<td></td>
<td>H L</td>
</tr>
<tr>
<td>Sump tank for propulsion engine, level</td>
<td></td>
<td>L</td>
</tr>
<tr>
<td>Drain tank, level</td>
<td></td>
<td>H</td>
</tr>
<tr>
<td>Sludge tank, level</td>
<td></td>
<td>H</td>
</tr>
<tr>
<td>Gravity tank, level</td>
<td></td>
<td>L</td>
</tr>
<tr>
<td>Cooling water expansion (makeup) tank, level</td>
<td></td>
<td>L</td>
</tr>
<tr>
<td>Purifier water tank, level</td>
<td></td>
<td>L</td>
</tr>
<tr>
<td>Cascade tank, level</td>
<td></td>
<td>L</td>
</tr>
<tr>
<td>Atmospheric drain tank, level</td>
<td></td>
<td>L</td>
</tr>
<tr>
<td>Distilled water tank, level</td>
<td></td>
<td>L</td>
</tr>
<tr>
<td>Starting air tank for propulsion engine, pressure</td>
<td>L</td>
<td>applied to steam turbine ship</td>
</tr>
<tr>
<td>Starting air tank for generator diesel engine, pressure</td>
<td>L</td>
<td>applied to steam turbine ship</td>
</tr>
<tr>
<td>Hydraulic control system, pressure</td>
<td></td>
<td>L</td>
</tr>
<tr>
<td>Pneumatic control system, pressure</td>
<td></td>
<td>L</td>
</tr>
<tr>
<td>Hydraulic coupling oil in main shafting system, pressure</td>
<td>L</td>
<td>not required when starting air is used without decompressing</td>
</tr>
<tr>
<td>Control electric power, failure</td>
<td></td>
<td>O</td>
</tr>
<tr>
<td>Bilge level in machinery room and shaft tunnel</td>
<td>H</td>
<td>in the machinery room, at least two positions are to be monitored</td>
</tr>
<tr>
<td>Influx of liquid is greater than the pump capacity or the pump is operating more frequently than would normally be expected</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td>Stern tube bearing or bearing oil in oil bath</td>
<td>H</td>
<td>or stern tube outlet oil when forced circulation system is used/applied to oil lubrication system</td>
</tr>
</tbody>
</table>

Source: Korean Registry of Shipping
machinery operation for at least 24 consecutive hours. UMS-ships are complied with all the requirements of CMA-ships in addition to this paragraph (5.9).

5.9.1 Bridge Control System:

The navigating bridge is provided with bypass devices to override temporarily the function of the program control devices. Override arrangement for the safety system is provided to stop the main engine(s) automatically in the event of abnormal condition. The visual alarm may be displayed as group alarm. The visual alarms for automatic stoppage and for automatic reduction of speed of the main engines are displayed separately. The navigating bridge is provided with bilge alarm devices. The bridge control devices are provided with program control devices or other approved means to ensure that the main engine will not suffer undue mechanical and thermal stress and the speed of the main engine is easily increased or decreased.

9.2 Electric Source:

When electric power is supplied from one generator, suitable load shedding arrangements are provided to ensure the integrity of supplies to serve for propulsion and steering as well as the safety of the ship in case when the generator is overloaded. In case of power failure of the generator in operation, adequate provision is made for automatic starting and restoring power to the main switchboard from a standby generator of sufficient capacity to permit propulsion and steering and to ensure the safety of the ship with automatic restarting of the important auxiliaries with sequential
The stand-by generator is capable of supplying electric power with in 45 seconds from the loss of electric power.

In case, when electric power is supplied from more than one generator simultaneously in parallel operation, provision is made, for instance by load shedding, to ensure that, in case of loss of one of these generating sets, the remaining are kept in operation without overload to permit propulsion and steering, and to ensure the safety of the ship.

5.9.3 Stand-by pumps and scooping:

Stand-by pumps are arranged to start automatically in the event of failure of pumps in operation. In scoop system, transfer between the scoop system and the circulating pump is performed automatically.

5.9.4 Air Compressors:

Stand-by air compressors are capable of operating automatically to maintain the pressure in the starting air reservoirs in a predetermined range. Control air reservoir charging air compressors are capable of operating automatically to maintain the pressure in a predetermined range.

5.9.5 Means of Communication:

A means of vocal communication is provided between the navigating bridge, centralized control station, local control station and engineer's accommodation to communicate in the event of failure of the main electric power supply.
5.9.6 Remote starting of fire pumps:

An arrangement is provided to deliver water immediately from the main fire system at a suitable pressure with remotely starting the main fire pump(s) from navigating bridge and fire control station or permanent pressurization of the main fire system.

5.9.7 Alarm Systems:

Alarm systems are complied with all the requirements of CMA-ships. Additional requirements for UMS-ships are follows:

(1) Alarm systems are arranged with automatic change-over to an independent stand-by power supply, in the event of loss of the normal power supply.

(2) Failure of the normal power supply and stand-by power supply is indicated by independent alarms.

(3) Alarms for main engine(s) electric generating sets and auxiliaries for propulsion of the ship are provided in the duty engineers accommodations and engineers public places.

(4) Audible alarm devices provides warning of faults for the machinery and equipment installed in the spaces of main engine(s), boilers, electric generating sets and so on.

(5) Alarm systems are such that navigating officer of the watch is made aware when a fault has occurred, the fault is being attended and it has been rectified.
5.10 Automated Equipment:

Some of the classification societies put the ships into different classes according to the extent of automated equipment installed for the purpose of manning reductions.

(1) Class - 1 automation equipment ships.
(2) Class - 2 automation equipment ships.
(3) Class - 3 automation equipment ships.

They meet all the requirements of UMA-ships and UMS-ships in addition to the individual requirements as follows:

5.10.1 Class - 1 automation equipment ships:

These ships are provided with:

(1) Remote-controlled ballasting and de ballasting arrangements.
(2) Automatic steering system.
(3) Remote-controlled handling system for liquid cargo in bulk.
(4) Power driven opening and closing devices for side ports, ramp ways and hatch covers of hatch ways on weather decks.
(5) Automatic recording devices for vital engine parameters for main engine(s).
(6) Remote controlled mooring arrangements.
(7) Main and auxiliary air-conditioning arrangement for centralized control station.
5.10.2 Class - 2 automation equipment ships:

These ships are provided with following automated equipment in addition to the equipment in Class-1 ships.

(1) Remote-controlled fuel oil filling arrangements.
(2) Centralized monitoring device for refrigerating containers or chambers whichever is applicable.
(3) Cargo hose handling winches.
(4) Automatic deck washing arrangements.
(5) Remote controlled mooring arrangements and auto tension arrangements at ship-sides.
(6) Power-operated pilot ladder winding appliances.

5.10.3 Class - 3 Automation Equipment Ships:

Ships under this class are equipped with following automated equipment in addition to those in class- 1 and class - 2 ships:

(1) Centralized monitoring systems for machinery.
(2) Centralized control systems for machinery.
(3) Remote control arrangement for main engines and steering gear at the outside of the navigating bridge.
(4) High level alarm devices for the bilge of the cargo holds.
(5) Independent remote-controlled mooring arrangements.
(6) Stopping and releasing devices of towing ropes.
(7) Emergency towing rope winches.
(8) Waste oil treating arrangement.
6.1 INTRODUCTION:

Shipping being a very capital intensive and competitive venture, deserves a careful choice of machinery and equipment to be fitted on board a vessel for its efficient and reliable operation. Equipment using latest technology should not always be incorporated into the design of the vessel when processes are being automated. The factor proven reliability should be more traditional approach of a ship owner in equipment selecting. Basic expectations of a ship owner is reduced overall economy which means:-
- Reliability at sea, with durability and low maintenance,
- High fuel economy,
- Low investment costs.

In this chapter attempts has been made to investigate reliability on equipment of automated vessels. It is essential to grasp the present reliability level of ships for designing and planning ships during ship procurement.

6.2 Reliability:

The reliability of an equipment is its ability to
perform with in specified tolerance for a specified period of time. It is the ability to perform a specified task, for a specified time, in a specified environment.

The statements regarding reliability must be in terms of probability of surviving the specified life with satisfactory life throughout. Thus, reliability is normally stated as one or more of the following:

- **MTBF**: Mean time between failure.
- **MTTF**: Mean time to failure.
- **MTBMA**: Mean time between (or before) maintenance actions.
- **MTBR**: Mean time between (or before) repairs.
- **λ**: Failure rate in some specified period.

Reliability = \( R = e^{-\lambda t} \)

![Figure - 6.1](image)

The ability which can be expected from an item of equipment is predominantly dependent on the MTBF and MTTR.
The following affecting the MTBF include:
(1) Component quality;
(2) Insensitivity to the environment; and
(3) Maintenance requirements of the equipment.

The factors affecting the MTTR include:
(1) Serviceability;
(2) Amount of spares carried on board; and
(3) Quality of service available with the service personnel on board, which is dependent on their education and training.

![Diagram showing the relationship between MTBF and MTTR factors]

Figure - 6.2
6.3 Reliability Investigation of Equipment of Automated vessels:

It is always a vital problem for ship's operation to secure the safety and economy, which naturally leads to the development of more enhanced automation, operation by less crew members, and more reduced shipboard maintenance works, etc. This is called automated ships. In order to realize additional investment for automation of an automated ships, it is necessary to ensure greater labor and financial saving through improved automatic functions in ship operation, running and maintenance preserving safety. This can only be achieved by installing the vessel with high degree reliable equipment.

Many attempts have so far been made to assess the reliability of ship's equipment and machinery by different classification societies, ship building research associations.

(1) The classification society, Nippon Kaiji Kyokai (NKK) has always been studying the statistics about failures and alarms on machinery and equipment in more than thousand MO ships of their registry with a view to evaluate the reliability. NKK formed following three groups of MO ships equipped with two and four stroke diesel engines.

Group - I MO ships which came in to service in or before 1973.
Group - II MO ships which came in to service between 1974 and 1980.
Group - III MO ships which came in to service in and after 1980.
Data acquisition commenced in July 1975. The number of ships, aggregate navigational hours and aggregate MO navigational hours (unmanned) for each group are given below.

<table>
<thead>
<tr>
<th></th>
<th>Group I</th>
<th>Group II</th>
<th>Group III</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>5,284,898,4</td>
<td>5,716,682,0</td>
<td>4,618,414,8</td>
<td>15,619,995,2</td>
<td></td>
</tr>
<tr>
<td>MO Nav.hour</td>
<td>3,439,293,9</td>
<td>3,555,769,7</td>
<td>3,154,348,8</td>
<td>10,149,412,4</td>
</tr>
<tr>
<td>MO Nav.rate</td>
<td>65.1</td>
<td>62.2</td>
<td>68.3</td>
<td>65.0</td>
</tr>
<tr>
<td>No. of MO ships</td>
<td>189</td>
<td>154</td>
<td>294</td>
<td>637</td>
</tr>
</tbody>
</table>

Table - 6.1

The average outputs of main engine were 15,522 PS for two stroke diesel engines and average number of cylinders were 6.88.

6.3.1 Numbers of Alarms and Failures by Time of the Day:

Number of the recorded alarms and failures classified by time is shown in figure - 6.3. The shaded area denotes those recorded during unattended period. Machinery spaces are usually attended during day time, and, as may be seen from the figure, the frequencies of alarm / failure during the attended machinery operation are higher in the period from 0800 to 1700 than in the rest of the day. The frequencies of alarm / failure during unattended machinery operation are higher at night from 1700 to 0800 hours and lunch time from 1200 to 1300 hours than in the rest of the day.
Figure- 6.3
Source- NKK

Figure- 6.4
Source- NKK
6.3.2 Aging effects:

Figure 6.4 shows the MO navigation rate of the ships which came into service in 1976 (76-ships), were processed on year basis annually from 1976 to 1985. The 76-ships were 37 in numbers showing 5.8% of the total number of two stroke MO ships investigated. The ratio of alarm/failure during MO navigation to the whole sum, and the same at night. The MO navigation rate is low in ships of younger age and increases as the ship's becomes older. It can be said that the MO navigation rate increases after the ships undergo the early failure period as well as the running-in-period. The ratio of alarm / failure during MO navigation to the whole sum, and the same at night increase as the ship's age and MO navigation rate increases.

6.3.3 Alarm Rate:

It is the number of failures indicated by alarms to the total number of cases/failures. In MO ships postulating a reduced manning, the monitoring works should be taken over by the failure detecting devices as far as practicable. When one thinks about automatic control, its feasibility depends upon availability of the sensor which converts system parameters into electric signal. Since the sensor technique for system control is basically identical to that for monitoring works, the more a certain equipment rely on the detecting devices, the easier automatic control of the equipment is. Table 6.2 are the alarm rates of machinery/equipment as classified by groups. In two stroke ships in Group III, their alarm rate is higher even though it includes machinery/equipment whose early
### Table 6.2

#### Alarm rates of machinery / equipments

<table>
<thead>
<tr>
<th>Equipment / machinery</th>
<th>Group I</th>
<th>Group II</th>
<th>Group III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main diesel engines</td>
<td>6.6 (56/864)</td>
<td>5.6 (327/582)</td>
<td>6.8 (90/1357)</td>
</tr>
<tr>
<td>Boilers</td>
<td>5.0 (2/12)</td>
<td>5.0 (132/270)</td>
<td>5.0 (3/12)</td>
</tr>
<tr>
<td>Generator engines</td>
<td>6.4 (2/0/12)</td>
<td>6.2 (1/0/12)</td>
<td>6.3 (0/0/12)</td>
</tr>
<tr>
<td>Electrical apparatus</td>
<td>7.5 (1/0/121)</td>
<td>7.5 (5/12/121)</td>
<td>7.5 (0/12/121)</td>
</tr>
<tr>
<td>Automatic equipment</td>
<td>6.0 (33/55/75)</td>
<td>6.0 (23/55/75)</td>
<td>6.0 (33/55/75)</td>
</tr>
<tr>
<td>Means general</td>
<td>6.0 (33/55/75)</td>
<td>6.0 (23/55/75)</td>
<td>6.0 (33/55/75)</td>
</tr>
<tr>
<td>Automatic equipment</td>
<td>6.0 (33/55/75)</td>
<td>6.0 (23/55/75)</td>
<td>6.0 (33/55/75)</td>
</tr>
<tr>
<td>of auxiliaries</td>
<td>6.0 (33/55/75)</td>
<td>6.0 (23/55/75)</td>
<td>6.0 (33/55/75)</td>
</tr>
<tr>
<td>Main shafting system</td>
<td>9.1 (45/18)</td>
<td>9.1 (45/18)</td>
<td>9.1 (45/18)</td>
</tr>
<tr>
<td>Emergency pumps</td>
<td>8.1 (45/18)</td>
<td>8.1 (45/18)</td>
<td>8.1 (45/18)</td>
</tr>
<tr>
<td>Other pumps</td>
<td>8.5 (12/0/12)</td>
<td>8.5 (12/0/12)</td>
<td>8.5 (12/0/12)</td>
</tr>
<tr>
<td>Pump driving turbine</td>
<td>10.0 (11/11)</td>
<td>10.0 (11/11)</td>
<td>10.0 (11/11)</td>
</tr>
<tr>
<td>Air compressors</td>
<td>8.1 (45/18)</td>
<td>8.1 (45/18)</td>
<td>8.1 (45/18)</td>
</tr>
<tr>
<td>Purifiers</td>
<td>9.5 (6/18/18)</td>
<td>9.5 (6/18/18)</td>
<td>9.5 (6/18/18)</td>
</tr>
<tr>
<td>Heat exchangers</td>
<td>9.3 (45/18)</td>
<td>9.3 (45/18)</td>
<td>9.3 (45/18)</td>
</tr>
<tr>
<td>Distilling plants</td>
<td>9.2 (33/33/33)</td>
<td>9.2 (33/33/33)</td>
<td>9.2 (33/33/33)</td>
</tr>
<tr>
<td>Pipes and valves</td>
<td>10.0 (11/11)</td>
<td>10.0 (11/11)</td>
<td>10.0 (11/11)</td>
</tr>
<tr>
<td>Other auxiliaries</td>
<td>8.4 (22/44)</td>
<td>8.4 (22/44)</td>
<td>8.4 (22/44)</td>
</tr>
<tr>
<td>Tanks</td>
<td>8.7 (16/16/16)</td>
<td>8.7 (16/16/16)</td>
<td>8.7 (16/16/16)</td>
</tr>
<tr>
<td>Mean</td>
<td>8.7 (16/16/16)</td>
<td>8.7 (16/16/16)</td>
<td>8.7 (16/16/16)</td>
</tr>
</tbody>
</table>

#### Source: NKK

### Table 6.3

#### Alarm rates of main engine related equipments

<table>
<thead>
<tr>
<th>Machinery / equipment</th>
<th>Alarm rate in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scavenging air space related items</td>
<td>93.8</td>
</tr>
<tr>
<td>Air coolers</td>
<td>93.1</td>
</tr>
<tr>
<td>Cylinder oil lubricators</td>
<td>88.8</td>
</tr>
<tr>
<td>Jackets and cylinder liners</td>
<td>71.6</td>
</tr>
<tr>
<td>Governors</td>
<td>68.2</td>
</tr>
<tr>
<td>Turbochargers and auxiliary blowers</td>
<td>68.2</td>
</tr>
<tr>
<td>Fuel injection pumps</td>
<td>68.0</td>
</tr>
<tr>
<td>F O high pressure pipes and joints</td>
<td>65.5</td>
</tr>
<tr>
<td>Other main engine related auxiliaries</td>
<td>63.6</td>
</tr>
<tr>
<td>Piston cooling and telescopic tubes</td>
<td>63.1</td>
</tr>
<tr>
<td>mechanism</td>
<td></td>
</tr>
<tr>
<td>Fuel injection valves</td>
<td>55.2</td>
</tr>
<tr>
<td>Exhaust valves</td>
<td>37.1</td>
</tr>
<tr>
<td>Cylinder covers</td>
<td>31.2</td>
</tr>
<tr>
<td>Rocker arm mechanism</td>
<td>23.0</td>
</tr>
<tr>
<td>Starting air valves</td>
<td>13.3</td>
</tr>
<tr>
<td>Indicator valves</td>
<td>6.3</td>
</tr>
</tbody>
</table>

#### Source: NKK
Whole machinery/equipment (excluding unknown other machinery/equipment)

Purifiers

Automatic equipment in general

Pipes and valves

Boilers

Automatic equipment of auxiliaries

Main Engines

Generator engines

Electrical apparatus

Main shafting systems

(1) Two stroke

Factors influencing the engine reliability and durability.

Source: SOLER.

Figure - 6.5

Figure - 6.6
alarm rate is low. In the light of positive measures towards the reduced manning in these days, two stroke diesel ships seems to increasingly rely on alarm devices.

In table 6.3 alarm rates of main engine related equipment are shown. Except for cylinder lubricators, scavenging air space related components and air coolers on two stroke diesel engines the alarm rates are found relatively low. The alarm rates of cylinder covers, valves and their driving mechanisms are found particularly low. The components are items which are continuously subject to thorough checks and inspections but the main reason is that the sensors for these components have not been developed to satisfactory level.

6.3.4 Failure Rate:-

NKK has considered failure rate as the number of failures per 10,000 navigation hours. In distinction from the case of aircraft, ships are generally admitted not to maintenance free, and the occurrence of failures at sea is tolerated being unavoidable to some extent. The advent of the ships of high added value, which will facilitate the lesser manning and should involve no degradation of labor environment, will be next to impossible, unless reliability of equipment/machinery is further improved. In this context, machinery failures at sea have to be eliminated as far as possible asking for improvement in reliability and development of condition monitoring and diagnostic system.

The failure rates are shown in figure 6.5. In two stroke diesel ships, the failure rates of automatic
devices/equipment, main engines and generator engines appear to decrease with their reliability pushed up. But the failure rates of purifiers remain at the unchanged high level. Though the new model of F.O purifiers with an improved performance in handling low grade fuel oil are available from different manufacturers, it will take some more time until such an improvement is reflected in the statistical figure.

6.3.5 Failure Rates of Automatic Devices / Equipment :-

Table 6.4 shows failure rates of automatic devices/ equipment. In two stroke diesel ships the failure rates on ships in Group III is just 3/4 of the same on ships in Group I. Since the automatic devices/equipment are understood to be of early failure type, reliability of these used in the recent two stroke diesel ships is concluded to have been improved.

6.3.6 Analysis on Failure Causes of Sensors:-

The Ministry of Transport and Japan Foundation for Shipbuilding Advancement organized a committee on ship reliability investigation and initiated full - fledged ship reliability investigation on Unattended Machinery Space ships ( MO - Ships ) to grasp reliability of ship and shipboard equipment. The alarm of main engine abnormality obtained from the survey, they conducted from 1981 to 1988 on failures, and alarms on a total of 216 MO ships are put in Table - 6.5.

It may be seen from the table that the alarm ratio, which is the percentage of detecting machinery failures by alarm-system to total failures, is only 35.1% . The rest are left for detection either by the
Failure rates of automatic devices/equipments
(Two stroke diesel)
(Figures in parentheses show No. of failures)

<table>
<thead>
<tr>
<th>Order</th>
<th>Group I</th>
<th>Group II</th>
<th>Group III</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Equipment</td>
<td>Frequency of occurrence per 10,000 hrs</td>
<td>Equipment</td>
</tr>
<tr>
<td>1</td>
<td>M.E temp sensors</td>
<td>1.81 (958)</td>
<td>Aux. boiler</td>
</tr>
<tr>
<td>2</td>
<td>Aux boiler</td>
<td>1.30 (634)</td>
<td>M.E temp sensors</td>
</tr>
<tr>
<td>3</td>
<td>D.G temp sensors</td>
<td>0.76 (400)</td>
<td>M.E monit &amp; others</td>
</tr>
<tr>
<td>4</td>
<td>M.E monit &amp; others</td>
<td>0.73 (396)</td>
<td>Tank level sensors</td>
</tr>
<tr>
<td>5</td>
<td>Tank level sensors</td>
<td>0.73 (384)</td>
<td>D.G temp. sensors</td>
</tr>
<tr>
<td>6</td>
<td>Monitoring print boards</td>
<td>0.70 (371)</td>
<td>Fire detect sensors</td>
</tr>
<tr>
<td>7</td>
<td>Fire detect sensors</td>
<td>0.59 (311)</td>
<td>Annunciator print boards</td>
</tr>
<tr>
<td>8</td>
<td>Datalogger print boards</td>
<td>0.55 (292)</td>
<td>Datalogger print boards</td>
</tr>
<tr>
<td>9</td>
<td>Annunciator printboards</td>
<td>0.48 (255)</td>
<td>Purifier elec. cont.</td>
</tr>
<tr>
<td>10</td>
<td>Purifier elec cont</td>
<td>0.34 (179)</td>
<td>Boiler level sensors</td>
</tr>
</tbody>
</table>

Total | 17.89 (9453) | 15.31 (8867) | 13.31 (6147) |

Source: NKK

Table - 6.4
Alarm ratio to total failures in main diesel engine  
(Period from October 1981 to September 1988)

<table>
<thead>
<tr>
<th>Components</th>
<th>No-alarm</th>
<th>Alarm</th>
<th>Total failures</th>
<th>Alarm ratio(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Combustion chamber</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cylinder jacket, liner</td>
<td>132</td>
<td>81</td>
<td>213</td>
<td>38.0</td>
</tr>
<tr>
<td>Piston</td>
<td>187</td>
<td>15</td>
<td>202</td>
<td>7.4</td>
</tr>
<tr>
<td>Cylinder cover</td>
<td>245</td>
<td>39</td>
<td>284</td>
<td>13.7</td>
</tr>
<tr>
<td>Fuel injection valve</td>
<td>207</td>
<td>112</td>
<td>319</td>
<td>35.1</td>
</tr>
<tr>
<td>Safety valve</td>
<td>65</td>
<td>3</td>
<td>68</td>
<td>4.4</td>
</tr>
<tr>
<td>Starting valve</td>
<td>71</td>
<td>8</td>
<td>79</td>
<td>10.1</td>
</tr>
<tr>
<td>Exhaust valve</td>
<td>383</td>
<td>96</td>
<td>479</td>
<td>20.0</td>
</tr>
<tr>
<td>Indicator valve</td>
<td>293</td>
<td>0</td>
<td>293</td>
<td></td>
</tr>
<tr>
<td>Paching-ring</td>
<td>8</td>
<td>0</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td>102</td>
<td>50</td>
<td>152</td>
<td>32.9</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>1693</td>
<td>404</td>
<td>2097</td>
<td>19.3</td>
</tr>
<tr>
<td><strong>Transmission gears</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crank journal bearing</td>
<td>29</td>
<td>0</td>
<td>29</td>
<td></td>
</tr>
<tr>
<td>Crankpin bearing</td>
<td>4</td>
<td>1</td>
<td>5</td>
<td>20.0</td>
</tr>
<tr>
<td>Crosshead bearing</td>
<td>35</td>
<td>3</td>
<td>38</td>
<td>7.9</td>
</tr>
<tr>
<td>Gear/chains</td>
<td>7</td>
<td>1</td>
<td>8</td>
<td>12.5</td>
</tr>
<tr>
<td>Cam shafts and cam</td>
<td>23</td>
<td>2</td>
<td>25</td>
<td>8.0</td>
</tr>
<tr>
<td>Rocker arm gear</td>
<td>56</td>
<td>7</td>
<td>63</td>
<td>11.1</td>
</tr>
<tr>
<td>Reduction gear</td>
<td>3</td>
<td>3</td>
<td>6</td>
<td>50.0</td>
</tr>
<tr>
<td>Others</td>
<td>23</td>
<td>10</td>
<td>33</td>
<td>30.3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>180</td>
<td>27</td>
<td>207</td>
<td>13.0</td>
</tr>
</tbody>
</table>

Source: Japan Foundation for Shipbuilding Advancement

Table - 6.5
physical senses of ship's personnel or thorough overhauling of machinery and equipment.

In the present status, satisfactory levels of ship reliability are maintained through detection of failures and subsequent corrective actions undertaken by the skilled crews. As we are now facing with the problem of fulfillment of the number of skilled crews on board from economical reasons, the development of reliable sensors, which are the key-components for ships automation, is urgently required.

6.3.7 Trends in Recent Diesel Ships:

NKK found the following trends in recent diesel ships from their statistical data:

1) Navigation rate is on the increase.
2) The alarm rate in two stroke diesel ships is increasing.
3) The failure rate of purifiers is still high.
4) The reliability of automatic devices/equipment in two stroke diesel ships is being upgraded.
5) Level sensors used for purifier operating and hot water tanks found failures due to fouling are on the increase.
6) The critical failure rate in two stroke diesel ships is decreasing, and this trend is particularly significant on scavenging air related equipment.

6.3.8 Conclusive Remarks on Reliability Investigations:

Following three issues on the present MO ships' needs attention:

1) Effective measures to cope with low grade fuel oil.
2) Improvement in the sensing techniques and monitoring
systems for main diesel engines.

(3) Enhancement of functions and reliability of automatic devices/equipment expected to be free from malfunctioning.

On item (1) attempts are being made through the development of purifiers of new type and at the same time it might be a reasonable idea to use higher grade fuel oil of high price to have safer and more reliable operation of MO ships with the reduced manning. On item (2) there are already improved type of sensor and monitoring systems in the market. Item (3) seems much easier to solve with the improved item (1) & (2).

6.4 Facts About Automation Equipment:

Automation is used mainly for increased accuracy and increased productivity. Automated equipment is more accurate and has better production capability than human beings, provided the system is instructed / programmed well. The weak side of automated equipment is that its intelligence only goes as far as it is instructed to do, which is a lower level of intelligence than a human controller. This is fact that automates can not perform in very complicated systems. The application of automated systems therefore lies in those processes which require a relatively low level of intelligence, but a high accuracy and high productivity. In these areas they perform more accurately and more economically than human being. The advances in microelectronics (ICs) and computers in the last decennia have contributed enormously to the development of very capable and relatively cheap controllers, the heart of automated equipment.

The main reasons of increasing automation in the
vessels are:
- Lower crew cost according to the extent of installing automated equipment for the purpose of labor-saving. As an example, Japan has modernized their flag vessels by introducing automated equipment and classed the vessels according to the degree of automation and has reduced manning from 18 men in class-A automated vessels to 16 in class-B and further to 14 in class-C. They have further reduced to 11 in the P-class ships (Pioneer-ships).
- Optimized the shipboard machinery operation close to the theoretical design conditions. The thermal efficiency of current low-speed engines has now reached values considerably close to the theoretical limits set by their basic parameters (P-max, BMEP, stroke/bore ratio, turbocharger efficiency, etc.). As one typical example, the volumetric air purity at the end of the scavenging process in SULZER - RTA engines has reached a value as high as 95%.

Ship operator's, engine designer's, and naval architect's have made greater contribution in improving operational economy by introducing automation to an wide range.

Step-1 - Ship speeds have been lowered. Reduced ship speed requires less power.
Step-2 - Manufacturers of low speed engine have dramatically reduced the rotational speed by increasing the stroke. Stern apertures of vessels have been re-designed to accommodate propellers of large diameter. Closed stern arrangements had to make place to open stern dispositions with hanging spade rudders. Propeller revolutions can be reduced and due to improved efficiency, less propulsive power is required.
Step-3 - Finally hydrodynamic improvements have been
introduced by refining stern lines, increasing length / beam ratios and adding all sorts of propulsion aids, eg. ducts, fins, vane wheels bulbs, asymmetric sterns, flow straightening nozzles, propellers boss cap fins, etc. Improved hydrodynamics reduce power requirement for same speed.

The reliability and durability of a propulsion plant is influenced by several factors, the most important are:
- Basic engine design and working parameters
- Manufacturing standards
- Maintenance
- Early identification of any malfunction by suitable monitoring system.
- Engine peripherals, such as the fuel, lubricating oil and cooling systems.

All above have improved considerably with the introduction of automation. The principal tools used in reducing fuel oil consumption are:
- Increase of firing pressure
- Increase of stroke/bore ratio
- Reduction in engine revolutions resulting in increased propulsion efficiency in ships with coupled engine.
- Application of high efficiency turbocharging system
- Electronic navigation system through satellite communication guides the ship from departure point to destination following optimum route. The tracking pilot used with total navigation system is expected to allow a saving of about 6% of fuel oil as compared to the old system.

Initially automation was introduced in ships to ease the work load and provide better working and living condition to the ships crew. In recent years automation has
produced better engine room arrangement which eliminate continuous attendance to machinery particulars at sea. Engineers previously employed for watch keeping has been freed to carry out maintenance work.

- Automation has added safety and reliability. Main engine, auxiliary engines, steering gears, navigational equipment, cargo gears, and other equipment have with the introduction of automation exhibited decreased failure rate.

- Automation has changed the organizational structure of the ship operator. Automation in the shape of maritime satellite communication and computer system has greatly influenced the organizational structure and work distribution between ship and head office. To compensate for the higher costs, ship owners have resorted to competitive measures such as greater efficiency, improved safety and reliability, less energy consumption, improved marketing and service. All these has achieved by putting additional investment on ships for automation to make them more reliable, productive and labor saving.

- Automation has reduced building cost in terms of integration, interfacing, installation, commissioning, testing, and also has reduced life cycle cost in terms of manning level, fuel saving, safety, reliability, competitiveness, and performance.

- In one hand automation has increased capital investment, maintenance cost. But, it is not always true proper and efficient management can achieve benefit out of the capital investment in the long run and reduce maintenance cost. To run and maintain these vessels high level of manning skill are required and hence training is more complex and
expensive. Automation has increased workload, reduced training facilities on board and reduced maintenance capability on board due to reduced manning, lack of man power during emergency. These are not always true and will be explained in chapter VII. On the other hand, it has facilitate ease of manning recruitment, provided better job satisfaction, and improved career prospects, increased pay and prestige, greater job challenges to the seafarers. Improved team work and a more flexible work force can be achieved from automated vessels.

- Finally, automation can perform for long periods, without coffee breaks, without sleep, without holidays, and in harsh environmental conditions. It also will not strike or argue for higher wages nor will go to the ITF.
Chapter: VII

IMPACT OF AUTOMATION ON SHIPBOARD
OPERATION

7.1 Trend of manning reduction:-

In ship operation, sail gave way to steam and until the late 1960s, most ocean-going vessels were powered by steam and had separate engine and boiler rooms. The engine department on a such ship of most of the part of the world was typically manned by a chief engineer, second engineer, third engineer, fourth engineer, three fifth engineers or one fifth engineer and two engine cadets, two electricians, three fire/water-tenders, three oilers, and three wipers each standing three watches. Three licensed engineers, three fire/watertenders, and three oilers stood watches, four hours on and eight off, round the clock.

The deck department consisted of as many as 18 members: a master, a chief mate, a second mate, one third mate, three fourth mates or one fourth mate and two cadets, a boatswain, six able-bodied seamen (ABs), three ordinary seamen (OSs), two day men, and a carpenter. A mate, two ABs and one OSs stood each watch. The ABs and OSs also did deck maintenance and anchored, moored, and unmoored the ship. A radio officer completed the crew.

The steward’s department had seven to nine members. Food was purchased in bulk quantities—sides of beef, bags of flour, and boxes of fruit and
vegetables— and reduced to meals by a staff of cooks, bakers, and utility messmen. Meals were served restaurant style. A room steward cleaned officers' cabins.

In the 1960's diesel propulsion came into common use. Ship designers and builders mechanized and automated shipboard machineries. Manual local control system have been replaced with remote control and ultimately automatic remote control brought the location of the control places to an engine control room. During the late 1960's integrated machinery space classified as an unattendant engine room. Similarly, ships navigation systems have changed from conventional bridge to integrated bridge system and integrated bridge to one man bridge. Now ship operators are looking for so called "Ship of the future". All above innovation reduced shipboard manning to a remarkable level.

After second world war, several generations at vessels have been launched. Advances in automation, mechanization and reallocation of crew members responsibilities, have each permitted reduction in crew levels. Western European and Japanese operators are the pioneer in developing all of these. The mid 1980s produced highly automated vessels like the products of the German "Ship of the Future" program: with propulsion, navigation, and communication controls centralized in the bridge; engine room layouts arranged for easy maintenance; and installation of a variety of automated safety equipment. These vessels were designed for crews as small as 11.

In the late 1980s, European and Japanese governments supported even greater automation, centralizing navigation, engine control, communications, and administrative functions on the bridge (which came
to be called a "Ship Operations Center" ) and more mechanization and automation throughout the vessel. Corresponding changes in crew members' job assignments were made in efforts to make the most effective use of both ship technology and labor.

Going back to the early sixties for a tanker a compliment of around 50 was quite normal. But, the same tanker is now manned by 10-12 persons. The reduction of number of people employed on board of oceangoing vessels has been significant feature of the past 20 years. We can see now, many ships coming out of the shipyard that are fitted with many labor saving devices. Many ships are built with latest technology to enable them to run efficiently with manning level of 17/18 crew members or less. We can visualize the phenomenon from the ship operational point of view.

7.1.1 Deck Equipment:

If we look behind, just 10/15 years, derricks were very common on general purpose cargo vessels for cargo handling. It used to take minimum 2-3 hours for rigging before cargo handling and same time for securing by 6-8 deck persons, more over breakdown was frequent. Since these were weather exposed, its maintenance specially greasing was very frequent and labor intensive. Gradually derricks were replaced by cranes. Initially, most of the crane gears were exposed to the weather, causing frequent electrical hazard. Gradually all these components took shelter inside crane housing. Trade pattern has changed remarkably to the design of the ships deck. Though containerization of cargo was introduced in the 1960's but it became popular around 1985 and accordingly ship's cargo gears took different
shape. Nowadays generally a container vessel is having one or two gantry cranes instead of 6/8 conventional cranes. Moreover, there are many container vessels without any cargo gears and depend on shore cargo handling equipment.

Similarly, there has been a remarkable change in the hatch opening system. Wooden batten-tarpaulin hatch cover gave away to chain driven pontoon system and same were replaced by self cleating hydraulic folding type hatch covers.

We can see, all above modernization gradually have reduced crew tasks and eliminated a good number of deck personals. Now, a single person or two can make necessary arrangements for cargo handling and take of the associated equipment.

Automatic sounding and ullage measuring equipment, mooring/unmooring and anchoring auto tension winch with centralized control stands, remote operation of anchor, one man operation of gangway became labor saving devices. New paint and coating systems eliminate frequent ship's structure maintenance, hull and deck chipping, painting diminished requirements for deck personals.

7.1.2 Engine Room Machineries:

Early reductions in engine room crew was made possible by installing automated boilers where no constant human attention was necessary. In an automated boiler, water level is maintained automatically. Firing electrodes ignites automatically getting signal from pilot burner and fire stubbles by the main burner as long photo cells monitors flame condition. So, there is not at all any job for the firemen (for each watch) who
used to maintain manually constant water level and fired the boiler. Similarly three oilers were also relieved from the watches with the introduction of sophisticated engine room machineries which has an auto lubricator and virtually the system does not have any oil leakage.

Ship board electrical D.C machineries were replaced by A.C which used to require frequent maintenance. Steam propulsion engines were replaced by greater economy diesel engines and later slow speed engines leading to lesser units with improved material quality and design, claims that in normal case they do not require to open for maintenance within five years. Also main engine and its auxiliaries control from local to remote and remote to engine control room and with the introduction of high level of automation allowed the system to be as Periodically Unattended Machinery space and could be unattended for prolonged periods of time. The system made the provision to relieve junior watch keeper engineer from the engine room watch and did not bind the only certified engineer to be on watch to be on watch round the clock. So, the watchkeeping engineer can do maintenance jobs not only in the engine room, in deck also and allowing further reduction in shipboard personnel.

7.2 Manning Innovation in the World Fleet :-

In developing the new concept for manning the vessel, ship operators generally adopt one of the two general approaches to allocate management responsibilities between ship and shore. The first approach is called "air line model", in this approach management and maintenance responsibilities are shifted
from ship to shore. Ship crews are responsible only to operate the ship from one port to another port. The other approach is shifting responsibility from shore to ship. A management body is formed, headed by the master. The team is responsible for operating expenses and maintaining budget, operation, repair and maintenance and personnel within the policy/guideline of the company's headquarter. In this system chief engineer is important part of the team, responsible for planning and scheduling maintenance of all mechanical system. In this system efficiency, responsibility and quality of officers job is improved.

In the late 1980s, European and Japanese government have lead the World in manning-related innovations. This phase of innovation has emphasized the centralized control of all ship functions on the bridge, with more comprehensive automation of navigation, engine control, cargo operations, safety and emergency systems, and communications. These changes have been accompanied by reallocations of crew members' responsibilities and dramatic crew reductions and have been supported by careful analysis and experimentation.

In state-of-the-art ships the bridge has become a "ship operation center," housing controls and monitors for essential vessel functions. Many routine navigational tasks, such as chart updating, position plotting, and steering have been automated: For example, aboard the German "Ship of the Future," eight of which were build by early 1989, the ship's position is determined automatically by a computer that integrates information from satellite navigation systems and other equipment. The position is displayed as a dot of light on an electric chart. Ballast is adjusted from the bridge while the ship is underway. Logs, reports,
certificates, documents, and letters are computerized, with electronic mail links via satellite to shore. The level of automation in these ships, and other advanced vessels, not only reduces the need for the helmsman and—in good visibility—the lookout on the bridge, but also reduce the need for deck and engine personnel generally. The result is that some foreign vessels operate with very small crews. Some large Norwegian vessels sail with crews of 8 to 12. The Japanese "Pioneer" vessels have 11-person crews. The German "Norasia" vessels carry 16 persons, but are designed to operate with 12. Japan, which has carried out the world's most ambitious reduced manning program, has mounted a research program to design a fully automated vessel, capable of operation from sea buoy to sea buoy by a single person or, ultimately, an advanced computer.

These radical manning reductions have lead some European and Asian shipping companies to eliminate or blur departmental distinctions with "general purpose" unlicensed ratings and dual-qualified officers. Further reduction may blur some distinctions between licensed and unlicensed personnel; in Japan, for example, some special trained senior ratings already are permitted to serve in charge of bridge and engine watches. In the Netherlands, some ratings supervise anchor watches.

Following are the few examples of manning innovation in Germany, Japan and Netherlands:

Germany:

In 1987 German government introduced license system for the shipboard ratings. At that time they introduced general purpose rating by eliminating separate deck and engine specialist, in the name of
ship's mechanic and can advance to the position of ship's foreman.

In preparation of above changes they experimented for 18 months in four numbers of Hapag-Lloyd AG vessels by 18 crew members, of which seven were general-purpose ratings. The success of experiment led the German government to change manning regulation in 1984. This regulation allowed even bigger ships to reduce manning to 19 in the general purpose concept.

Recently German shipping industry developed the concept of "Ship Management Officer." In this system, a ship manned by such officers would have a master and four ship management officers. In 1986, German shipping industry with government support started training existing top level deck and engineering license officers in the medium-level credentials in the opposite specialties to make them dual-qualified officers. In this system a vessel with controls and monitors centralized on the bridge is normally manned by master, three deck-officer and two engineer officer of dual-qualification in addition to the general purpose ratings.

In 1989, the first of a series of 34,800 tones dead weight container vessels for Hapag-Lloyd, the "Bonn Express", commenced operating with a crew of 15 members.

The salient features of this generation of the ships are:-

(1) Incorporation of both a Ship Operation Center (SOC) and a Board Management Center (BMC).
(2) The SOC, which can be served by one person.
(3) This enables the entire operation of a ship to be controlled and monitored from the bridge. The engine room control console has been eliminated.
(4) The deployment for the first time of all-purpose
officers trained in both nautical and engine-room functions. This allowed the permanent crew to be reduced to 15.

(5) The communication interchange between the vessel and headquarters ashore setting new stands of reliability and efficiency.

(6) Simplification of all technical units so as to achieve a combination of low maintenance costs and high reliability.

By 1994, eleven such vessels will be operating for Hapag-Lloyd with crews of 14. A manning structure of 12 is targeted in the German vessels for the end of the decade.

Japan:

In 1979, Japanese shipping companies started initial experiment with a goal towards elimination of departmental barriers and to introduced shipboard management team. In 1981, they launched first phase of the experiment on board several new vessels whose bridges were fitted with control and monitoring systems for propulsion machinery and safety systems; remote control for mooring winches, cargo handling equipment, and ballast; and satellite position location and communication systems. The distinction between deck and engine departments were removed for unlicensed personnel, and junior officers' positions (third officer and third engineer) were filled by duel-qualified watch officers.

In 1983, manning law was incorporated with 18 man-crew of above pattern of organization and its application was widened to more diverse types of ships. By 1985, 145 ships were started operating with 18-man
crews. Meanwhile, an experiment with 16-man crews had begun in 1982 on board vessels with additional automated cargo handling and navigational equipment. Watched officers replaced engine and deck officers up to the level of second officer and second engineer. In addition, specially trained ratings were used as watchkeepers on the bridge. The success of this experiment resulted in this manning pattern being put into law in 1986 and applied to 98 ships. Also in 1986, experiment with 14-person crews were begun. The vessels' bridges were further automated, with all functions of the deck, engine, and radio watches centralized in a ship operation center configuration, and with addition labor-saving devices for mooring and unmooring. The 11-person Pioneer Ship experiments begun in April 1987 aboard 7 new vessels. The main technical innovation were the placement of auxiliary engine and navigation controls on the wing of the bridge, a labor-saving galley, and "labor-saving oil processing devices with sufficient disposal facility".

The "Intelligent Ship Project " of the 1990s has a designed manning level of 10 based on an equipment standard of 6 months maintenance free. The Japanese training system allows for the major/minor studies to follow a pattern of either N/e or E/n.

Netherlands:­

Dutch shipping companies are the pioneer in using general-purpose ratings and duel-qualified officers. They took up the project 20 years ago. Dutch officers are trained and licensed with major and minor specialties (navigation and technical) and are expected soon to be completely integrated as "maritime officers" or "ship managers".

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Highly trained ship mechanics with general-purpose qualification have been employed aboard Dutch ships since the late 1970s. However they reportedly are generally used in traditional engine and deck specialties, since there has been too little highly skilled work available on today's modern automated ships. Vessels may carry one or two ship mechanics to maintain mechanical systems. More recently, they have been assigned as core crew aboard vessels manned largely with unskilled Third World crew members. In the guise of ship technicians, they may assume supervisory responsibilities in such cases.

7.3 Human Error and Automation :-

Human error happens. It happens in all walks of life, in all aspects of industry and is committed by trained and untrained people alike. Human error can not be eradicated but by careful design and management can be tolerated and high level of automated system can be protected from its effect.

The U.K P&I club's analysis of major claims shows that human error was to blame for nearly 60% of the claims. Eight out of ten personal injury claims were caused by human error, and language difficulties, even between officers and crew on the same ships, contributed to them. Language problems surfaced in the case of property damage as well, as they led to communication difficulties.

The root and intermediate causes entering the conjunction are quite often acts of humans and the diagnosis of what people actually do wrong can be greatly helped by classification of these actions. The classification used in a study by the Society of
International Gas Tankers and Terminals Operations Ltd (SIGTTO) on a number of shipping incidents are presented below.

(a) Cognitive System:
1. Human information processing
   1.1 Senses  1.2 Perception
   1.3 Attention  1.4 Memory
   1.5 Decision  1.6 Risk taking and action
   1.7 Monitoring  1.8 Feedback

2. Visual illusions  3. False hypothesis
4. Habits  5. Motivation
6. Training  7. Personality
8. Fear

(b) Social system
1. Social pressure  2. Role  3. Life stress

(c) Situational System
1. Physical stress
   1.1 Physical condition  1.2 State of Nutrition
   1.3 Drugs  1.4 Smoking
   1.5 Alcohol  1.6 Fatigue  1.7 Sleep loss
2. Environmental Stress
   2.1 Visibility  2.2 Glare  2.3 Temperature
   2.4 Noise  2.5 Vibration
3. Ergonomic Aspects
   3.1 Design of controls  3.2 Design of displays
   3.3 Presentation of materials
   3.4 Policy for dealing with emergencies

7.4 The Role of Automation

The role of automation in process control is to replace manual control, planning and problem solving by
automatic devices and computers. However, the computer is generally left to those tasks which the system designers can not think how to automate, and to monitor the automatic system.

However, a high degree of automation distances the operator from the process being controlled so that, in the event of an emergency situation, the operator is not in full possession of all relevant information required to provide an up to date mental picture of the plant process. This means that an operator in an highly automated plant losses valuable manual skills and mental plant process reasoning, is unable to check the decisions that have been made by the automated system and generally losses vigilance "because the machine is taking care of it ". Automatic and computer systems work on "yes/no" or "if..then..else" logic and are unable to cope with doubt, gut feeling and other intuitive skills that highly experienced manual operators can call upon to perform their task in an un-automated environment. In their favor, automated systems probably allow the most economical plant operation to be carried out, irrespective of the skill of the operator.

Automated computer systems are only as good as the system designer and the software programmer and it is essential that human error is avoided in design and writing the software. This requires a thorough understanding of the process being controlled and whilst software "bugs" are likely to be removed form stable state process operation, there is potential for the inclusion of latent errors in infrequently used software routines called into operation during plant or process excursions from the stable state. Evidence suggests that over 60% of automation errors are committed during
the specification/requirements and design phases and the remainder during software coding. The coding is the final stage of the whole design process and the more complex the system, the more faults will stem from ambiguities and omissions in the specification stages. Investigations by the United Kingdom Health and Safety Executive found that 20% of incidents were caused by inadequate consideration of hazards when using programmable system. The systems had worked as intended but had not been designed to take all potential problems into consideration. Another 17% of incidents had been caused by software error, 12% were due to the poor design of the man-machine interface and 5% were caused by hardware errors, usually sensors.

7.5 SAFETY

Some operators, maritime labor unions, and regulators have voiced concerns that reduction in crews, if not managed properly, could degrade safety. Some believe maintenance is widely neglected. Other say fatigue - a perennial concern aboard ship - has grown more widespread and more serious. Still other worry that the elimination of entry-level positions has degraded the skills of unlicensed crew members.

These concerns, if substantiated, would be expected to manifest themselves in increased accident rates, yet data to prove or disprove them are scarce. Available casualty and accident data bases are insufficient for firm judgements, and no full-scale statistical study of the problem has been done so far. The National Research Council, U.S.A, collected personal injury data of a 16 company ships through a large operator over six years during which crews were reduced.
from 34 to 21 to evaluate the effect of smaller crews on maritime safety. They observed that during this period, the annual rate of injuries per crew member remained stable. While this isolated case demonstrates the possibility of making meaningful statistical assessments, it is grossly insufficient as a basis for general conclusions. Comparable data covering a broader range of casualties and accidents and a large cross-section of the world's fleets are needed.

It has been observed from Lloyd's vessel loss data that the rates of ship casualties and personnel injuries have declined steadily during the crew reductions of the past 20 years, the contribution of manning practices to this safety improvement is observed by the fact that many new technological advances and safety requirements, with no bearing on manning, have occurred simultaneously. Anecdotal evidence of growing safety problems is compelling to many, but there is a lack of substantiating data to support or refute these perceptions.

7.5.1 Lloyd's Vessel Loss Data:

Figure - 7.1 displays worldwide vessel loss rates (percentage of ships) for commercial ships, 1970-1988. During this period, the loss rates have dropped from about 0.65% to 0.32% per year, a 50% decline. Although total losses worldwide are a gross measure covering large and small vessels, the figure demonstrates that the combined impact of all factors including changes in the size and types of vessels sailing, ship design, manning, and operating practices - has been to reduce total vessel losses substantially.
In terms of tonnage shown in figure - 7.2 (a more accurate indicator of commercial activity), a downward trend is also evident. Although there was an upturn in the late 1970s, over the past 18 years annual tonnage losses have declined 20%, from about 0.35% to 0.28% per year.

7.5.2 Marine Index Bureau Injury Data:

Marine Index Bureau, issued statistical data on injuries. Figure - 7.3 shows that, over the year 1970-87, the aggregate incidence of injuries per working seaman in U.S deep water vessels has declined by more than 40%, from about 0.45 to 0.25 injuries per year per seagoing employee. While this is a gross aggregation of data, it supports a conclusion that during the last two decades the net impact of the aggregate changes in the seagoing environment has been to reduce injury rates for seamen significantly.

7.5.3 Individual Company Data:

The National Safety Council (U.S.A) obtained some safety data from an individual ship operator who has reduced crew members from their ships. Figure - 7.4 shows trends in the number of billets, casualties, material failures and breakdowns, and personnel injuries and fatalities per ship for a company during three-year intervals from 1973 to 1988. While injuries and fatalities have declined as manning dropped, ship casualties fluctuated around an average of 0.53% ship year.

Data provided to them by another company shown in figure-7:5 indicates declines in oil spills per vessel.
The decline in the % loss of commercial ships since 1970 has been linear at a confidence level exceeding 99%.

Source: Lloyds Casualty Reports.

The decline in the rate of loss of commercial tonnage since 1970 has been non-linear (power function) at a confidence level exceeding 99%.

Source: Lloyds Casualty Reports.

The decline in the injury rate for oceangoing seamen since 1970 has been linear at a confidence level exceeding 99%.

Source: Marine Bureau Index.
Figure 7.4. Trend in number of billets, casualties, material failure/breakdown and personnel injuries/fatalities per ship for a company during consecutive three-year intervals from 1973 to 1988 (index with 1973=1.0). Source: Marine Board Survey (U.S.A).

Figure 7.5. Manning levels and annual rates of oil spills per vessel of a company, 1974-1989. The solid line is a linear regression fit to the data. Source: National research Council (U.S.A).
and personnel injuries per million man-hours worked. Oil spills per vessel have declined 45% in the last 15 years, and injuries per million man-hours worked have declined 50%. Since, as shown, the average number of employees per vessel of that company has declined 30% (from 30 to 21) the absolute number of injuries per vessel has dropped 65% during the 15-year period.

7.6 Safety Concerns:

Ship operators generally believe safety has improved aboard automated ships with smaller numbers of crews, owing greater safety consciousness and improved equipment. But, many union representative believe safety has deteriorated with smaller crews. They point to increased fatigue due to longer working hours, maintenance practices, and fewer opportunities for on-the-job training. However, there has been a measurable and substantial improvement in the rate of vessel casualties (accidents) and personnel injuries during last decades.

The Nation Research Council noticed that, there are many safety concerns, should be the object of effort to further improve safety.

(1) Fatigue:

The potential for fatigue is the safety concern, inattention of which can cause accident. A few casualties have been attributed to inattention associated with fatigue. Long working hours are common in the maritime industry which is also a means of increasing their take-home pay. Where long hours are a recognized problem (e.g., the round-the-clock cargo responsibilities of deck officers or the heavy work
loads imposed by frequent port calls), many companies employ personnel in excess of the minimums set by the authority to compensate for the increased workload. Others use shore-based personnel for cargo operations, so that crew members may rest.

Little information is available to indicate the increase or decrease in working hours as crews have been reduced. Management of the shipping companies opinion in this regard is that average working hours need not increase and that in some cases fatigue may decrease; for example, in engine rooms certified for unmanned operation, engine department personnel can work days only instead of standing four-hours on, eight-hours off watches. In a given situation, either point of view may be correct, depending on the degree of work planning and management of work effort.

(2) Maintenance Practice:

Traditionally, vessel crews has done most of the deck and engine maintenance. Newer materials and design changes have eliminated some of this work or made it a biennial shipyard/dockyard repair item. Nonetheless, ship safety will be impaired if reduced manning causes deferral of needed maintenance on safety-related equipment. To avoid this potential problem while carrying smaller crews, some companies employ "riding crews" or repair firms to perform needed maintenance in port.

(3) Emergency response capacity:

More attention to safety systems and emergency procedures will be necessary as crews are reduced day by day. Three general categories of emergency should be considered:

First - and perhaps most critical - is the "all
hands" type, such as fire and explosion, collision or grounding. Vessel design and personnel training can help ensure the shipboard capability to evaluate and respond. Preventive maintenance programs can help ensure that the vessel is in condition to operate properly and safely. Strict adherence to safety procedures is also necessary.

Second, the vessel must be able to operate safely in case of power losses and failure of vital equipment such as steering gears, navigational equipment, mooring equipment, the main propulsion plant including failure of automation and problems with diesel engines or boilers, and cargo gears.

Third is the ability to handle personnel casualties. Manning decisions must allow rapid and efficient response without depriving the vessel of its ability to operate. For example, evacuating a crew member by helicopter requires enough personnel to transfer the injured person as well as enough to operate the ship. Rescues at sea presently involve at least people in addition to those left aboard to operate the ship. Launching and retrieving lifeboats also can be labor intensive.

(4) Reduced Training Opportunities for Unlicensed Personnel:

The elimination of entry-level positions on many vessels has reduced the opportunity for on-the-job training. To prevent such problems, some companies have instituted "cadet" programs to train unlicensed personnel. Others hire in excess of the normal compliment until crew members gain the necessary experience.
(5) Service Continuity by Crew Members:

The continuity of service by crew members is an important safety factor, particularly with high degree of automated and sophisticated shipboard systems requiring intimate knowledge. Repeated service aboard the same vessel ensures familiarity with the equipment and promotes teamwork. Crew level of 9 to 11 person would require 100% continuity.

(6) Physical demands on Crew Members:

The reduction of ship board crew members is growing the need for physical fitness of them. Smaller crew means fewer people available for emergency operations and very likely fewer physically strong people in situations where strength is needed. Assessment of minimum manning levels must take in to account the degree to which labor-saving automatic devices are available (as mentioned earlier in chapter 5) or tasks requiring strength have been eliminated.

(7) Changed Shipboard Social Conditions:

With the smaller licensed and unlicensed group of ships crews and the breakdown of some of the traditional distinctions between the deck, engine, and steward's departments, new social structures will be necessary. Some companies are already promoting the ship's team concept, an effort that may be assisted by movement toward greater continuity of assignments. One ship operator, whose ships carry crews as small as 14 persons, reported that it had used psychologists from the beginning of its manpower reduction program.

7.7 Legal and Regulatory Issues on Manning:

In addition to the safety requirements set by the
domestic law, all ships must meet certain requirements set by international conventions. The existing international agreements, however, provide no clear framework for assessing manning issues.

(1) International Maritime Organization (IMO):

IMO's main objective is to facilitate cooperation among governments on technical matters affecting international shipping in the interest of safety and efficiency. IMO has special responsibilities for safety at sea and for preventing pollution by ships of the maritime environment.

Much of IMO's work is devoted to producing and implementing international conventions. These conventions nearly address all aspects of maritime safety: ship design, construction, equipment, operation, and the competency of crews. IMO has not to date addressed specific manning levels. The STCW convention specifies the qualification of crew members and their watchkeeping practices, but is silent about crew levels. Many shipping states have requirements that exceed those of STCW in many respects. The SOLAS conventions addressed manning in Chapter-V, Regulation-13, by stating that, governments "undertake measures for the purpose of ensuring that, from the point of view of safety of life at sea, all ships shall be sufficiently and efficiently manned". Following up on work at the IMO that produced the STCW convention, the IMO Assembly adopted Assembly resolution A.481(XII), "Principles of Safe Manning," in 1981. This resolution urges IMO members governments to ensure that each seagoing ship to which STCW applies carries a document specifying the vessel's minimum safe manning. The nonbinding resolution also contains recommended manning practices for bridge watches, mooring and unmooring, and other
shipboard functions. It does not specify the levels of manning recommended, except in the case of bridge watches.

(2) International Labor Organization (ILO):-

ILO is a United Nations body concerned with matters such as worker safety, compensation, and conditions of employment. The ILO Convention Concerning Minimum Standards in Merchant Ships (ILO 147) was adopted in 1970, and entered into force internally on November 28, 1981. This convention requires that the member states implement safety standards including competency, work hours, manning, appropriate social security measures, shipboard employment conditions, and shipboard living arrangements. This convention is similar to IMO resolution mentioned earlier and in that contracting governments must set their own standards. The significance of the ILO convention, however, is that its provisions are mandatory (flag states must set national standards) and contain enforcement provisions (giving port states some enforcement authority over vessels entering their water). Article 4 of ILO 147 allows a port state to rectify any conditions that are clearly hazardous to safety including insufficient manning.

7.8 CONCLUSION:-

Rates of maritime casualties and personnel injuries, world wide, have declined steadily over the last two decades, at the same time the manning of vessels has been reduced. While concerns about safety have been raised - including neglected maintenance, increased fatigue and stress, and lesser opportunities for on-the-job training - management, labor unions, and
governments have addressed these concerns through training, qualification standards, technological development including automation and other management techniques.

The introduction of new technology/automation in ships has taken account not only of the technology, but also of the human factors issues affected by the technology. Ships are considered as sociological systems, consisting of technologies, personnel, organizational structures, and an external environment. Change in any of these four sub-systems should be accompanied by appropriate change in the others. With appropriate training, organizational innovations, and ergonomic design, new vessel technology will not degrade safety. These approaches, for example can reduce the potential problems of stress, fatigue, and boredom.

The developing countries, at present, does not have the necessary tools to make solid certification decisions about highly automated ships. Training programs will need to be altered as new technology is adopted, to reflect changes in work organization and the shipboard environment.
8.1 Introduction:

Developed countries having substantial resources and less manpower, can go for highly automated vessels like the Pioneer ship, ship of the future, one man bridge ship, and can justify a substantial reduction of manning levels on ships. However, the developing countries, like Bangladesh, with a surplus of cheap labor, lack of logistics to cater for spare parts availability, shore base high-tech repair facilities, highly trained personnel and on top of all a scarcity of financial resources, cannot justify such a high capital intensive venture without careful evaluation, analysis and judgement.

In this chapter I am going to analyze, evaluate, and judge whether we should go for automated vessels despite techno-socio-economic conditions mentioned in chapter II. If yes, then it is the aim to find out:

- What level and mode of automation we should have,
- What level of manning should have to operate those vessels,
- What level of training to be imparted to them to operate and maintain the automation,
- What amount of shore support and back up facilities to be provided to the vessel.

8.2 Cost Benefit Analysis:

To analyze the cost benefit it is necessary to
find out additional investment costs for a shipowner for procuring a newly built automated vessel.

8.2.1 Costs for Automation:

(a) I have contacted M/S GEC Alsthom, a highly reputed and busy shipyard in France, and requested to evaluate the cost difference between a conventional and a UMS tanker, container, and multipurpose vessel. They were kind enough to inform me of the following:

1. For ships such as tankers, container carriers, general cargo, multipurpose vessels, there are no important and remarkable cost differences for automation even when considering:
   - type of ship,
   - size of ship,
   - installed base power.

2. A comparison between conventional and UMS ships (values are given in million French francs - January 1992)

<table>
<thead>
<tr>
<th>AUTOMATION FOR</th>
<th>CONVENTIONAL</th>
<th>UMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine Control Room</td>
<td>1.0</td>
<td>1.5</td>
</tr>
<tr>
<td>Remote Control</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>UMS</td>
<td>-</td>
<td>1.5</td>
</tr>
<tr>
<td>Electric Switchboard</td>
<td>-</td>
<td>1.0</td>
</tr>
<tr>
<td>in Engine Control Room</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>2.0</td>
<td>5.0</td>
</tr>
</tbody>
</table>
(b) Similar new building costs for automation have been received from the Japan Shipowners Association, summarized below:

<table>
<thead>
<tr>
<th>SHIP TYPE</th>
<th>MANNING LEVEL</th>
<th>ORE/BULK CARRIER</th>
<th>BULK CARRIER</th>
</tr>
</thead>
<tbody>
<tr>
<td>TYPE</td>
<td>GRT</td>
<td>93,000 GRT</td>
<td>37,000 GRT</td>
</tr>
<tr>
<td>MEO-type</td>
<td>22</td>
<td>61,000 ¥/GRT</td>
<td>78,000 ¥/GRT</td>
</tr>
<tr>
<td>A-type</td>
<td>18</td>
<td>63,000 ¥/GRT</td>
<td>82,000 ¥/GRT</td>
</tr>
<tr>
<td>B-type</td>
<td>16</td>
<td>63,000 ¥/GRT</td>
<td>83,000 ¥/GRT</td>
</tr>
<tr>
<td>C-type</td>
<td>14</td>
<td>64,000 ¥/GRT</td>
<td>85,000 ¥/GRT</td>
</tr>
<tr>
<td>Pioneer-type</td>
<td>11</td>
<td>64,000 ¥/GRT</td>
<td>85,000 ¥/GRT</td>
</tr>
</tbody>
</table>

(c) There is an article on "The design and construction of the ships of the future" in the Motor Ships, written by Mr. K.H. Paetow of HDW. HDW is one of the most reputed shipbuilders in Germany and provides project management to the ship of the future (sdz). We can get an indication of costs for the automation and labor-saving equipment additionally invested on the sdz type of vessels (described in chapter-IV) from the article.

Mr. Paetow compares sdz vessels with a 12 man-German crew with conventional vessels of 24 man-German crew and concludes with the opinion that the additional investment for advanced technology and automation could be realized within four years.
8.2.2 Automation Cost Analysis:

We can roughly estimate from the above data that it will cost an approximate additional one million USD for the UMS class and other medium level automation on the bridge and other sectors, and three million for a highly automated vessel like the sdz.

8.2.3 Manning Savings:

At present BSC vessels are manned by an average crew totally 45, which is not even in line with other developing countries. In the 1970s, when developed countries used to manned their vessels with crews of about 30/35 then we used to man them with a crew of 50/55. Since then fuel, labor, and other ship operating costs have increased considerably. Economic competition in shipping has increased, technological changes, automation, mechanization, and labor saving shipboard equipment have resulted in a continual reduction in the sizes of crews in the developed countries and also in a lot of developing countries. Today the average crew in recently built U.S or other European flag vessels totals 20 to 22. Similar North European vessels are manned by crews of 12 to 16. Recent high automated ships may operate with crews of 8 to 10. The Danish ship of the future is certified to be manned by a 6 man-crew.

Around 1980 BSC procured four vessels from Japan of a similar size and capacity and out of them two were UMS vessels. But, the crew level of both the vessels of UMS and non-UMS were the same, 48 (LBC-55).
They did not even consider to take advantage of UMS by reducing at least the manning level. One of our vessels, the m.v. Banglar Kakoli, a UMS class vessel, made a recent visit (August 93) to Europe with a crew of 45.

### OFFICERS

<table>
<thead>
<tr>
<th>Master</th>
<th>Chief Engineer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chief Officer</td>
<td>Chief Officer Second Engineer</td>
</tr>
<tr>
<td>Second Officer</td>
<td>Third Engineer</td>
</tr>
<tr>
<td>Third Officer</td>
<td>Fourth Engineer</td>
</tr>
<tr>
<td>Cadet -- 3</td>
<td>Fifth Engineer</td>
</tr>
<tr>
<td>Radio Officer</td>
<td>Electrical Engineer</td>
</tr>
<tr>
<td>Purser</td>
<td></td>
</tr>
</tbody>
</table>

### RATINGS

<table>
<thead>
<tr>
<th>Carpenter</th>
<th>Diesel Mechanic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deck Serang</td>
<td>Engine Serang</td>
</tr>
<tr>
<td>Sea Cunny - 3</td>
<td>Electrician</td>
</tr>
<tr>
<td>Laskor I - 3</td>
<td>Greaser - 3</td>
</tr>
<tr>
<td>Laskor II - 3</td>
<td>Fireman - 1</td>
</tr>
<tr>
<td>Bhandary</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Carpenter</th>
<th>Diesel Mechanic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deck Serang</td>
<td>Engine Serang</td>
</tr>
<tr>
<td>Sea Cunny - 3</td>
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<tr>
<td>Laskor I - 3</td>
<td>Greaser - 3</td>
</tr>
<tr>
<td>Laskor II - 3</td>
<td>Fireman - 1</td>
</tr>
<tr>
<td>Bhandary</td>
<td></td>
</tr>
</tbody>
</table>

Our vessels cannot operate in isolation because shipping is an international industry. So, it has now time to review our crew levels and to establish the level considering our socio-economic condition, otherwise we will not be able to build prototype vessels or procure secondhand economically viable vessels. None of these vessels has a higher crew capacity, though our government's policy is to create more job opportunities. However, in shipboard employment this will not only increase the ship.
building costs because of a higher number of accommodations, it will also curtail cargo carrying space and hence loss of revenue. Before establishing crew levels, it is my opinion, when major parts of the world can operate their vessels with an 18 - 20 mancrew then why cannot we run our same type of vessels with at least crews of 35, provided we go for automation to the level of UMS class and use some labor saving equipment.

Now, the question is, in this case, how much we will be able to save? Reducing the number of junior officers and ratings to 13 we will be able to save a maximum of 80,000 USD per year. In this case generally speaking, it will take more than 10 years to recover the additional investment for the above mentioned UMS vessels and may be more than 20 years. This means not in the vessels life for the sdz type of vessel.

6.3 Feasibility of Automated Vessels:-

Then next decision is under above circumstances whether we should go for automated vessels! In my opinion the answer is yes, and apart from the benefits and reliability of automation, mentioned in chapter VII, the additional reasons are:-
- Investment for automation is not large compared to the total cost of the vessel. It is within one percent of the total cost.
- Savings in crew reduction may not be remarkable. But, an efficient management / ship operator can get other benefits and can reduce the ship operating costs.
- Machinery and equipment in automated vessels and
automation itself are more efficient. It has been proved that sdz type vessels can save fuel only by 25% as compared to conventional vessels.

- Maintenance and spare parts consumption is reduced.
- The duty of national flag carriers is also to look after the nations’ interest. It facilities training to the seafarers, who can earn foreign exchange later by serving foreign companies. So, if the vessels' automation is not up to the level of international standards then how can they get proper training and serve outside! As we have seen in the past, our crews were occupying a big part of the international shipping market since they were hard working, obedient, and disciplined. Now, technological development has modernized the ships, ship operation needs brains and know-how rather than mussels. They lost the track since they could not move with the wind.

- It has been viewed that another way of surviving in the shipping economic competition is to procure secondhand vessels 5/6 years old. It is beneficial for the developing nations because of their limited resources as well as 5/6 years of running the vessels equipment can be identified from the proven technological point of view. Most of these vessels are designed for their high level of automation and require competent and skilled personnel to grasp the technology. So, if we are not with the present shipping trend, then we will be nowhere in the economic competition.

- If we consider the evolution of technological revolution in the electronic world, we can find even two decades before the vacuum tube was dominating feature in electronic components, even in our daily
used articles. If had not followed the trend of technology then at this stage no manufacturer would make equipment for us with such components. A solid state transistor is a hundred times cheaper than a vacuum tube, and a micro processor which may dominate the next few years in the electronics world is much cheaper than a transistor, more efficient and can perform more functions. This is why the price of electronic equipment is falling day by day and becoming more efficient. The first electronic digital computer weighed over 30 tons and filled several rooms. It required several thousand watts of power to operate and its maximum speed was less than 5,000 calculations per second. It cost millions of dollars. In contrast a tiny micro computer chip that can sit on a finger tip is approaching 1,000,000 calculations per second, operates on less power than a flash light, and costs under 1000 USD.

Considering the above, if we are not with the present trend of shipping technology, then no manufacturer will make equipment for our needs and moreover it will not be cost effective. If we want to build a vessel 10 years later, at that time no shipyard will be in a position to build a vessel fitted with equipment which we are used to.

- Shipping also exchanges technology. Imported technology might influence shipping supporting industries as well as the industrial development of the country.

Considering all the above views, in my opinion we should go for medium level of automation for our
8.4 Mode of Automation:

My next function is to decide the mode of technology or product which we should use to automate our vessels. In my opinion it should be microprocessor based solid-state products.

Devices using the latest technology are not always immediately incorporated in maritime industrial design when processes are being automated. The additional factors are cost and proven reliability which have often led to more traditional approaches in the equipment.

Since the PC hardware is all solid state (no moving parts) and the operation of the control logic occurs in memory rather than with actual relays, the problem of changes in the timing of relay contact opening or closing is eliminated. Such changes in timing, which are common real relays, may change machine sequencing and cause unsafe operation. In contrast, a solid state memory is very reliable and has a much longer life expectancy than a relay contact. Electronic equivalents of electro-mechanical sequencing drum timers, time-out timers and counters also are built in to the controller and need only to be programmed to be used. No additional hardware is required. This extra capability of a PC can often simplify and improve the performance of the control system without increasing cost. PC controllers perform the same function as electro-mechanical relays, timers and counters, can perform mathematical calculations, can be easily programmed rather than rewired and have a performance that is much more
The mechanical or electro-mechanical (relay logic) parts usually cause reliability problems. Either preventive maintenance or repair downtime must be considered for the machine.

Electronic control does not totally eliminate the mechanical or electro-mechanical parts, but reduces the number significantly and improves reliability accordingly. As a result, downtime is reduced and time between preventive maintenance is increased greatly.

When proper design margins are included, most electronic failures or machine failures can be traced to solid state connections or cable connections. Using integrated circuits where all components are made at the same time on a slice of silicon with uniform and standard processing, the interconnection by solder connections and cables is greatly reduced. Orders of magnitude improvement in reliability occurs because of this fact.

Even though a new electronic control has not been used previously, the reliability of individual components (which has an excellent history because they have been manufactured for some time) provides an excellent foundation for a predicted reliability of the new control.

The reliability of a new family of integrated circuits may be predicted based upon the proven reliability of similar types of integrated circuits.
made in the same process. Thus, the reliability of the new product which uses the new IC can also be predicted to provide confidence in using the new product in the system.

Because of the complexity of microprocessor systems it is normally not possible for the ship's personnel to trouble-shoot and repair faulty components on printed circuit cards. PCs are constructed by modules with LEDs, which clearly indicates the status of the module. Therefore identification of replacement is easy for a ship's personnel. This gives a new maintenance concept, the maintenance by replacement. Moreover, the university of PC systems enables the same type of hardware to be utilized for several automated functions on the same ship. Therefore, one set of spare modules can serve several systems. Additionally, PC system spares, which are just modules, are usually much cheaper than the spare cards required for special purpose computer systems.

During procuring vessels we consider the lifetime of a vessel as being 20 years, but many ships built before 1965 are still in use. Their control systems are mainly on a relay logic system and now experiencing many problems with regard to efficiency, reliability and acquisition of spare parts. I believe, with the presently available microprocessor based system we could have encountered all the above problems easily at a moderate cost.

So, considering all the above merits, in my opinion, we should go for microprocessor based solid-
0.5 Conclusion:

It was analyzed that we needed to take the necessary steps immediately to go over to the UMS class in the machinery space automation and medium level of automation in the bridge to automate our vessels. The mode of automation should also be microprocessor-based solid state products. To maintain and run these vessels economically and efficiently it is necessary to impart training to our ship personnel, improve shore repair facilities at home, especially as most of our vessels make at least 3/4 calls in a year at home ports and stay for a considerable period and moreover lighterage vessels spend most of their time at Chittagong. It is also necessary to re-organize the technical and commercial departments of the shore office so that they can provide the required improved support. Finally it is also necessary to establish crew levels on board the vessels.
Chapter IX

RECOMMENDATIONS AND CONCLUSION

9.1 Recommendations:

In the previous chapter it was analyzed that we should go for automated vessels. A medium level of automation, like the UMS class of microprocessor based on solid state products, should be used for automating our vessels. To run the vessel efficiently and successfully we need to:

- establish our crew level,
- train our ships’ personnel,
- improve shore repair facilities at home, and
- re-organize the shore supporting system.

In this chapter I present my recommendations to improve the above structures.

9.1.1 Specification on Automation of the vessel:

The automation of the vessel should meet the following general guidelines/requirements:

A centralized engine room and bridge control system, meeting all regulatory requirements for Unattended Machinery Space operation, shall be furnished providing integrated remote control and an information display. The plant shall respond automatically to either bridge or engine room throttle
control over the complete range of plant operations.

During all cruising and maneuvering modes, the integrated engine room control system shall continuously monitor all important temperatures, pressures, flows, levels, and electric load characteristics.

The automation equipment of the vessel shall meet all the requirements of Unattended Machinery Space (UMS / MO / EO) as described in Chapter V and satisfy class requirements of the classification society with whom the vessel is classed.

The automation system shall be microprocessor based with a minimum of two CPU’s and a hierarchical design on a fully modular concept, distributed control system.

One part of the system shall be dedicated to the control of the power generation plant / generator control.

It shall, in a particular manner, be possible to operate the ship in case of instrumentation and control system failure. Back up facilities or equivalent system shall be arranged to keep control of all functions in case of automation system failure. Back up facilities shall be provided for effective local control of all automatically controlled functions. Such local control shall be readily transferable from automatic operation under emergency conditions.

In case of bass communication breakdown, a separate group alarm shall be installed in the control room. The group alarm shall indicate the individual local process station in the alarm. Separate hand wiring shall be installed for this group alarm.

The system shall be arranged with a double independent bus cable or coaxial system to facilitate reciprocal redundancy between units. The individual
bus cables shall be routed separately from each other and be well protected both against fire and mechanical damage. The cable shall be of a high temperature type making it possible to operate as long as possible during a fire. Any fault in the bus communication shall give the alarm and a diagnostic system shall identify the problem and the location. The installed equipment shall be able to operate continuously in the environment where it is installed.

Power supply systems shall have redundancy. Any channel that utilizes a current signal shall be constructed with an individual electronic current limitation device. The system's diagnostic system shall be able to identify and locate faults such as overload, earth fault, etc. down to the individual channel.

The control system design shall allow automatic plant operation across the full operating range with variables maintained at their set values. All control loops shall be capable of manual operation from a manual loading station incorporated in the process station. Control valves will be equipped with manual handwheel and by-pass.

An electronic positioner converter associated with pneumatic positioner may be used.

In case of power failure or re-connection on process station used for digital command the output command shall not change. The system shall be designed and well documented for trouble shooting and easy maintenance. The system shall report alarms and events on separate printers.

Computer Aided Performance Analysis (CAPA), or its equivalent performance analysis system suitable for the type of main engine fitted, shall be installed as a diagnostic tool for monitoring and maintaining engine performance. The system provision shall be
there to get engine performance values required for diagnostication which can be entered into the computer manually by the ship’s engineer from the normal engine monitoring system. The software program shall be used in a PC with MS-DOS or PC-DOS operating system and should not require more than a 2MB harddisk. It shall be possible to easily store an alarm and to transfer this data to an IBM compatible PC. It shall be possible to define and modify display and report formats by ships staff in to the PC.

The PC and all necessary software and hardware for transfer to, and editing the PC shall be supplied. The PC shall be equipped with the following minimum standards:

CPU: 486DX-33Mhz, 4MB RAM, 120MB hard disk, 2 serial ports, one printer port, one mouse port, monitor - Super VGA graphics, MS-DOS 6, Microsoft Windows and mouse.

All motors in the propulsion, power generation and domestic system such as FW hydrophore circulation and pressure pumps, gray and black water sewage pumps etc. shall be controlled and monitored by the system. In addition a manual centralized back-up control system for selected equipment shall be installed to facilitate running if faults occur in the automation system. The systems concerned are the systems for ME and AE (LO, CW, FO) critical for the operation of machinery. Full redundancy shall be planned for all standby systems both with regard to the main power supply and the control system. Each motor in pump pairs shall be controlled from different Process Control Stations (PCU). The programmable group start of motors for electric motors related to propulsion should be arranged.

None of the installed equipment shall be affected by the use of any of the ship’s communication
The instrumentation for monitoring, alarms and control, including motor and valve control, shall be separate micro-processor based systems with a distributed configuration and shall be monitored by a minimum of two independent CPUs.

The system shall be able to distinguish between short circuit/earth/break in sensor cables for normally open contacts (pressure switches—flow switches—temperature switches—level switches—breakers).

The fault finding shall be explained in comprehensive and easy to read manuals. A flow diagram or equivalent representation and a program listing of control logic shall be supplied. Suitable media such as EPROMS or hard disk with back up programs shall also be supplied.

It shall be possible to easily distinguish between critical or non-critical alarms on the screen. Critical alarms are in this case defined as alarms where immediate attention is required.

Identification of critical and non-critical alarms is possible by use of color differentiation or an equivalent solution.

Alarms shall be blocked at normal stop of machinery. Listing of blocked alarms shall be available.

The setting of alarm parameters for each individual point shall be possible by the ships staff. The alarms shall include, but not limited to, the following:

1. One high alarm and one low alarm on all analog channels.
2. Transmitter out of range.
3. Time delay adjustable up to 60 seconds.
For FW/LO/SW/F0 the temperature control loops shall be a part of the automation system using PID controllers in by-pass control. Three-way valves shall be used.

All of the primary monitoring and control equipment associated with the cargo refrigeration systems shall be located within the engine control room. This will include the monitoring and control equipment associated with the refrigerated cargo stowed in the holds as well as the refrigerated cargo stowed in the on-deck reefer containers.

Instrumentation:

All instrumentation and related equipment shall be of a design and construction proven in marine service and be obtained from internationally well known marine suppliers. Each element to be able to withstand the different environment and temperature to which it will be exposed.

Great care shall be taken with regard to calibration/checking facilities. Zero, calibration and set point adjustment shall be easily accessible with the sensing device in its location and sensing position.

Calibration and test procedures for the various systems and equipment shall be described in detail.

All level indication signals shall be available with the possibility to set both high and low level alarm with time delays.

Valves and pump motors in the various systems mentioned under the level indication section shall be connected to the central monitoring system for monitoring and control.

A bilge pumping system shall have an arrangement where the closing of individual suction valves is controlled by the alarm mobrey, and the pump is
9.1.2 Manning Level:

The next step is to consider the manning level. In paragraph 8.2.3 I have tried to explain circumstances under which we need to review our vessels manning level.

It is not always true that reducing manpower will decrease quality of maintenance or hamper shipboard operations or increase ship operation costs. I have gone through an article on "Nine years' experience with low manned vessels and future low manned concept" by Mr. Bengt Olofsson. He was ship manager of M/S Transatlantic, a Swedish owned company. In 1977 they procured MS Trebeland a 33,000 DWT RO/RO vessel and manned by a 16-man crew. They expected that with reducing the crew, maintenance, repairs and other ship operational costs would increase. The actual result showed that not only the personnel costs were reduced but other costs as well. The maintenance, spare parts and repair costs, including dry docking, showed the following development:

<table>
<thead>
<tr>
<th>Year</th>
<th>1979</th>
<th>90</th>
<th>91</th>
<th>92</th>
<th>93</th>
<th>94</th>
<th>95</th>
<th>96</th>
<th>97</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESTIMATED</td>
<td>0.397</td>
<td>0.417</td>
<td>0.438</td>
<td>0.446</td>
<td>0.462</td>
<td>0.482</td>
<td>0.506</td>
<td>0.522</td>
<td>0.548</td>
</tr>
</tbody>
</table>

(Calculated 9 years average at project stage
0.340 million
USD with 1%
Inflation each year.)

<table>
<thead>
<tr>
<th>Year</th>
<th>1979</th>
<th>90</th>
<th>91</th>
<th>92</th>
<th>93</th>
<th>94</th>
<th>95</th>
<th>96</th>
<th>97</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACTUAL</td>
<td>0.130</td>
<td>0.225</td>
<td>0.304</td>
<td>0.370</td>
<td>0.350</td>
<td>0.318</td>
<td>0.190</td>
<td>0.308</td>
<td>0.232</td>
</tr>
</tbody>
</table>

The actual cost became half of that calculated and in fact lower than they had assumed if the vessel had been running with a 24 man-crew. At the same time they made a savings of 400,000 USD / year (108
USD/ton) as bunker cost. The vessel was planned off-hired during 8 years for only 17.8 days for dry docking and 13.3 hours per year as unplanned off-hire.

Every man is important in a small crew and this improves the working morale as well as the general quality of the crew. The detailed calculation of man-hours was worked out and discussed by the senior officers. This resulted in good pre-planning, where everybody knew the expected work load. Shortage of manpower made it necessary to establish priorities such as avoiding unnecessary work; more condition-based running hour-actual experience based maintenance; simplifying routines; minimizing paperwork. Priority given to equipment, which can cause off-hire in the case of failure. Only failures or deviations from normal operations are reported to the head office. Good cargo planning, i.e. trying to get optimum trim with minimum ballast quantity; preplanning of the voyage and continuous follow-up to cover distance between two ports could reduce fuel consumption. Seminars for all officers held once a year when fuel efficiency, running cost etc are evaluated and discussed. On the successful operation of MS Trebeland they have taken on another project, Rp/Lo 51.500 DWT vessel. Theoretically they believe it could be run with about 6-8 persons, with a full scale test of a crew 10 to 12 persons.

In this decade it is really inconceivable to run our vessel with crews of 48. It is high time to turn our attention to establishing safe and required crew levels considering our country’s techno-socio-economic condition.

9.1.2.1 Establishing Crew Levels:

In establishing safe and required crew levels
for the country’s fleet, the government/ministry/authority concerned and the shipping industry need to consider demands on the crew, each vessel’s technology, level of automation, type of service, crew skills, and quality of management and management programs.

A committee was formed by the National Research Council, U.S.A to establish safe crew levels. They developed a functional model for task analysis and evaluated it by applying it to data from two actual ships. The model proved easy to use, comprehensive and accurate. With further development it could be used by the maritime administration of the developing countries and by the shipowners and operators to determine, systematically and reliably, the minimum manning levels for a variety of ship types and operating conditions. Additional work, for example, would make it more robust and flexible and would add risk or hazard analysis information.

The thorough assessment of shipboard functions and tasks permitted by the model would be practically useful to the maritime administrations of the country in setting manning levels. An initial determination of crew requirements could be made using the model with data from expert opinions, and then confirming, during sea trials, by entering actual voyage data into the model.

9.1.2.1.1 Shipboard Task Analysis:

Shipboard task analysis can be carried out beginning with a requirements analysis to determine the mission and functional requirements of present and future systems to help identify the tasks that must be supported. Next, a task analysis identifies
the tasks presently performed and those to be performed in the future. During the task analysis a man-machine trade off study is to be performed to determine which tasks will be performed by people and which by machines. The next step is an organizational analysis to determine how the human and machine tasks of the future will be supported in the organization. A software analysis then focuses on the information processing requirements of the tasks allocated to machines to determine. Finally, a hardware analysis is to be performed to identify the appropriate hardware.

9.1.2.1.2 A Functional Model for Assessing Crew Levels:

A task analysis can be done in line with the committee's model to determine safe manning levels. The model used a taxonomy of 10 general functions, broken down in to subfunctions that describe all aspects of shipboard operations across a broad spectrum of cargo, ship, and voyage types (Table 9.1). The general skill and time required to perform these functions are then determined to yield qualitative and quantitative minimum manning requirements.

The model can be applied to two actual vessels of the developing countries/BSC to code two sets of data of actual maintenance/engineering and summarize deck operations to be developed by the ships officers over a period of 2/3 years.

Ten major shipboard functions identified in table 9.1 are cargo, ballast, navigation, main engine operations, general operations, general administrations, and catering functions. Data can be collected from two of the vessels of the same type and capacity (sister vessels) for each
function, subfunction, and sub-subfunction, and for each three types of voyage phases - at dock, transiting restricted waters, and at sea. The time it takes to perform any specific function is to be recorded for the range (i.e. the minimum and maximum times) and for the average time required. The maximum number of people required to perform the function at any specific time is to be recorded, along with number of persons of any given skill level required. For example if the average time for a given function (such as loading cargo) is four hours, and one person of a given skill qualification (a licensed deck/engineer officer, for example) works on the function full time, while another of the same skill classification is required for two hours, 1.5 would be entered as the number of people of that skill classification required to perform that function. Five general skill classifications can be used: licensed (N1) and unlicensed (N2) deck personnel; licensed (E1) and unlicensed (E2) engineering personnel; and steward's department personnel (G).

Any task that must be done in conjunction with the specific task is also to be noted. Where the manning requirements for a specific function under restricted visibility are greater than those in good visibility (for example, while transiting restricted waters), the restricted visibility required is to be recorded. Above the function coding portion of the form, spaces are provided for indicating whether tasks are mandatory or discretionary for the given time periods, and whether they are intended to be performed by the ship's crew or by a riding crew.

To determine the manning requirements, the ship voyage profile and operating conditions are first specified. For each shipbound function, the
average time required to be recorded is then multiplied by its frequency of occurrence per voyage. This data is then to be multiplied by the number of persons of a given skill classification needed to perform the function. This gives the total amount of time required by persons of a given skill classification to perform that specific function during the voyage. Dividing this figure by the total number of voyage days yields the average time per day required for that function. Dividing this number by the average number of true working hours per day per person in that skill classification gives the number of persons required per day. In the validation studies an 8-hour working day may be used as a base time.

This procedure can be replaced for each function and skill classification. For each skill classification, the total numbers of persons per day required across all functions yields the total number of persons of that skill required to operate the vessel safely and to support the requisite shipboard workload. Summing-up these total across all five skill classifications (N1, N2; E1, E2, and E6) yields the total manning requirement for that ship, that voyage profile, and that set of given operating conditions.

Based on the two validation studies, it appears that simply adding the data across all phases provides an accurate estimate of the minimum manning requirements for a particular ship. The data can also be calculated for different phases of the voyage (in dock, transiting restricted water, at sea) to determine if different voyage phases require different manning levels.

9.1.2.1.3 Emergency Conditions:
The procedure described above applies to normal operating conditions only. Based on expert opinions, manning requirements can be determined to fight shipboard fires and deal with emergencies. This may require larger crews than normal operations on some highly automated ships. This analysis requires estimating both the manning required for operating the ship while the fire is being fought and those for actually fighting the fire.

The procedure may help us to find out the safe crew level of a particular vessel. The maritime administration and shipping industry of the government department concerned may consider demands of the crew, quality of management, management program, government policy etc. above that level to establish the crew level.

9.1.3 Training Shipboard Personnel:

The next job is to develop our shipboard personnel skills. This can only be achieved by imparting appropriate training on them so that, they can run, operate, and maintain the mode and level of automation as described earlier.

According to the present regulations of IMO and the national regulatory body, presently one senior watch keeper of the vessels certified. But, one cannot classify the courses for the certificates of competency as proper "training". They are very concentrated in content and time, and basically enable candidates to prove to the examiner that he is competent and able to hold a more senior position... During shipboard training many important aspects are commonly learned by role, owing to lack
of time, experience and the personal cost to the candidate. The outcome is often that they do not really understand certain subjects of their profession.

With the increased use of microprocessor based solid-state electronic technology and centralized instrumentation and control system for ship’s machinery, the future demand for traditionally trained ship personnel will be much reduced and requirements will arise for a new technologist having a broad knowledge of fundamental principles and an understanding of their application to a wide variety of problems associated with the present marine automation system. Considering this the objectives of the training will be:
- To familiarize the crew with automation system of new technology.
- To develop crew skill.
- To run the plant to give maximum efficiency.
- To maintain the plant to give highest possible availability (MTBF / MTBF + MTTR) in order to keep vessel’s schedule and company’s reputation.
- To reduce spare parts costs.
- To reduce maintenance and repair costs.

The training can be organized in three phases:
(a) Shipboard training.
(b) Workshop training.
(c) Simulator training.

Most of the reputed automation equipment manufacturers have an arrangement for theoretical and practical laboratory training. They arrange these kinds of training at their manufacturing plants for their customers. We can avail of these opportunities to train our selected high caliber
shipboard and office technical personnel. A special agreement on the above can be signed with the automation equipment manufacturer through the shipyard during vessel procuring. These personnel afterwards can train the remaining officers in phases on board the vessel and in the BSC Marine Workshop. A training schedule can be prepared considering length of sea service of the officers, availability of them and trainer at sea and on shore and the training capacity of the workshop. Theoretical and practical automation training should cover at least a few basic outlines:

- Instrumentation Technology: Pressure, liquid level, flow, temperature, time, speed, vacuum and other physical and chemical properties measurement technique.

- Electricity and electronic: electric safety, electrical principles, operation of D.C, A.C circuits, solid state technology, electronic components, integrated circuits, microprocessor, operational amplifiers, operation of electronic circuits, logic and logic circuits and gates.

- Automation and control system: electrical relay logic control, pneumatic control, hydraulic control and combination of two or more of them; programmable controller and programming; computer and computer control system; data transmission and display.

In chapter II, I spoke about the maritime training institute of my country. Chittagong Marine Academy is the only officer training institute in the country and it is a branch of WMU. But, the Institute is not in a position to buy an expensive training aid like a simulator from their own funds.
Shipping companies, the ultimate beneficial of the academy and our government can help the academy in this respect. Provisions can be made while procuring a vessel from foreign assistance / loans at lower interest rates or grants from friendly donor countries under bilateral agreements. Ship handling and engine room simulators can be a vital tool for training ships’ personnel. Basic operational training on shipboard equipment can be imparted during pre-sea training to the cadets in the academy. Advanced operational training to the mid-level officers before appearing for the certificate of competency examination and economy and optimizing studies training to get the maximum efficiency of the shipboard equipment can be imparted to the senior-most officers.

9.1.4 Shore Repair Facilities:

In Chapter II, I have highlighted the present repair facilities of my country. We do not have exact repair and servicing facilities to handle precision jobs like automation. Private workshops are also not in a position to carry out any repair/servicing of automation systems of electric/electronic, hydraulic, pneumatic, or a combination of any of them. In general, private investment is very shy in the country and it is very much so in the ship-repair industry since the market is very limited. In this respect BSC Marine Workshop, as a part of an enterprise of the government, can come forward to take up this new challenging project with their routine repair jobs. In this case expenditure like establishing a new workshop can be minimized. BSC’s afloat as well as technical department in the office and marine
workshop itself has good expertise in the marine field. Only, it is needed to train them in this specialized field and this can be done, as I said before, by the automation equipment manufacturers' in-house training facilities which can be availed to train a selected number of personnel. Some of them will work in the workshop to develop a new branch of repair and servicing facilities of the automation control system.

The complexity of a microelectronic system makes it difficult to trouble-shoot and repair faulty components. But, it provides new opportunities for internal self-checking facilities which automatically locate hardware faults, for repair by replacement. This brings a new repair concept into light, the repair by replacement, and it is also cost effective. The workshop need not have a spare parts stock of these microelectronic components to handle repair jobs of controllers of the automation system. They can use ships’ stock and moreover in case of emergency these can be flown from the maker since these are light and interchangeable. However, the main effort of the workshop will have to put to the understanding of the automation process and input/output device i.e. sensors and actuators. Hydraulic and pneumatic control media fault, and specially finding out the cause of efficiency lowering, requires extra skill. I believe workshop personnel will gain these skills during their training with the maker as well from a practical point of view.

9.1.5 Shore Support:

Somebody asked me, "Is it possible to run your vessels with 20-25 man-crews, when similar vessels are run with a crew of six". My answer was
"yes of course, it’s possible when one man can fly to the moon or even a dog (Laika)". But, the thing is when one man is flying to the moon there are thousands of people on the ground supporting him. Good control is the key to success everywhere. To run automation successfully good control is needed as well as well support from the ship operators office.

At this moment I am not advising to go for Ship Board Management System, since, it is a new concept for us and it will not be effective until our techno-socio-economic condition is improved. However, our present ship operation system in the office can be modernized and re-arranged according to the requirements of the present technology. Communication is at the heart of the shipping business, but, still we communicate with the rest of the world and even domestically by telex; the old, time-consuming and expensive media of communication. Ships communicate with our London office by telex via expensive shore radio stations and the same is retransmitted to our Chittagong head office by telex. It is a hindrance for our agents and clients to communicate with us by telex and we are the ultimate bearer of these expensive expenses.

Nowadays the computer permits fast information transmission between ships, shipping companies, and agents for the efficient planning, organization and implementation of strategic and technical ship’s operation. The communication module permits data to be exchanged in a protected mode, at high transmission speeds and thus, at lower costs than conventional systems like telex. It permits information, for example, to be extracted or transmitted directly via the satellite and PTT network:
- complete cargo configuration,
- order transactions resulting from the servicing
  and maintenance modules,
- data of the ships log stored via electronic log
  management.

In this system access to the databases of the ship,
shipping company or agent, is protected against
access by unauthorized persons. It is also possible
to issue communication jobs or check pending jobs
directly via the communication module provided in
the standard operation interface.

We can go for installing the said
communication system with the mandatory
implementation of the Global Maritime Distress
System (GMDSS) on board our vessels. The initial
investment may be a little higher in this respect,
its return can be achieved within a short period.
This will:
- reduce communication expenses,
- provide better communication and support from the
  office to the ship,
- improve communication between ship, office, and
  the clients,
- provide better maintenance philosophy and keep the
  schedule in time for maintaining a good reputation
  in the business,
- reduce maintenance and spare parts cost, and
  improve the safety of the vessel.

It is high time for us to introduce computers
for automating our office to some degree. Many
people have an unfounded fear that "office
automation" means "loss of jobs", when just the
opposite is often true. In fact, lack of automation
to some degree may put people out of work. If a
company cannot compete economically because of lower
productivity from the office due to improper manual data handling, they will be forced to lay off personnel or even close down. Nowadays, more than 70% of office employees are spending all their time in normal typing and retyping, record keeping and updating manually. I believe the present employees can do a larger volume of work, can keep track in every corner especially where more financial involvements are and can perform better and challenging jobs while improving personal ability with the introduction of computers in the office.

So, the organizational set-up of the operation department of technical and commercial section of the office also needs to be rearranged with the implementation of a computer and computer-based communication system. I believe good communication at the heart of the shipping business and office computerization is its blood. We must go for that if we want to survive in the present shipping hard economic competition.

9.2 Conclusion:

In the present increased shipping economic competition and depressed world economy, increased ship operating costs, coupled with stringent international requirements for safety and environmental protection, marine automation is the only solution. It improves system efficiency, increased sensitivity, accuracy and consistency; processes experience less wear, less maintenance and have greater reliability.

Like all other developed nations we also need to take advantage of all these benefits because:

- They reduce ship operating costs.
- Equipment reliability and safety increase.
- The present trend in shipbuilding is toward a high degree of sophisticated automation. Equipment manufacturers have also employed microprocessor-based solid state technology to automate their equipment since it is cheaper, simple, reliable and space saving. (In my opinion after this decade conventional relay logic technology to automate a marine process will be of no use.)
- As potential shipowners embark on purchasing secondhand ships, they are of low fixed operating cost (FOC) and economy. However, most of them are equipped with a good amount of automation and the latest technological equipment. To run and maintain them we need to gain experience.
- Properly trained manpower with the present technology can be economical and productive to both the country's shipping industry and can supply manpower to the developed nations which are currently experiencing a shortage. This will set the pace for technological development and improvement in shipping related industries.

Keeping in mind all the above we need to go for due planning and adapt a policy on "Vessel Automation" considering the:
- intended service of the ship,
- intended manning arrangement,
- type of propelling machinery,
- ship maintenance policy,
- techno-socio-economic condition of the country,
- classification society and national regulation, and
- ship sale value.

The plan may be included in the next "five year plan" for vessel procurement.
In my opinion we need to go for UMS class vessels for the machinery space automation and medium level of automation on the bridge and the mode of automation should be microprocessor-based solid state electronics. To run and maintain these vessels we also need to adapt a policy beforehand for:

- establishing our crew levels,
- training our shipboard personnel,
- improving shore repair facilities, and
- reorganizing our vessel support system from the shore office.

My recommendations (Chapter ix), in this regard, may be be taken into account.
### Historical background

<table>
<thead>
<tr>
<th>Date</th>
<th>Event</th>
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<tbody>
<tr>
<td>January 1988</td>
<td>Germany undertakes trials under the German flag.</td>
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<tr>
<td>October 1988</td>
<td>United Kingdom informs IMO of the start of night assessment tests.</td>
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<td></td>
<td>NB: Tests contrary to the IMO STCW Convention, but an observer attends sea trials.</td>
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<td>January 1989</td>
<td>IMO begins work on drafting provisional guidelines.</td>
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<td>United Kingdom begins testing on two small ships of less than 1 600 grt in NW Europe, for coastal navigation, manned by crews of 8 or 9.</td>
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<td>December 1989</td>
<td>United Kingdom report to IMO on phase 1 of trials; results considered acceptable by the United Kingdom.</td>
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<tr>
<td>January 1990</td>
<td>Publication of Bureau Veritas Rules for CNC mark, which do not exclude night watch by a single officer, if vigilance support is provided to supplement the dead-man device.</td>
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<tr>
<td>September 1990</td>
<td>IMO revises its provisional guidelines and decides to include the question on its research programme, until assessment of sea trials is completed (at a date postponed from 1991 to 1993).</td>
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<td>An instruction from MSC henceforth requires the human factor to be taken routinely into account in all IMO work.</td>
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<td>Following its proposal, France is invited by IMO to present a vigilance monitor, of higher quality than the dead-man device.</td>
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<td>May 1991</td>
<td>IMO decides to continue work on the subject until 1994, with the following remits:</td>
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<td>- to analyse reports received from participating governments (at the time United Kingdom, Germany, Denmark, Norway and Vanuatu);</td>
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<td>- decide to what extent the human factor should be taken into account;</td>
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<td>- to revise provisional guidelines to make them permanent, then to draft an IMO Resolution;</td>
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<td>- to amend the 1978 STCW Convention, so that tests can be carried out legally, and OMBO at night generalised.</td>
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<td>Denmark announces the start of experiments on two sophisticated ships.</td>
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<td>Norwegian request to authorise OMBO on oil, gas and</td>
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chemical tankers is turned down.

June 1991

French proposal on a vigilance monitor and duplication of radionavigation systems with mutual surveillance.

August 1991

Denmark informs that new tests will be performed on 6 ships for delivery in 1992, of 17 000 grt, operated by deck officers who have received training on simulators.

July 1991

IACS sets up an ad hoc OMBO group to draw up unified rules, with the participation of 11 IACS members.

September 1991

37th session of IMO S/C NAV:
- French proposals to be taken into account in any amendment of the test guidelines;
- United States memo by Navigation Safety Advisory Council concerns:
  - required level of experience for OOW;
  - night vision;
  - length of watches;
  - need for properly integrated navigation systems.

February 1992

IEC committee TC 80, on navigation instruments, sets up GT 9, with the task of producing a safety and type-testing standard relevant to integrated navigation systems.

April 1992

German report to IMO on experiments carried out on board 22 container ships, involving 23 485 watches, including 132 interrupted watches.

December 1992

OMBO ad hoc Group findings approved by the IACS Council.
- Amendment to the STCW Convention, as approved, comes into force, meaning that night OMBO tests can now be carried out in full conformity to IMO Resolutions.

Source: Bureau Veritas
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