The utilization of failure in marine engineering training

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THE UTILIZATION OF FAILURE DIAGNOSIS IN MARINE ENGINEERING TRAINING

By

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I certify that all material in this dissertation which is not my own work has been identified and that no material is included for which a degree has been previously conferred upon me.
The contents of this dissertation reflect my personal views and are not necessarily endorsed by the University.

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ABSTRACT

Over the last half century, changes in the maritime industry have led to major adjustment in training of seafarers in general and marine engineers in particular. There are innovations not only in the training programs, but also in the means to fulfil them.

This paper advocates the utilization of fault diagnosis in the training of marine engineers using a personal computer. It is hoped that students may get interested as they would, playing with a computer game.

By using Electronic Workbench software students will be able to build, test and print their own projects without the need of baying real component.

In addition to saving time and money the students will familiarize themselves with computer operating. Since the computer is being used more and more in various type of ships, it can only be to their advantage to know how to use this important tool.

CHAPTER ONE

GENERAL INTRODUCTION OF REPUBLIC OF MOZAMBIQUE

1.1. GEOGRAPHY

Mozambique is a country with an area of 800.000 Km^2, situated on the east coast of southern Africa facing out to the Indian ocean.

Geographically then, Mozambique is a potential linkage for the land-locked inland countries in its neighbourhood, namely Malawi, Zambia and Zimbabwe. (See Fig.1.1)

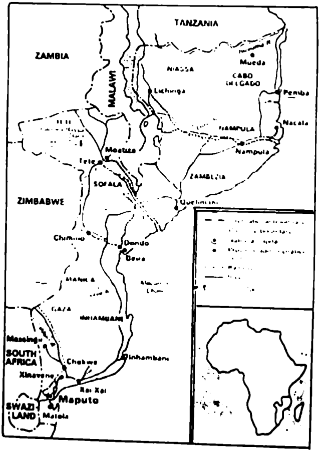


Fig.1.1. Mozambique: administrative region
(Source: Torp 1989)

The countries inland of Mozambique, rely heavily on Mozambique for trans-shipment of goods across Mozambique to the Indian Ocean. Presently much of this transport of goods is re-routed around Mozambique to avoid problems stemming from domestic civil war, however, recently Mozambique has embarked on a rebuilding effort which includes improvements to infrastructure and efforts to re-attract lost freight.

Thus we can understand the importance of training marine engineers to cope with the future demand. Taking into account that Mozambique is organizing its maritime sector, we are willing to become strong competitors to the neighbouring coastal countries in the region. Furthermore, there exists in Mozambique several large rivers some of them navigable, which may potentially be used to transport goods across Mozambique using maritime resources. (Torp, Jeans Erik 1989).

In review of the future potential demand for transportation to and through Mozambique, we do urgently need to create and prepare the infrastructure and human resources with the know how to respond effectively.

1.2. HISTORY

Mozambique became an independent country in June 25th 1975. This was achieved after a long hard struggle during which many has lost their life. The anti-colonial war was started on 25th of September 1964 by Frelimo (Frente de Libertaçao de Moçambique) and went on until year of 1974 when the Portuguese Armed Forces overthrew the dictatorship of Marcelo Caetano.

As history shows, the Mozambique people are persistent fighters to achieve their goals.

Despite all the pressures and difficulties throughout the pre-and colonial times, these people have managed to profit from the positive sides of their inheritance. An additional consideration for Mozambique is the potential in communication between different countries in that region of the world, that have also been Portuguese colonies before. These other ex-colonial countries now represent a good potential for commercial exchange and cooperation in many areas.

1.3. EDUCATION

Taking into account that the training of marine engineers in our Nautical College is part of our National educational system, it is important that the reader is acquainted with the history of our educational system, to put the present means and objectives at the Nautical College in clear perspective.

1.4. EDUCATION IN THE COLONIAL PERIOD

The education system in Mozambique was initially created for Portugal and then adjusted to local conditions when used in Mozambique. Access to schools was very poor since they only existed in the city and town areas.

Under the old Portuguese system, the evaluation and type of examinations were decided by Portuguese educational policy. Only three topics were taught under the Portuguese prior to independence. These were: Portuguese history and language, geography of Portugal, and Religion. These few subjects were taught at a very low level (Torp 1989).

According to Torp, in 1974 only a few state schools were located throughout the country and only a small number of African children had access to the education. The same can be said of the University of Lourenço Marques. In academic year of 1973 only 40 of its 2500 students were Mozambican. (Please see Fig.1.2)

Educational distribution, 1973, 1981 and 1986 ('000)

	Educational institutions			Number of teachers			Number of pupils		
	1973	1981	1986	1973	1981	1986	1973	1981	1986
Primary*	5.3	5.7	4.6	9.0	18.8	20.8	598	1,377	1,305
Secondary†	0.1	n.a	0.2	2.6	3.8	2.4	45	136	114
Middle‡	0.007	0.138	0.046	0.175	0.157	0.976	1.5	2.0	16.1
University	0.001	0.001	0.003	0.266	n.a.	0.342	2.5	1.9	1.6
Total	5.4	5.9	4.9	12.0	22.7	24.5	647	1,517	1,437

* The primary school has four grades, 1 to 4
† 5th to 6th grade
‡ Upper secondary level, 7th to 11th grade

Fig.1.2. Educational distribution. 1973, 1981 and 1986 ('000)
(Source: Torp 1989)

The above mentioned realities are offered to help illustrate the difficulties faced by people in our generation in order to be prepared to respond to the need for trained and educated personnel in Republic of Mozambique today.

1.4. POST INDEPENDENCE EDUCATION POLICIES

A National priority after the independence was to transform the education system in order to provide proper guidance to the students. When the Portuguese left, all the teachers went with them. The new school staff and books with a Mozambican focus were provided by the national government. The numbers of students and schools increased enormously in two decades.

Degree courses in medicine, economics, education, agronomy and veterinary medicine, are now provided by the University at Maputo called Eduardo Mondlane (Torp 1989).

As a response to this development and the significant maritime potential of Republic of Mozambique, the Nautical School was founded in 1977.

1.5. PRESENT EDUCATION SYSTEM

The new educational system consists of five different levels as follows: general education, vocational training, technical training, adult education, teacher training as well as university. The primary education is now of seven years duration and it is obligatory.

According to Torp, after the completion of secondary level of education there are three educational options available in Mozambique:

"- Technical education at middle level
- a preparatory course for university studies
- teacher training". (Torp 1989)

The fourth option is Nautical studies at our Nautical college. As with all the rest of the educational system in the country, this school was formed with the purpose of giving appropriate training to respond to the needs of the country and to specifically improve the efficiency of maritime activities. The Nautical School includes four Departments: navigation, marine engineering, radio and electronic engineering, as well as the department of general subjects. The focus of this paper is on engineering training. The engineering department consists of approximately 6 persons. The academic term lasts about 7 semesters (3-½ years) and consists principally of laboratory and classroom time. The Nautical school has one computer laboratory which shared among all the departments and students. Currently there is no instructional or mechanical linkage between the computer laboratory and the engineering laboratories. In this paper I will attempt to present the benefits of linking these two assets, and the essential nature of this type of linkage to modern marine engineering practice.

1.6. TRANSPORT

The land transport system is of extreme importance to the maritime development in Mozambique. What happens in the land determines in large scale the level of ports activities. In the past, the civil war destroyed a major part of Mozambiques' land-based infrastructure. This has had as consequence, a negative impact in the economic situation of the country.

However, in 1981, a number of investments were made to provide rehabilitation of the means of transportation available by land, having as focus point the Beira corridor which runs between the coastal town of Beira across Mozambique to Zimbabwe, and in the north, investment in the Nacala port as well.

It is expected that the improvement of land transportation systems will have an positive effect on the sea side, namely an increase of activities. This will require that a bigger number of marine engineers be prepared and available to be placed in the different fields as necessary, if this added demand is to be met solely by the Mozambique Marine fleet and personnel.

1.7. ECONOMY

There are other significant indications that the Mozambican economy may be positioned for future growth, because of introduction of new economic policies, namely the relaxation of regulatory limits on new investors and privatisation programs. (Torp 1989)

Mozambique has many natural resources such as: coal, iron-ore, bauxite, copper and other minerals that can contribute to a strong economic system, but we must have the know how to be able to extract and export them. (Torp 1989) Here the Nautical School will directly influence the effectiveness of the supporting transportation services and this will help facilitate the growth.

A country with an effective infrastructure will be attractive to overseas investors. Effective education is one of the ways to an effective infrastructure.

CHAPTER TWO

ELEMENTS OF ENGINE CONTROL SYSTEMS

2.1. GENERAL OVERVIEW

In the recent past the marine engineers used to work in close physical contact with machinery in the engine room. But today they are more typically informed of the status of the machines through the operating control system in a separate room. This became possible due to introduction of remote sensing devices known in the electronics field as transducers. There are different types of transducers. All are used to sense all the different functions of the engine and transmit them via a multiplexer to the controlling unit. This processing unit which, is the actual engine control system, is working as an interface between the engineer and the machinery.

This technology represents an outstanding development in performance and maintenance procedures as well as in failure identification within the machinery.

The advantages of being able to understand and operate such a system are numerous:

A fully developed control system can monitor a range of functions, and conditions in the engine that are not apparent from the standard external gages. It can warn the engineer if functions or conditions, fall outside normal parameters. An engine control system can save time in accessing the exact nature of suspected problems. Often disassembly to pin-point the problem can be rendered unnecessary. It can save money through reduced diagnostic time and also through continuous monitoring to ensure maximum efficiency of day to day operations.

There are draw backs to this kind of systems, as well: Typically, control systems are electronic vice mechanical and their function is not as intuitive to engineers as those of the engine itself, which are purely mechanical. A control system installed with poor or inadequate system design can lead to misinformation and false diagnosis, leading the engineer to discredit and often to disconnect the system.

In this situation the engineers need to have deep understanding and be familiarized with this new type of engine operation and control. However the engineers still have to undertake the necessary repairs and maintenance although they now can use the help provided by the system to improve effectiveness and capacity for planning, maintenance and operation.

With a well developed failure analysis training program, it is felt that many of these system disadvantages can be overcome and that graduates can realize the full potential benefits of the system advantages. These systems are installed on ships that call in Mozambican ports and we must teach our engineers how to use them.

2.2. CONTROL MEDIA

In the past, control of ship based machinery was effected principally by mechanical, hydraulic, or pneumatic systems. Recently, the use of electrical controllers has become predominant. The discovery of semiconductors led to a revolution in the technology of control. A semiconductor is a material which is neither a conductor nor an insulator. Depending upon circumstances, it can act as either. There are only two types of semiconductor material here referred to as **N** and **P** types, signifying neutral and positive polarity.

In order to understand and operate this type of electronic engine control technology the marine engineer should have as part of his educational program the priority of becoming familiarized with all its different components. As a natural consequence Nautical colleges would have electronic laboratories equipped with all these electronic devices and components which are part of the controlling media. Here the author presents an economical alternative by presenting the utilization of a microcomputer as hardware and "Electronic Workbench" software as described in chapter five of this dissertation. The other means of transmitting control signals on ships today is through the application of fibre-optics techniques. This technique is not addressed by this paper. However, more widespread use of this technology may require that Mozambique probably give instruction in fibre optic controls in the future.

2.3. ELECTRONIC CONTROL SIGNALS

Electronic control signals come in two distinct formats, digital or analog. Analog signals are anologous to real number signals and can have any value, whole or fractional with infinite precision. Digital signals are analogous to integer number signals and can represent only discrete whole or fractional values with finite pecision.

Signals detected or produced by sensing devices in the control loop may require amplification, prior to use. The most commonly used signal in measuring processes is a digital one. But in some equipment, analog types of signals can be found.

When signals of analog type are sent to a control unit or a microcomputer, then the incorporation of a converter (converting analog signals to digital signals) into the system is imperative. A converter is required for the analog signals because the above cited digital computer equipment only recognizes or understands the digital signals.

2.4. AUTOMATIC CONTROL

All types of automatic controls for ships have been approved by national regulatory authorities and classification bodies. The port and flag states i.e. (the national regulatory authorities) under which the vessel operates are usually responsible for the safety of the people operating the system, the safety of the environment, the operation of the equipment, and the functions of the operators. Because of this, their requirements are mandatory. In contrast, the classification societies are for ensuring a technically appropriate installation, a predetermined quality of equipment is installed and, that through inspection, the correct technical function of the equipment is maintained over the ships life.

So the classification societies are usually present during the constructions of new ships for inspection and to certify that all material used and equipment installed are in accordance with their specification and standards.

It is clear that high standard ships will always require well trained engineers. Here again their education should play a major role to satisfy the requirements for safety which apply to these high-technology ships. In author's opinion, the human element plays a great role in the loop. So the right place to modernize and be well equipped should be the training institution. This should precede the modernization of the national ships where they will be working, and will prepare the engineers to work on other modernized systems available throughout the shipping world today. Usually ship owners are interested in building sophisticated ships, modernized, with high tech equipment without first having human resources to handle them. This process seems to forget that the training aspects for safety and economical operation, must also come into play before any of the expected benefits of higher technology can be realized.

CHAPTER THREE

CONCEPT OF SEQUENTIAL CONTROL SYSTEMS

3.1. OVERVIEW

The results of application of automation in marine engineering systems shows that it is important that the engineer should be well trained in its operation. (Taylor, D.A. 1987). In control systems, there are many potential areas for problems which vary according to the system design and arrangement.

The first automated systems were relay (or switch) based. This type of system required the reliability of the process to be dependent not only on electrical signals, but also on numerous mechanical switches or relays. With application of computers to marine automation, this way of structuring the connections via mechanical relays is gradually being phased out and replaced by transistors which may also function as switches. In the new system architecture the closing or opening of the transistor switches is controlled by software which introduces some concerns of its own. As software must be implemented by people, difficulties can be introduced through inexperience or lack of knowledge of the system operator. Another location for potential unreliability of the system is the computer connection to the power supply, there is also a danger of magnetic interference which can cause the malfunction of the system. Because of this, ever-present possibility for control system malfunction, it is often recommended that a watch dog technique, a system to watch the system, should be used for safety reasons.

Also it is important to mention that once the computer and a transistor-based type of system is used to the best of its capacity and capabilities it provides an enormous number of possibilities that don't exist in the more rudimentary relay-based automation systems.

On the ship, the marine engineer can be faced with a control system of any level of complexity and capability, from simple mechanical relays to multi-level watch-dog type software-driven systems. Understanding what he is tasked with managing is fundamental to proper preparation and training for the manager (in this case the marine engineer).

3.2. BINARY OPERATIONS

To appreciate the functions of modern failure analysis and system monitoring hardware it is extremely important also to understand the more basic machine level operations where all decisions and instructions depend on a simple on-off, yes-no type distinctions. This is binary logic and is the basis of all digital processes.

Binary operations are based on the application of the Boolean algebra techniques. In this system the values are given only two possibilities, and so all problems and expressions must be restated in terms of only two possibilities. That is to say the value is present or is not present. For instance, even the common system of counting numbers that we use must be converted to corresponding Boolean numbers, consisting only of on-off, (1 and 0) distinctions. To do this, all numbers are written in a base of powers of 2 vice the normal traditional base of powers of 10. Here the number 7 becomes 111 which from left to right represents: $1*2^2 + 1*2^1 + 1*2^0$ and are the (first three powers of 2).

A memory computer is based on the same system. So using Boolean logic, math and calculations can be performed by electrical signals. In the electrical medium, 1 is a voltage (positive) and a 0 is a non-voltage condition. Similarly logical functions can also be performed in terms of two possibilities. Here a 1 is yes and a 0 is a no.

So we have seen that through Boolean algebra and logic, all manner of numerical representations, math calculations and logical decisions can be reduced to simple on-off, yes-no distinctions.

In syntheses there are three principal logic functions known as NOT, AND and OR. The combination of AND an OR with a NOT give rise to the NAND and NOR functions respectively.

By taking several of those logical functions, which can all be performed by transistors, and placing them all on a single semiconductor chip, several functions can be performed.

3.4. ANALYSIS

Boolean functions can be represented in a table known as a truth table. A truth table is a visual flow-chart that shows the result of all possible combinations of input signals. A function with n inputs will have consequently 2^n listings results in the truth table to cover all possible permutations taking in consideration that a logical variable can have either of two values. The following diagram shows a truth table for an "AND" function.

INPUT SIGNAL	INPUT SIGNAL	OUTPUT SIGNAL
A	B	Z
1	1	1
0	1	0
1	0	0
0	0	0

Fig.3.1.Truth table for an "AND" function

The AND module requires the presence of both signals a and b signals to produce an output. Therefore, if one is missing, the gate does not produce an output. The NOT module is usually known as an invertor because of its capacity for reversing signal. A truth table for a NOT function is shown bellow (Fig.3.2) that is if no input is present an output is present.

INPUT SIGNAL	OUTPUT SIGNAL
A	Z
0	1
1	0

Fig.3.2. Truth table for an "NOT" function

The "OR" function will give a positive output if any or all of the inputs are positive. The truth table for an "OR" function with three inputs would look like the following:

INPUT SIGNAL	INPUT SIGNAL	INPUT SIGNAL	OUTPUT SIGNAL
A	B	C	Z
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	1
0	0	0	0
0	0	1	1
0	1	0	1
0	1	1	1

Fig.3.3. Truth table for an "OR" function

3.5. LOGIC SYSTEMS

Automated control systems of todays ships are designed based on standard logic modules, with some variations depending on the designer. Fig.3.4 illustrates a standard basic module with 4 individual logic functions, a NOT, two ANDs, and an OR functions. This practical module, provides safe logical switching between engine room and pilothouse control for some system that should not be controlled simultaneously by both.

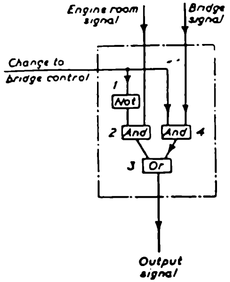


Fig.3.4. Selector module
Source: (Marine automation handouts WMU)

This diagram shows the selector module which has responsibility of selecting and letting pass either bridge or engine-room signals. That is to say not allowing the passage of both signals at same time. Apart from selection, the module also has a safety responsibility. By integration many of this modules can be tied together and be operated by a general "Change to bridge control" signal.

This is just the briefest introduction to a vast topic. The mariner engineer, who will interact with digital logic control systems, must be familiar with all of the basic functions and equipment, and many of the more complex ideas as well.

3.6. PROGRAMMABLE CONTROLLER

Because of the new semiconductor technology it is possible to manipulate by software the interconnections and functions of the various components we have been addressing, OR, AND, NOT, and NAND functions etc.

A programmable controller is a machine that controls the algorithm of the automation system. That is the logical set up and decision process. The majority of installed systems are either hard-wired systems or programmable. In this first type, we find a power source and a number of other electrical and mechanical components. On the other hand the programmable system requires only two principal features that is a hardware which is known as the heart of the system and software currently referred to as the programme.

The advantages of the programmable controller are many. The principal advantage is flexibility of function without requiring equipment changes. For instance, when modifications are necessary in the system we only need to change some parts of the program. In the same situation with the wired-type of controller system we would need to.

change the whole circuit spending therefore much more time and money as well.

Another big advantage of programmable controllers is that they can easily be expanded in capability and complexity of functions. An example might be in the evoking area of pollution control. If new sensors are installed monitor the fractional composition of exhaust gases, with a programmable controller this output could easily be linked by software to the other monitored engine functions like air and fuel delivery, engine load, combustion, timing etc.

In this fashion, a simple system, installed today for identification of optimum maintenance, and maximizing fuel consumption, can tomorrow be expanded to meet future air pollution considerations. The old system does not have to be replaced, merely reprogrammed to account for new inputs and new desired functions.

I would like to point out therefore the importance of making this system known to the marine engineers trained in our Nautical college. Because off the evident effectiveness of the above mentioned system as well as the simplicity of the ways of operating it and all its economical advantages, it should be indeed part of training of marine engineers of our days.

3.7. PROGRAMMING A PROGRAMMABLE CONTROLLER

In a programable control system, the functions of the system that would have to be made by physical connections and use of switches and relays can now be all programmed into a digital computer.

A wired concept is easily converted into a programmed type of control by application of digital and logic techniques. Before programming it is necessary to assign specific duties to the sensors and actuators. From there, the programmer can determine amount and type of data he desires the system to understand and develop the algorithms to manipulate this data and control the machine. (WMU handouts in marine automation)

In case of malfunction, the programmer or operator can easily correct it by simply reprogramming the system without having to change the whole circuit.

While the Nautical School could hard-wire a one-function controller to the teaching machinery, teach the functions of controllers in this fashion, it is felt by the author that teaching with a programmable controller would be preferable and would serve two purposes;

First, the students could, through experimentation, come to understand common methodologies in one-function systems, and second, they would through hands-on experience become familiar with, and able to adapt to the most complex systems available today.

Additionally, by adopting programmable controllers the computers the school already has in its computer laboratory could be put to better use. A programmable controller would still need to be purchased but it could be driven by the PC's the school already owns.

The author's personal experience at the Nautical School is that many engineering students view the computers as an overly-complex typewriter. One of the goals of effective engineering education is to redirect their thinking along these lines through "practical" exercises using computers to control "engineering systems". This is learning by doing and making learning more concrete and less abstract we can better prepare future Mozambican engineers for the challenges of operating and managing modern engineering systems.

CHAPTER FOUR

TOTAL RELIABILITY OF ENGINE SYSTEMS

4.1. INTRODUCTION

Reliability can strictly be defined as the probability that a component or a system will perform the pre-determined functions between assigned margins for a pre-fixed length of time and numbers of cycles as well.

To simplify this definition we can say that a system can either perform well or fail. Also the concept behind this is that the success in the use of different systems depends upon the quality of the components and the devices which are installed into the system. People's concept of reliability can easily be distorted. To illustrate, consider the following example:

> "Is a twin screw vessel more reliable than a single screw vessel? The popular and intuitive answer would probably be yes, naturally, because if one engine fails, you still have another to get you home, this may be a conforting thought, but, of course it has nothing to do with reliability. With only one engine available, the twin screw vessel can no longer operate within the designed parameters. Consequently, within the strict limits of the definition of reliability, a twin screw vessel may or may not be more reliable than a single screw vessel".
> (Tamaki 1990)

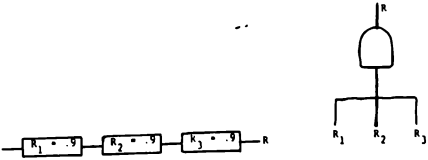
4.2. SERIES SYSTEMS

Systems on board ships can typically be subdivided into two broad categories namely; series systems and parallel systems. To begin with let us start by considering the series system. In a series system the input to each component is the output from the previous component, and all must individually function correctly for the system to operate. The reliability of the system is dependant upon the joined performance of a number of the total components which are a part to the system. This is because in a line series system, the individual components are strictly interconnected, that is to say if one component in the loop is of a low reliability index the whole system will be then affected. This is supported by the following formula which is based on some statistical theory and calculations:

$$R_s = R_1 * R_2 * R_3 \ldots\ldots * R_n,$$

Here R_s is the total reliability of the series system and R_1 through R_n are the reliability index of each component in the system. Take note that $R < 1$. A perfectly reliable part (never fails) would have a reliability of unity.

This can be also interpreted by graphic representation as well as by application of the earlier cited Boolean concept. By analyzing Fig.4.1. we can easily understand how the total reliability is highly dependent upon the average reliability of each and every component. Besides that, the total reliability decreases when the number of components in the system increases.



$R = (0.9)^3 = 0.729$

Fig.4.1. Series system
Source: (Howard)

Let us take as an example a system described by Howard as having a 100 components, each with 0.995 probability of survival for one year and we will find the overall reliability under this conditions to be:

$$R_s = (0.995)^{100} = 0.606$$

If we double the number of components in the system we then have:

$$R_s = (0.995)^{200} = 0.367$$

In series system the reliability of each components plays an important role on the total reliability of the system. (Howard)

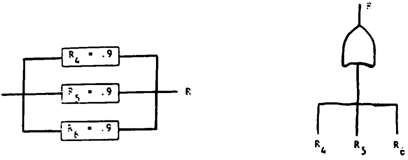
4.3. PARALLEL SYSTEM

In a parallel system, the individual components have duplicity of functions, the individual components often have a common input and output and therefore can serve to augment or replace each other.

The reliability of this system is very high because the components this circuit can take over for each-other.

But it has a disadvantage because the system becomes more expensive, with each additional redundancy.

The parallel system as illustrated in Fig.4.2 shows a system with three components, only one of each is necessary to accomplish the required function.



$R = 1 - (1 - .9)^3 = .9999$

Fig.4.2. Parallel system
Source: (Howard)

In such case, the reliability of each component will only contribute to the increase of the total reliability and this is known as redundancy concept.

Some features however require obligatory application of concepts from both systems, (parallel and series), safety reasons. The choice between parallel and series system architecture usually comes down to finding the most cost effective way of providing the best overall reliability. The following chart illustrates a few of the considerations involved in such a choice:

PARALLEL SYSTEM ARCHITECTURE	SERIES SYSTEM ARCHITECTURE
Low individual reliability	High individual reliability
Big effect on "total" system for individual part failure	Small effect on "total" system for individual part failure
Low cost per part	High cost per part

Only three principal considerations are listed here, obviously others can be added. The first is the individual reliability of parts. With low individual reliability, parts would be better used in a parallel structure where reliabilities are additive.

For parts with high individual reliability, series connections without redundancy may be the most cost-effective.

The second considerations is the effect of individual part failure on the "total" system. A big effect would lead to the choice of parallel arrangement (duplicate parts). A small or nuisance effect would lead to a series installations.

The third consideration is probably the most important and that is cost per part. With low individual costs-per-part, parallel architecture is affordable but at a high cost-per-part, only one part can be purchased and classical marine of this example of this is the prime-movers.

All of these considerations must be given an appropriate weight, and often they tend to oppose each other so the system becomes the result of the "best" compromise.

An example is a lubricating oil pump system or a fuel oil pump system that are key functions in the ships' machinery. These are expensive (series choice) but also have a potential catastrophic effect on the whole system with individual failure (parallel choice). For most ships the potential catastrophic failure consideration outweighs the consideration high-cost and more than one pump is installed to provide redundancy for each system.

In other words, the effectiveness of performance relies on the combination of both systems, and thus maximum benefit is derived by investing more on key-point areas upon which the whole system is depending.

To Consider the choices made here, we have in the following example taken from Howard, a simplified segment of a lubricating oil system, which is composed basically of piping, sump tanks, strainers, pumps, valves, (not shown), and a cooler (lub. oil side), etc.

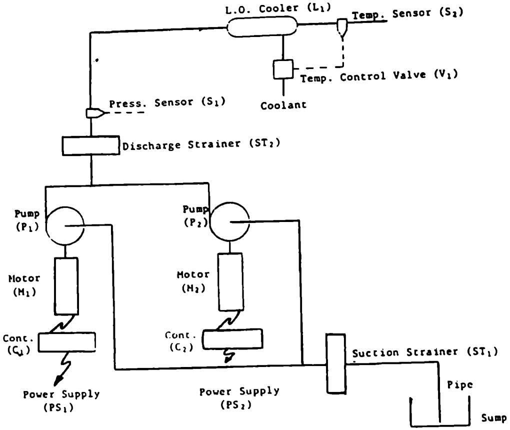


Fig.4.3. Simplified segment of lub oil system

Source: (Howard C. Blanding)

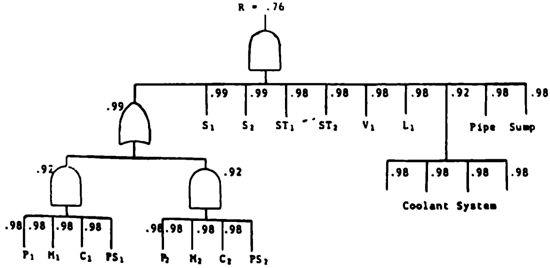


Fig.4.4.Logic representation (Boolean concept) of Fig.4.3. Source: (Howard C. Blanding)

4.4. FAILURE RATE AND AVAILABILITY

4.4.1. OUTLINE OF SURVEY

To illustrate the concept of failure rate and availability, the author selected results from a survey made by the Japanese Ministry of Transport, on total reliability of ships from January 1982 to December 1984. The general information of this system is reported by Tamaki (1990).

The summary of a survey of 176 vessels from January to December 1984 is introduced here.

i) Surveyed objects

Vessels	**176**
Hours at sea	**2,255,244.1**
Number of alarms	**38,307**
Number of Failures	**25,082**

ii) Types of Main Engines as of 1983

Diesel engines	**96 vessels**
Turbine engine	**32 vessels**

iii) Type of Ships as of 1983

Container	**39**
Oil Tanker	**39**
Bulk Carrier	**22**
General Cargo	**16**
Others	**12**

All ships in this survey are classified as MO-ships (Unattended Machinery Space Classification given by Class NK in Japan). All details of failures alarms and repairs of machinery or systems are filled in data sheets on the ships and sent to the Ministry of Transport.

The reliability of the machinery of systems is considered an exponential distribution as a function of time elapsed. The total reliability of ship is measured by failure rate, repair rate and availability.

Failure rate: λ = [1/h] , where lambda is equal to the number of failures during the operating period. In this case, a representative example failure rate could be $\lambda = 3.3140*10^{-3}$. Statistically then, a failure occurs every $1/\lambda$ = (301.8 hours).

Repair rate : μ = [1/h]

μ = Number of failures / Total hours for repairing. In this case, a representative example repair rate could be

μ = 0.5729 it takes 1 / μ = (1.75 hours) to repair one failure.

Availability A = μ /(μ + λ). For the above example cases of A = 0.99942, this is the probably a given system will be available for use. A Relation between reliability and the ages of the ships is shown in Table 4.5.

Age	Failure Rate	Repair Rate	Availability
Total	0.003314 [1/h]	0.5729 [1/h]	0.9948
0	0.0030068	0.5798	0.9948
1	0.0024153	0.5236	0.9954
2	0.0030847	0.7589	0.996
3	0.0030163	0.5222	0.9943
4	0.0030347	0.6426	0.9952
5	0.0037884	0.5135	0.9927
6	0.0037039	0.4936	0.9926
7	0.0052216	0.4466	0.9884
8	0.0050793	0.5288	0.9905
9	0.0038502	0.516	0.9926
10	0.0043337	0.5096	0.9916

Table 4.5. Reliability & ages of ships
Source: (Tamaki 1990)

This table is presented merely to give the reader a feel for ship failure, repair and availability rates. It may be interesting to note that the best availability (0.996) did not come not in the first year, but in the third. Anecdotally we might say that the majority of delivery problems are debugged by that time, but there is really not enough data to draw that conclusions.

This chapter has investigated some of the ideas surrounding marine reliability. The engineer is always interested in ways to keep his equipment operating or available-to-operate 100 % of time.

To make sure this becomes reality, he should always be informed, about the situation or condition of the machinery.

A study of the specific reliability of various shipboard machinery may help the engineer better understand the weaknesses of his plant, and to appreciate the ability to detect failures in their incipient stage. Reliability helps the engineer better understand the value and applicability of failure analysis and the impact of specific types of failures or the availability of the whole system.

The concept of failure diagnosis which will be introduced in chapter five, correlates statistically the causes and effects of the failures.

CHAPTER FIVE

TRAINING SYSTEM OF FAULT DIAGNOSIS FOR MARINE ENGINEERING PLANTS

Engine repairs are very expensive; not only in terms of replacement parts, labour and repair time, but also because of lost revenue and continuing operating costs to support an idle vessel. Owners and managers spend a great deal of money for sophisticated instrumentation and controls but sometimes forget the value of "fine tuning" the man in the loop.

The engineer training programs should aimed at improving the engineer's ability to recognize problems early and to respond quickly with the proper action. This is accomplished by employing a unique combination of training methods.

According to Chesmond the engineering officer on watch in the central control room is typically required to perform the following duties:

"1. Monitoring for malfunction of operation equipment.
2. Monitoring key operating variables for deviation from the norm.
3. Detect and interpret alarms.
4. Obtain prompt access, display, and control systems during malfunctions.
5. Implement proper emergency procedures.
6. Implement proper start-up and shut-down procedures.
7. Check control and monitoring system calibration and performance".

(Chesmond 1994)

This is a very large and comprehensive list of duties. To ensure the engineer can actually perform these duties, correctly, without errors, necessitates lots and lots of practice and some trial and error.

A training system for fault diagnosis is presented in this chapter. It is a computer based software designed with purposes of training students in recognition and identification of an engine working difficulties as well as to solve them. The software will help the student to become skilful in finding and understanding what is wrong and to act upon it.

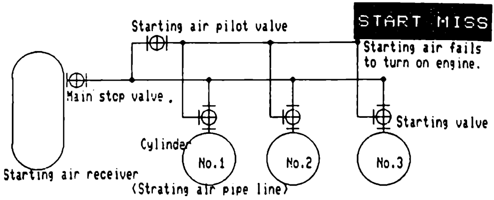
In most academic institutions, on the their free time many students often play computer games. Therefore, well designed software should take this into consideration. It is hoped the students will learn how to solve engine difficulties by allowing them to play with a computer like they would when playing a computer game.

Also, the computer is a good teaching tool for learning skills in failure analysis and fault diagnosis, taking into consideration that marine engineers are required to perform the previously listed duties and responsibilities.

Software exists, where an engine working difficulty is classified according to cause and related complexity, to check and discover the fault which is causing the malfunction. The trainee has to identify the proper diagnostic procedures.

In the fault diagnosis program written by Oshima College, by answering yes or no to the questionnaire the student is oriented to check the appropriate part or parameter of the engine and consequently to discover the cause of the fault. This could be possible if the student follows the correct procedure. Therefore the checking points must be done in logical order. For this purpose, the Oshima College program uses an analytic hierarchy process to put a set of possible diagnostic steps in order of priority. The student using this program must analyze the problem, and classify diagnostic steps as, emergency check points, frequent check points, and easy check points. In the Oshima program, each of these checking points are codified and represented graphically on the computer screen. The student should then choose his answers on the evidence in the diagrams illustrating each check point.

In the Oshima program, the diagrams illustrating each check point are schematically similar to those used on books and those used on board, the ship. Consider the diagram of a pipe line and a phenomenon for training in Fig.5.1.



A pipe line and phenomenon for training.

Fig.5.1. A pipe line and phenomenon for training

Source: (Bulletin of Oshima College)

It is felt by the author that this types of graphical presentation, keeps the ultimate objective of knowing-the-systems in focus. In each phase of the Oshima program the student can chose from different possibilities as to the causes for the failure presented. He may then see his results and the evaluation of his answers. If one or more of student's choices are incorrect, he has a possibility of repeating until his answer is correct then his score is displayed as in illustrated in Fig.5.2.

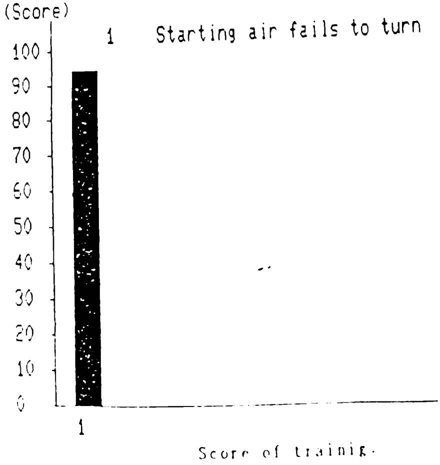


Fig.5.4. Score of training
Source: (Bulletin of Oshima College)

There is great deal of merit in utilizing the Oshima program or one with similar capabilities. This is a very cost-effective way to give the student experience in failure analysis before he goes to the ship and his mistakes cost money. This program or.one like it can easily be adapted to the facilities available at the Nautical school of Mozambique.

By being self-paced and having rapid feedback the student can compete against himself on the computer in a no-risk environment. So he tries to maximise his "score" and in the process, learns a great deal about the valuable process of intelligent failure diagnosis.

5.2. ELECTRONIC LABORATORY IN A PC

Presently the Nautical School has an electronics laboratory. It is a good laboratory. However, the resources of the lab must be shared among all of the Schools students. With the idea of maximizing the utility of the now scarce hands-on time in the lab, I have investigated the possibility of augmenting the marine engineers' electronics instruction by means of a "virtual" software electronics workshop.

This is accomplished by utilization of a microcomputer and Electronic Workbench software (EWB), which is a new software on the market with capabilities of simulating an electronic laboratory. It has a lot of potential for augmenting a real laboratory which uses real components.

For instance the software has a possibility to support teaching of the following topics:

"D.C and A.C circuits
Diodes, Rectifiers and Power Supplies
Transistors: switches and amplifiers
Operational amplifiers
Oscilloscope
Sequential Logic". (Everyday with practical Electronics, 1994)

With utilization of this powerful software, it becomes unnecessary to keep additional stocks of electronic material and instruments to support the additional instructions because all these features are incorporated into the system. It is economical because, projects destined for the real lab can be first built and tested in the "virtual" lab to help avoid costly and unsafe misuse of equipment and parts which is good for institution like ours with very limited economic resources. In author's opinion, this could be a useful acquisition for the Nautical School as the above cited software, installed in the existent computer lab, could be used by students as well as the staff in developing instruction curricula. As stated in earlier chapters, marine engineers of today should understand the digital and analog circuits in order to understand the automation of marine engineering systems, as well as the working principle of computers and programmable controllers etc.

5.3. THE PROGRAM CONTENTS

The full (1994) version of Electronic Workbench comes with a set of 150 model circuits. The software also comes with a trouble shooting book, and a book of practical teaching ideas (books and disks). It contains a wide range of analog and digital circuits, which gives the student possibilities, for designing, and verifying circuits before actually building them. It is of great use for teaching and learning purposes since the students can build their own projects, test them and then print out the diagrams and list of components as well as the calculations.

Using the specific Electronic Workbench software I am proposing, the students can see the circuit diagrams on the computer screen framed by a wide range of pull-down functions that can be used by clicking the mouse or by the pressing of a button. The following illustrations are taken from Electronic Workbench screens.

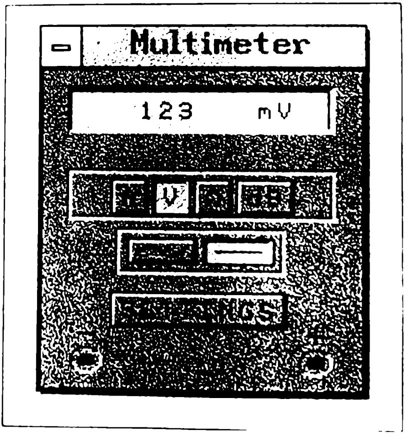
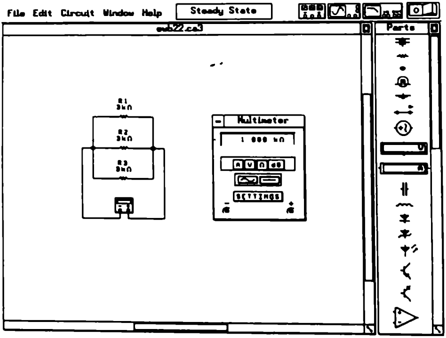
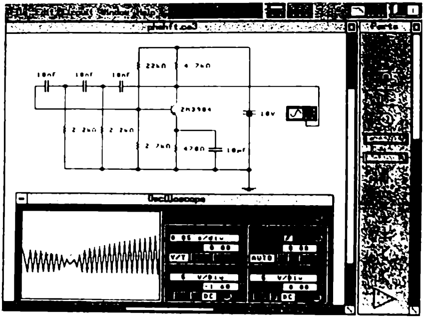


Fig.5.5.EWB's auto ranging multimeter measuring current and voltage drop
Source: (Everyday with Practical Electronics)



Circuit for assignment (measuring parallel resistance).

Fig.5.6. Electronics Workbench layout
Source: (Everyday with Practical Electronics)



A typical Electronics Workbench display

Fig.5.7. A typical Electronic Workbench display
Source: (Everyday with Practical Electronics)

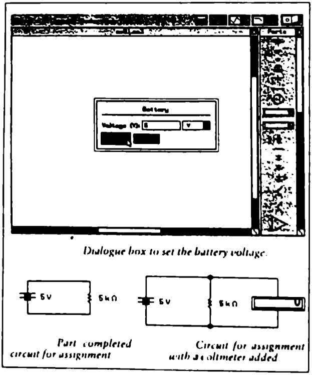


Fig.5.7. Dialogue box to set the battery voltage
Source: (Everyday with Practical Electronics)

In Fig.5.5. We see a multimeter that the student can use in exactly the same way as a real one.

5.4. SYSTEM REQUIREMENTS

The Electronic Workbench sales brochure gives the system requirements as follows:

> "The **EWB** requires an **IBM PC-AT, PS/2**", or compatible with a 286 or higher processor, the PC should have a hard disk, at least 1 MB of RAM and a Microsoft compatible pointer device (**e.g., a mouse**). It requires **EGA** or **VGA** graphics and **DOS 3.3** or later. The software will make use of a math coprocessor, where available.
>
> The full version needs a minimum of 4MB of hard disk space and a minimum of 550 Kb of RAM".**Source: (Everyday with Practical Electronics)**

Presently, the **EWB** software can run without any equipment upgrades on all the PC's owned by the Nautical School in the Republic of Mozambique.

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1. SUMMARY

We are faced with the introduction of computers in marine automation systems. No doubt the new techniques come with some risks or disadvantages such as: the increased electro-magnetic and electro-static susceptibility, complicated failure modes, and the ever-present human factor in software. However, computers now are absolute necessary for achieving the increasing number of high-level tasks which through now standard, were not possible up until now. If they are well applied, and properly administered these new more complex systems can even-bring in the addition of more reliability.

6.2. RECOMMENDATIONS

An electronic laboratory in a microcomputer allows a trainee to make a mistake without causing any economic loss or hazard to his safety. The computer forms the main brain of any simulation process. There is then the programme which may be permanently installed or installed only when using the program. The signals from the computer, depending on the inter-action of input signal and the programme, are then fed into various items for display and actuations.

There is therefore the possibility of the maritime college assembling its own simulated laboratory from acquired components. Some of these components may be acquired in sets e.g software for failure diagnosis and electronic laboratory use, programmable controllers and software to drive programmable controllers.

The example is the previously presented training system of fault diagnosis in chapter five which was developed by group of professors at Oshima maritime College in Japan.

These days virtually any process can be simulated, or controlled electronically.

It is advantageous for both students and staff to put together a controller like this because repairs and modifications to the controller will become easier as the modifier also happens to be the builder. There are a lot of expensive controllers lying idle and disconnected in various ships because of a minor defect which needs an expatriate repairer. In a maritime training college where students undergo training to repair and maintain, and in some cases design complete set ups, there is enough knowledge and manpower to tackle this kind of job.

Controller laboratory assembling will need time, coordinating of various human resources and pure hard work. The finished work will be the pride of the team and it is well known that this team which has put so much work into it, will ensure that the controller is maintained to achieve its teaching functions.

The school administrators should encourage teachers and staff to use computers to do more things in their jobs and periodically they should organize computer training for staff and teachers.

Effectiveness repays investment because reputation creates demand. The Electronic Workbench, will give our engineering trainees matchless competence in handling serious situations. This is evident from all engineers that have had access to and been trained in failure regonition by means of computers or simulation processes. They show to have much better knowledge and skills on failure analyses.

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