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The education and training of marine engineers on an engine room simulator at the Vietnam Maritime University

Van Uy Dang

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"The Education and Training of Marine Engineers on
An Engine Room Simulator at The
VIETNAM MARITIME UNIVERSITY"

By

DANG VAN UY

VIETNAM

A dissertation submitted to the World Maritime University in partial fulfillment of the requirements for the award of the degree of Master of Science in Education and Training (Engineering).

Year of Graduation
1992

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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WORLD MARITIME UNIVERSITY
MALMO-SWEDEN

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October 1992

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CHAPTER I

INTRODUCTION

I- INTRODUCTION

1.1- Limitation of Traditional Training for Maritime Education and Training (MET) System

For many years, the concept of teaching technology meaning the one direction transfer of knowledge, has always taken first place. The spoken word is its main traditional tool. Chalk and blackboard or ink-pen and overhead projectors are subtools to fix keywords or headlines.

The next level can be seen in the use of drawings, function graphs and other illustrations to improve the transfer of information beyond the channel of the verbal symbols. The visual symbols of information again may be a blackboard, transparency or paper handouts.

The highest level of traditional teaching in MET is achieved by the use of physical models, either of reduced scale or real size, either sheer statical or even functional.

In terms of learning, the traditional tools in MET are textbooks or paper handouts for re-reading, tasks for exercising mostly in written form, and to a lesser amount practical exercises with functional models.

By means of these, students are enabled to directly drill only the subjects in question. If in operational training they may start learning at the same instant by checking the reactions after changing parameters.

On the skill training side, until recent years it was considered that to acquire practical skills seafarers should go through a course onboard specially designed training ships. It is well known that seafarers should be trained so that they will be ready to act in any emergency that could be met at sea. Obviously, the training of seafarers on real ships cannot meet such requirements because, it is impossible or rather inexpedient to create critical situations onboard real ships.

Furthermore, in the countries where the MET system has changed into a dualpurpose system the traditional training of seafarers is no longer useful to achieve the objectives due to the very high required level of seafarers of the new MET system.

Therefore, to meet the new requirements of seafarers the modern teaching and learning technology in MET has been introduced in almost all countries and simulators have become useful teaching tools that are being used in every country.

1.2- Simulators as Most Effective Teaching Tools for MET

With the present sophistication of ship automation and the complication of technical management, many seafarers can no longer meet the requirements that arise from the developments in technology. So in September 1978, the International Maritime Organization (IMO) established the International Marine Simulator Forum (IMSF) to study the manufacture and utilization of marine simulators for the education, training and examination of seamen. From these points of view, simulators as teaching aids of a MET system are urgently needed.

A marine simulator can be understood as the form of equipment that is able to generate an environment where a group of trainees may be trained in both operational and corrective procedures on equipment related to realistic ship's systems where the maximum penalty for incorrect actions is limited to the embarrassment of the trainee knowing he has "got it wrong".

In the maritime field, the following simulators are mainly used for education and training purposes:

- Radar or Automatic Radar Plotting Aids (ARPA) simulator
- Navigational equipment simulator
- Manoeuvring simulator
- Ship simulator (including all above simulators)
- Cargo handling simulator
- Engine room simulator (E.R.S)

As a training aid, the marine simulator can provide advantages over the following areas:

- Creation of a dangerous situation which does not actually exist
- Repetition of the same situation
- Creation of any place and any condition in a training environment
- Easy changing of parameters to the condition required
- Economical training of students and in short time
- Studying human performance under stress
- Studying of man-machine interrelation.

Besides these advantages, the using of simulators as teaching aids has also some weak points:

- A need for experienced instructors
- Complicated equipment which can cause different troubles even for a simulator expert
- They cannot simulate real life
- High cost

At the First International Conference on Marine Simulation (1978), the marine simulators used as teaching tools were very highly appreciated. The simulators can help the trainees (either students or senior officers) to get more knowledge and experience and to display good performances in providing decision-making. In his paper "A simulator assessment of training effectiveness" Dr Johns Gardennier showed that in terms of the training effectiveness, the trained group scored 43% higher than the untrained group and in terms of transfer of learning the trained group has significantly greater consistency in the range at which they have to come to "decision-making".

Since the Marine Simulator Conference (MARSIM) 1978, simulation techniques applied to MET have widely spread in many countries in the world. The Vietnam Maritime University (VMU) is also involved in improving the methods of educating and training the Vietnamese seafarers to meet the international requirements. Therefore, to help the VMU to apply the engine room simulator to train the engineer officers of the future, I decided to choose a dissertation under the title " The Education and Training of Marine Engineers on An Engine Room Simulator at The Vietnam Maritime University".

The objectives of the dissertation are:

- To explain why we need to use the Engine Room Simulator(ERS) for the purposes of educating and training Vietnam's seafarers
- To Describe what is the engine room simulator and the basic principles to build up an engine room simulator
- To create the syllabus to train the marine engineer officers and students on an engine room simulator.

The paper contains seven chapters. Chapter I briefly explains why we have to use the marine simulators for training purposes.

Chapter II describes Vietnam's shipping industry, the marine engineering education and training in Vietnam, and then the need for an engine room simulator for the education and training.

Chapter III gives the background of simulation and the basic principles in simulating an engine room of a given ship.

Chapter IV and Chapter V describe the typical engine room simulators and some experiences with engine room personnel on simulators respectively. There is also some basic knowledge given for our maritime institution to select the engine room simulator for training purposes and how to apply the engine room simulator to train marine engineers for the Vietnam Merchant Fleet.

Chapter VI deals with the implementation of the engine room simulator for training purposes including the time schedule, selection of ERS, instructors, participants, and the very important section- training syllabus on a simulator.

Chapter VII. is the Conclusion and Recommendations.

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CHAPTER II

AN ENGINE ROOM SIMULATOR AND MARITIME EDUCATION AND TRAINING (ENGINEERING) AT THE VIETNAM MARITIME UNIVERSITY

II- AN ENGINE ROOM SIMULATOR AND MET (ENGINEERING) AT THE VIETNAM MARITIME UNIVERSITY

2.1 - The Vietnam Shipping Industry

2.1.1- Vietnam Location and Ports

Vietnam is situated in the south-eastern area of Asia which is emerging as a world economical center. It is the country that has the long sea coast. Vietnam considers the shipping industry as one of the most important industrial branches needing to be developed.

Along the sea coast of 3000 km from the north to the south of Vietnam, there are 3 main ports: Haiphong, Danang, Saigon and several smaller onces such as Hongai, Campha, Cualo, Quinhon, Nhatrang and Cantho. The location of these ports can be seen in Figure 2.1.

Each main port occupies a place with special trade sectors as follows:

The Haiphong port is concerned with the export of coal, tin and agricultural products and import of machinery and equipment for the biggest industrialized part of Vietnam.

The Saigon port is a "main gate" with a very large area of agriculture, leading to the international sea-roads. Every year through this port, Vietnam exports about 2 to 3 millions tons of rice and other products. The current value of goods which is passed through Saigon port reached 4.5 millions tons in 1991.

Danang port which is a "main node" of the transport system of the middle part of Vietnam, also plays the role of exporting and importing cargoes for the neighbouring country-LAOS e.g timber, general cargoes and machinery.

Furthermore, since 1988 Vietnam, in co-operation with the former Soviet Union, has exploited sea-bed mining and has produced already 2 million tons of crude oil every year. In a few years to come, the production of crude oil will increase to 12-20 million tons annually, and 80% will be for export.

At the same time, another port was established in Vungtau. It will become the biggest port in Vietnam and will receive even the largest tankers.

It is evident that Vietnam greatly profits from its location, the open-economic policy from 1988 and the very large resources of goods for export can develop the maritime industry adequate to its capability.

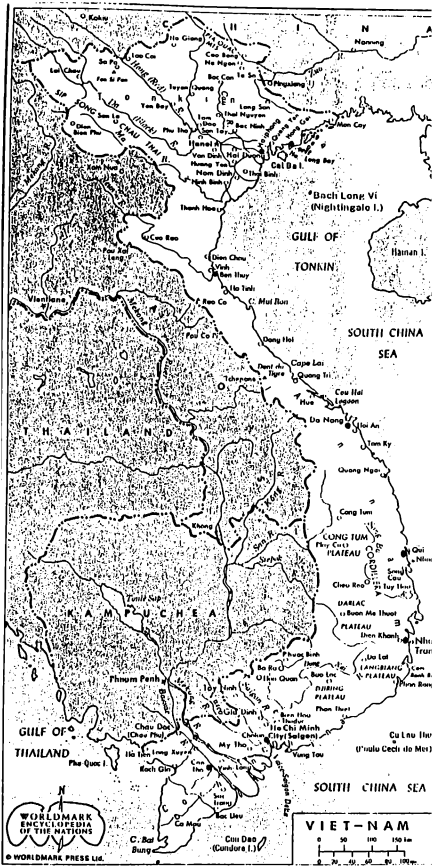

Figure 2.1 Vietnam Location and Ports

2.1.2- The Vietnam Fleet

Due to the very good capability to develop the seaborne trade of the country, Vietnam has been interested in foreign trade since ancient days. According to Vietnamese historical information, during the period from the 11th to 14th century Vietnam established foreign trade with the neighbouring countries and had a strong merchant fleet to transport goods and to exploit the natural resources of the wild islands. At the same time, cargoes were carried out by sailing vessels to another countries e.g China, Korea, Philippines, Thailand.

During the colonial period of France, all the sea-going vessels were controlled by the French companies while only inland-water ships belonged to the Vietnamese Government.

In 1954, after peace was established in the north of Vietnam, the Vietnamese Government founded the Vietnam Shipping Company which was the first national company. At first, the newly established company operated with several ships. The majority of the officers and ratings were the personnel who had served on board the ships of French companies before.

After the liberation of South Vietnam in 1975, thanks to the support from foreign countries, the infrastructure of the shipping industry in the whole country was established.

The Vietnamese merchant fleet consists of two kinds of shipping companies. Firstly, in the governmental sector there are four companies: VOSCO-Vietnam Ocean Shipping Company; VINASHIP-Vietnam Shipping Company; VITRANCHART-Vietnam Transport and Chartering; VITACO-Vietnam Tanker Company, with a total of about 90 ships with the size from 1500DWT to 15,000 DWT. Secondly in the private sector there are 10 shipping companies. Furthermore, about 20 ships with Vietnamese crews are sailing under foreign flags.

In accordance with the list of shipowners 1990-1991 published by Lloyd's Register of Shipping, Vietnam's national fleet consists of 142 ships with a tonnage of 401,984 GRT, including 80 general-cargo ships and 11 tankers.

The average growth rate of the fleet over the period 1976-1989 is 11% (see the Table 2.1 and Figure 2.2).

Table 2.1 Vietnam National Fleet 1976-1989

Year	1976	1977	1978	1979	1980	1981	1982
Tonnage (GRT) /Thousand/	107	129	163	202	241	250	262
Growth (%)	-	20.5	26.4	23.9	19.3	3.7	4.8
Year	**1883**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**
Tonnage (GRT)	269	279	299	339	360	381	402
Growth (%)	2.7	3.7	7.2	13.4	6.2	5.6	5.5

Sources: Statistical Yearbook 1982- United Nation
Statistical Tables 1983-1986- Lloyd's Register
List of Shipowner 1990-1991- Lloyd's Register

As can be seen from Table 2.1 and Fig 2.2 the Vietnamese shipping fleet has had a consistant annual increase. Because of this, the demand for the number of masters, chief engineers and engineer-officers is increasing.

Therefore, in order to satisfy the safe operating requirements of machinery and systems it is evident that there has to be appropriate training and a competence relevant to the international and national requirements.

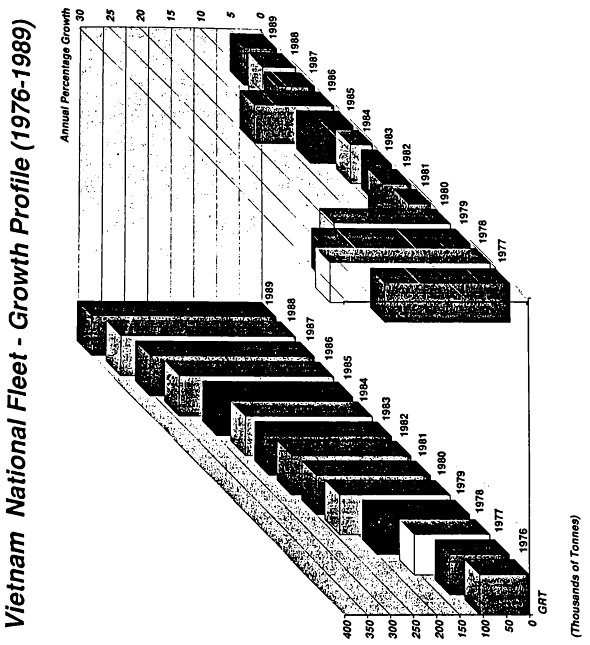

Figure 2.2 Vietnam National Fleet-Growth Profile

2.2- The Marine Engineering Training at Vietnam Maritime University

2.2.1- Brief Overview of The Vietnam Maritime University

After the liberation of the country from the French colonials, on April 1, 1957 the Marine Vocational School was established in Haiphong city. This is the founding organization of the Vietnam Maritime University aftoday.

The development of the maritime institution can be divided into three stages. In the first three years, due to a critical lack of the seafarers, the Marine Vocational School had the function to educate the numbers of seafarers to meet the realistic requirements following an 18-month training syllabus.

From 1960 to 1973, the three-year syllabus was applied to educate and train the seafarers. During this period, thousands of seafarers graduated from the Marine Vocational School. They are still participating in establishment and management of the Vietnamese shipping industry today.

Since 1974 due to the rapid requirements not only in the recruitment of seafarers, but also in their quality, the maritime institution has been established at the university level-Vietnam Maritime University. At first, the University was composed of three Departments: Navigation, Engineering and Electric. Ten years later, in 1984, the University was enlarged and the other Departments were added e.g Marine Technology, Hydrodynamic Structures and Maritime Trade.

Since its establishment, the Vietnam Maritime University has already played a significant role in the development of Vietnam's shipping industry.

2.2.2-Marine Engineering Training Program

The Vietnam Maritime University as the unique and highest training center in Vietnam, represents the best traditions of the Government's training of ship's officers. Training takes place after grade 12 in secondary schools and an entrance examination of "A level" to the University. The university-level studies have a duration of five years or ten terms.

The basic studies take place in the first four terms. In the later terms, the training is concentrated in the critical subjects related to the specific field of study.

The practical exercises are divided into two periods and carried out onboard ships of the Vietnamese shipping companies and in ship repair or shipbuilding.

After completing the university-level studies, the thesis and final examinations, if successfully completed, will result in the graduates being awarded the academic degree of a "Diploma in Engineering". Figure 2.3 shows the marine training model applied at the VMU.

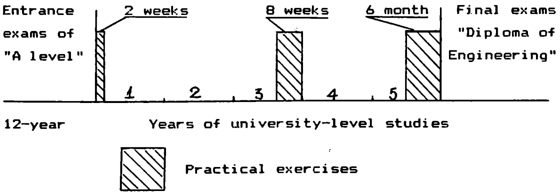

Figure 2.3 The Marine Training Model at VMU

The training program of marine engineers for Vietnam's fleet is, in principle, based on regular studies at the Vietnam Maritime University. After a five-year course of studies, the graduates receive a "Diploma in Engineering"

The main objectives of the marine engineering program are to educate seafarers with high-standard qualifications and to promote the graduates to be able to serve onboard ships or shore-side. Because of this the Vietnam Maritime University demands competency in the following subjects:

1- Subjects of social system
2- Technical subjects.

For social knowledge, the marine engineer will be able to communicate effectively in written, graphic or oral forms. He will also be able to display professional attitudes in his behaviour, actions and to assume the responsibility associated with the supervision of others and through the use of teamwork, leadership, delegation and scheduling of activities.

Besides this, on the technical side, the marine engineer can exhibit the high practical profession of his specialized field. He will also understand the technical and economical importance of optimizing performances and will be able to take measurements, record data, analyze data, compare data with specification, take appropriate actions and compile reports.

Furthermore, the marine engineer has the ability to operate machinery and systems and to maintain and repair in compliance with classification and statutory rules and regulations.

To meet the above-mentioned objectives, the appropriate syllabus required is shown in Table 2.2.

Table 2.2 The Engineering Training Curriculum at VMU

No	Subjects	Credit /hours/	No	Subjects	Credit /hours/
1	Physical Training	120	21	Technical Chemistry	45
2	English	360	22	Naval Architecture	75
3	Political Economy	90	23	Basics of Navigation	60
4	Philosophy	90	24	Basics of Automation	75
5	General Mathematic	300	25	Steam Propulsion Systems	105
6	Applied Mathematic	60	26	Ship Refrigeration & Air Conditioning	75
7	Physics	210	27	Ship Machinery & Equipment	120
8	General Chemistry	64	28	Diesel Engines & Gas Turbines	150
9	Descriptive Geometry	60	29	Ship Electronics	90
10	Technical Drawing	90	30	Ship Automation	70
11	General Electric	90	31	Operation of Marine Propulsion Plants	100
12	Thermodynamic & Heat Transmission	110	32	Installation of The Marine Propulsion Plants	72
13	Basic Electronic	60	33	Manufacturing & Repair	96
14	Computer Science	75	34	Firefighting & Marine Safety	72
15	General Mechanic	120			
16	Material Strength	120			
17	Metalurgy Theory & Technology of Metals	105			
18	Theory of Machinery & Mechanisms	75			
19	Basic of Machinery Design	105			
20	Hydromechanics or Fluid Engineering	60		Total:	3596

To complete the aim of the training program, in addition to the training syllabus, there are some training facilities equipped such as:

Marine Propulsion Plant Laboratory - It consists of a four-stroke diesel engine with power of 450 BHP at 600 rpm; hydraulic brake and relevant associated subsystems. Some necessary measured instruments and monitoring facilities are also fitted to carry out laboratory exercises and training purposes.

The Laboratory of Auxiliary Equipment- Here practical exercises and training jobs can be carried out with different kinds of auxiliary machinery such as centrifugal pumps, reciprocating pumps, purifiers, ventilators and so on.

The Laboratory of Refrigeration and Air-conditioning equipment- For educational purposes the students can learn the principles of refrigeration and air-conditioning systems onboard ships. Besides this, for training purposes the trainees can gather experience on how to operate the systems and trouble-shoot on realistic equipment.

In addition, in the Vietnam Maritime University there are also numbers of laboratories for the education of common subjects such as:Thermodynamic Laboratory; Material Strength Laboratory; Lub. Oil Laboratory; Laboratory of Electrical Facilities etc.

Besides the laboratory facilities, the VMU has two training ships. One is used to test the new students how to withstand sea-conditions. The other ship was built for the sole purpose of training students to perform the necessary service functions required on merchant ships.

2.2.3- Proficiency and Updating Courses at Vietnam Maritime University

For the purposes of updating seafarers in accordance with the demands of the national shipping, in the Vietnam Maritime University there is the Officer Training Center. The objectives of the Center are to organize and conduct:

- Courses for certificates of competency examinations
- Specialized courses designed to improve the knowledge of the technical and technological developments in the maritime industry
- Proficiency and updating courses for senior officers of various specializations.

Training courses are based on academic programs that comply with the international requirements as well as Vietnamese regulations.

The teaching staff lecturing on these courses comprises the VMU staff and highly qualified experts from the shipping industry.

The training courses are programmed annually in accordance with the request of shipowners and shipping companies and scheduled for each academic year.

Trainees are selected by their Personnel Department and then have to be submitted to the Ministry of Transport and Communications.

The career of Vietnamese seafarers can be illustrated in Figure 2.4

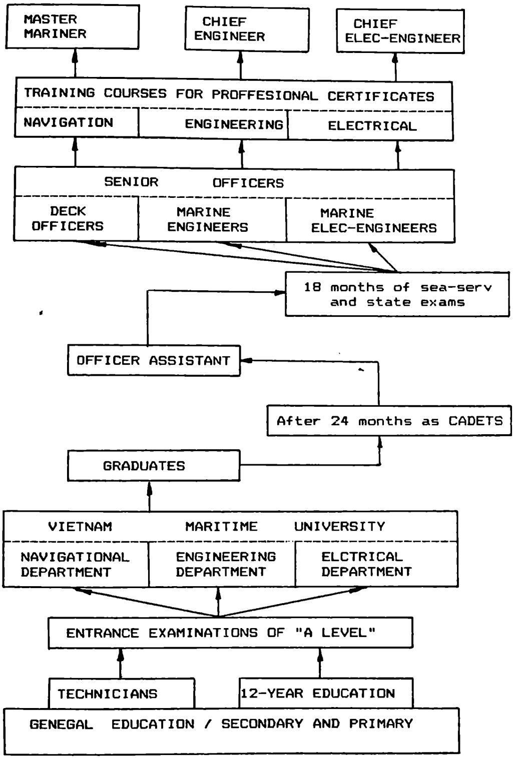

Figure 2.4 Seafarer's Career after Graduating from VMU

List of Courses Offered by The Officer Training Center

A- Deck Department

1- Course for Master First Class Certificate of Competency /Ships more than 1600 GRT/
2- Course for Master Second Class Certificate of Competency /Ships between 200-1600 GRT/
3- Course for Master Third Class Certificate of Competency /Ships under 200 GRT/

B- Marine Engineering Department

1- Course for Chief Engineer First Class Certificate of Competency /Main propulsion machinery of 3000 KW and more/
2- Course for Chief Engineer Second Class Certificate of Competency /Main propulsion machinery between 750KW and 3000KW/
3- Course for Chief Engineer Third Class Certificate of Competency /Main propulsion machinery less than 750KW /

C- Electrical Department

1- Course for First Class Marine Electrical Engineer
2- Course for Second Class Marine Electrical Engineer

D- Special Courses

1- Advanced English for Seamen
2- Technical Management
3- Merchant Aspects for Navy Officers

The details of each course are given in the Appendix I

Through the aforementioned Marine Engineering Training Centre at the Vietnam Maritime University I would like to summarize as follows:

- The Marine Engineering Training Program, in general complies to the international and national requirements.
- However, in a detailed analysis, the program is based strongly on the academic subjects and supportive preparequisit subjects which cover 70% of the duration. The credit which is set aside for practical exercises is very small in comparison with the time for theoretical learning.
  of very poor quality and quantity, and not reasonable of very poor quality and quatity and not reasonable fo training seafarers at a high level for the future.
- For the purposes of training of the dual-purpose seafarers and to meet the requirements of operation of advanced ships, the training program, in my opinion, is not adequate.
- To meet the new requirements of highly trained seafarers, the training program has to be changed as soon as possible to teach advanced subjects such as integrated ship automation systems, applied computer science, electronics etc, and step by step it must follow the dual-purpose training program.
- As a facility to convert the theoretical knowledge into practical experiences, the training facilities at the Vietnam Maritime University have to be equipped with the advanced training simulators.

2.2.4- Need for An Engine Room Simulator for MET-Engineering at The Vietnam Maritime University.

The International Convention onthe Standards of Training, Certification and Watchkeeping for Seafarers, 1978 requires that the main task of the engineer officers onboard ships is to safely and efficiently operate the ship's propulsion systems and machinery.

In detail,this means Vietnamese national regulations require that the marine engineer should have advanced practical skills in his specialized field. He should be able to start up, load-test, calibrate, adjust, optimise and shut down machinery. He should also be able to maintain and operate ship emergency systems in an effective and efficient manner.

Present day propulsion systems are increasingly complex. According to the results of survey (*), a main diesel engine consists of approximately 30,000 parts and making total of parts of machine in an engine room, the number of parts per ship is about 400,000. Furthermore, almost all engine rooms are equipped with very sophisticated engine control and monitoring systems.

When carrying out analyse of engine troubles, the three authors in the paper "The use of modern technology in the training of marine engineers" showed that the rate of detection by an alarm system was small especially for the indicator valve (0%), piston (7.4%) and the adjacent parts of the combustion chamber in spite of the regular occurrence of trouble. These results are obtained from an engine trouble survey of 217 ships between 1982-1988. It should be remembered that almost all the troubles in the engine room were detected by experienced crews.

(*) Sources:"The use of modern technology in the training Marine Engineer".
Prof T.Hashimoto and Prof M.Kimura.

Therefore, to meet the international requirements and national regulations of an engineer officer in such circumstances of an engine room it is essential that the marine engineer must not only understand the fundamental working of the machinery and systems but, also quickly recognize and diagnose unexpected plant behaviour and malfunctions to which he must respond properly in order to guarantee safe plant operation.

In Vietnam, at the present time, the training of an engineer's skill of operating machinery and systems is still carried out only onboard ships. The scheduled training of an engineer officer is inherently inefficient since a second engineer officer has to watch over the trainees. Also, only normal and simple operating procedures can be permitted to be practised due to the possible hazards to capital, equipment and lives. Additionally, the students have long periods of inactivity during the passage of a vessel between ports, with the exception of possible involvement in normal watchkeeping duties.

Furthermore, there are about 100 chief engineers and over 1000 engineer officers that are working onboard Vietnamese ships. In addition about 50 engineers are sailing on foreign ships as employees. The number of chief engineers and engineer officers is growing all the time. But there is only one maritime education and training institution - The Vietnam Maritime University.

Due to these reasons, the question is how can we train Vietnamese seafarers to meet the international and national requirements of today and in the future. To solve this problem, there is only one solution and that is that we have to apply the new technology to train the seafarers. Therefore, the Vietnam Ministry of Transport and Communications has planned to acquire and install an engine room simulator at the Vietnam Maritime University.

We hope that improvements in marine engineering education and training based upon such techniques will significantly contribute to the safe and efficient operation of machinery as the international requirements require.

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CHAPTER III

ENGINE ROOM SIMULATOR
AND
SOME THEORETICAL BACKGROUND
ASPECTS

III- ENGINE ROOM SIMULATOR AND SOME THEORETICAL BACKGROUND ASPECTS

The concept of simulation has emerged over a long time. In 1939, E.Link of the U.S first invented the simulator by simulating signals. In 1950, mathematical simulation with electronic digital computers emerged. The gradually improved simulating technology has created the simulator training for aviators and astronauts more true to life.

In the maritime sector, simulator training for ship and machinery operation was not given heed to and did not become popular until the 1970's. Meanwhile advanced equipment had been even installed onboard many ships.

Due to the large gap between the high-tech applied onboard ships and the seafarer's capability, the new technology of training and training aids have been introduced.

The marine simulators have been applied as teaching aids in many maritime schools and they are playing an essential role in accelerate seafarer's knowledge and experiences.

Nevertheless, usage of the marine simulators to train seamen is always a difficult task for every simulator expert. Therefore, this chapter deals with the background of simulation and considers some advanced engine room simulators.

3.1- General Background of Simulation

The dynamic characteristics of many physical systems can be described by mathematical equations. These systems include electrical, mechanical, thermal, hydraulic, biological etc. Usually the mathematical description are obtained from physical laws governing a particular system.

For example, Newton's law can be used to describe mechanical systems and Kirchoff's laws can be used for electrical systems. These mathematical representations of the dynamic characteristics of a physical system are models of the system and described by using differential equations.

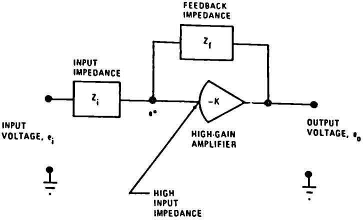
In the technical field, to analyze the interactions of complex systems or to verify the designs obtained using linear analysis techniques usually requires a so-called simulation. The realistic meaning of simulation is that to use a computer to solve the mathematical equations which model a system. In other words, simulation is usually considered to be the representation of individual physical items in a system by computing elements. The interconnection of the computing elements is the same as in the simulated system.

There are two major types of computers used for simulation. The first, the analogue computer, was more commonly used 10 to 15 years ago. The second is the high-speed digital computer. Simulations are also simulated on a combination analog and digital computer referred to as a hybrid computer.

Computers are used to solve the mathematical equations which represent the dynamic behaviour of a system then the outputs always refer to the performances of a system.

3.1.1- Simulating by Using an Analogue Computer

The primary element of an analog computer upon which the equations of a system are implemented is the operational amplifier. The operational amplifier consists of a high-gain, high-input impedance amplifier around which various impedances are arranged as shown in Figure 3.1



Z_i - Input Impedance

Z_f - Feedback Impedance

K - High-gain Amplifier

e_i - Input Voltage

e_o - Output Voltage

Figure 3.1 The Basic Analogue Computer Operational Amplifier.

The high-input impedance allows the transfer function (*) of the operational amplifier to be written as follow:

$$\frac{e_o}{e_i} = \frac{\dfrac{1}{-Z_i}}{\dfrac{1}{Z_f} + \dfrac{1}{K}\left(\dfrac{1}{Z_i} + \dfrac{1}{Z_f}\right)} \qquad (3.1)$$

(*) Source: "Dynamic Positioning of Offshore Vessels" Dr Max J. Morgan.

If K is very large, say 10^6 or 10^8, then equation 3.1 can be approximated as follows:

$$\frac{e_0}{e_i} = -\frac{Z_f}{Z_i} \qquad (3.2)$$

For example, if the feedback element is a capacitor of capacitance C and the input element is a resistor of resistance R, then the transfer function of the analogue computer amplifier is given as follows:

$$\frac{e_0}{e_i} = -\frac{1}{C(S)}\left(\frac{1}{R}\right) = -\frac{1}{RC(S)} \qquad (3.3)$$

where S is the Laplace transform operator.

Equation (3.3) is the transfer function of an integrator with a gain of 1/RC. Thus, if R equals one megaohm and C equals one microfarad, then the transfer function of the analog element is that of pure integration with a sign inversion.

When an integration is performed the output of the integration is equal to the sum of the integral of the input function plus the initial value of the output variable. Then, as the input voltage is applied to the integrator, the output starts at the initial value.

In a more complex example where the feedback element is a combination of a capacitor in parallel with a resistor and the input element is a resistor, the resulting transfer function of the analog computer element is

$$\frac{e_0}{e_i} = \frac{\dfrac{R_f}{R_f*C(S)+1}}{R_i} = \frac{R_f/R_i}{R_f*C(S)+1} = \frac{K}{T(S)+1} \qquad (3.4)$$

where $K= R_f/R_i$ and $T= R_f*C$.

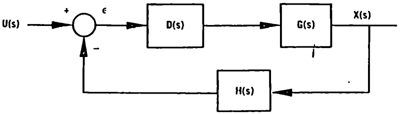
The analog computer element simulated by equation 3.4 is a first-order lag.

If one system is represented in block diagram form as shown in the second part Figure 3.2, then an analog computer circuit or combination of circuits can be implemented to represent each block of the system. In each case the output of one amplifier or transfer function becomes the input to the next amplifier. As a result, the structure or interconnection of the analog computer is exactly the same as the block diagram.

Differential equation format

$$\frac{dx^n}{dt^n} + a_1\frac{dx^{n-1}}{dt^{n-1}} + \dots\dots\dots + a_{n-1}\frac{dx}{dt} + a_n * x = u(t)$$

Transfer function with Laplace transforms



$$\frac{X(S)}{U(S)} = \frac{D(S)*G(S)}{1+H(S)*D(S)*G(S)}$$

State space format : $d/dt(\overline{Xt}) = \bar{\underline{A}}(t)*X(t) + \bar{\underline{B}}(t)*U(t)$

$Y(t) = \bar{\underline{C}}(t)*X(t) + \bar{\underline{D}}(t)*U(t)$

Figure 3.2 The three possible systems represented

Most commercially available analog computers do not provide the user with a generalized input and feedback impedance from which he can synthesize his desired transfer function. Instead they provide four basic elements:

1- Multiple input integrator
2- Multiple input summer
3- Inverter
4- A gain

These elements are illustrated in Figure 3.3 with their corresponding equations.

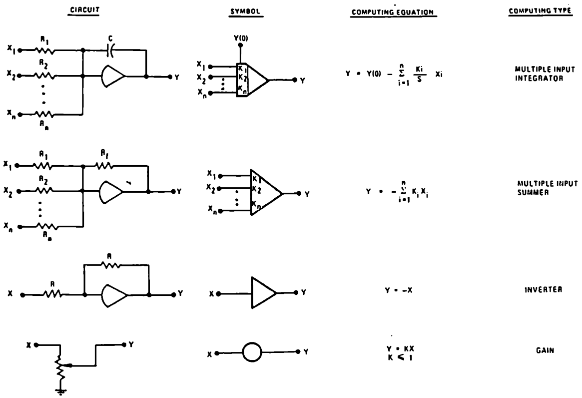


Figure 3.3 Common Analog Computer Elements

To synthesize more complex transfer functions from the basic analog computer elements, the transfer functions or differential equations can be rewritten in a form which is composed of first-order derivatives or single integrations. The resulting equations can be easily implemented with single integrations and summing amplifiers. Such decomposition methods are equivalent to those used to rewrite differential equations in state variable form.

A solution to every problem by using analog computers requires the proper scaling of simulation equations not only in the magnitude of equation variables but also in terms of time.

Magnitude scaling is required not only to limit computer variables to linear regions of computer operation but also to scale the units of physical variables to units of a computer i.e volts. To limit computer variables to linear regions of computer operation requires at least an initial estimate of maximum expected magnitude of physical variables. Then magnitude scale factors can be computed as follows:

$$\alpha_M = \frac{|\text{Max. Expected value of physical variables}|}{|\text{Max. linear voltage of computer}|} \qquad (3.5)$$

where physical variable is equal to α_M times computer variable in volts.

Time scaling is often necessary to improve computing accuracy or to adjust the length of time required to perform the simulation or a combination of both. If a simulation represents a system which operates beyond the frequency capabilities of a computer, then the simulation will not be accurate.

Time scaling is performed by replacing physical or real-world time with a scaled computer time, or an equation time

$$\tau_c = \alpha_\tau * t \qquad (3.6)$$

where τ_c is computer time and t is real time.

So, once the computer equations are programmed and scaled, then the elements of the computer are interconnected to implement the programmed equations and the pots are set to the proper values to achieve the desired equation coefficients. Then the initial conditions are set for the system variables and the test input applied.

3.1.2- Simulating Systems by Using Digital Computers

When digital computers are used to simulate dynamical systems, they solve the same mathematical equations that the analog computers solve in performing a simulation. Instead of using a voltage which is proportional to a physical variable, the digital computer uses a number. Thus, in performing the basic mathematical operation involved in simulation equations such as addition, subtraction, multiplication and division, the digital computer does a very accurate, time-invariant job. Magnitude scaling is not a problem for a digital computer with floating point arithmetic. Nonlinearities and logical operations can be implemented in digital computers with ease. The one simulation task which can be more difficult for the digital computer than the analog computer is the integration of the differential equations.

Various numerical integration routines are available for performing integration in a digital computer. In each routine an incremental procedure is used to compute the solution to the differential equation. With each step another increment is computed which is related to the function being integrated and the stepsize. The increment is then, added to an accumulated sum of past incremental computation. This step-wise process is described in Figure 3.4.

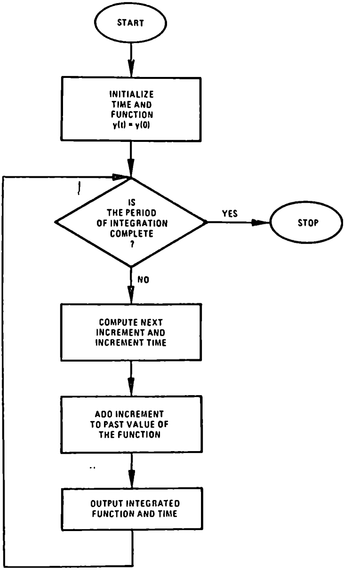


Figure 3.4 Basic Numerical Integration Process

The simplest integration algorithm is the Euler method which assumes that the function to be integrated, the derivative function, remains unchanged from t to t+Δt with the values which it has at time t , i.e $\dot{x}(t)$. Hence

$$x(t+\Delta t) = x(t) + \Delta t * \dot{x}(t) \qquad (3.7)$$

which shows that the value $x(t)$ and $x(t)$ are used to estimate $x(t+\Delta t)$. For any specified input function $u(t)$ starting from a known initial output value $x(0)$ equation 3.7 can be alternately and repeatedly applied to calculate successive values of the output functions as follows:

$$\begin{aligned} x(\Delta t) &= x(0) + \Delta t/\ ax(0) + bu(0)/ \\ x(2\Delta t) &= x(\Delta t) + \Delta t/\ ax(\Delta t) + bu(\Delta t)/ \qquad (3.8) \\ x(3\Delta t) &= x(2\Delta t) + \Delta t/ax(2\Delta t) + bu(2\Delta t)/ \end{aligned}$$

The Euler method is a helpful introduction for understanding the principles of integration algorithms, but is not often used in practice service since it employs a poor estimate of the mean value of the derivative function for the time interval Δt.

Better accuracy for a given integration stepsize is achieved by making use of multistage algorithms. The improved Euler method is a two stage computation in which a first estimate of the next point is made using the Euler method, the derivative is calculated for this estimated point, the average of this derivative value and that at the beginning of the step is the next point.

A more complex and efficient algorithm which, like the above, not only uses the current value to estimate the next value, but estimates three, or more usually four derivative values to do so, is the Rung-Kutta method. A different class of integration is that of predictor-corrector methods which make use of both present and past values to predict the next value then correct the predicted value by an appropriate algorithm, the prediction and the correction sometime being done iteratively. A complication is that at the start there are no past values, hence one of the Runge-Kutta class of algorithms must be used for the first one or two steps of integration.

3.1.3- Simulation Languages

With the above background, to simulate a certain physical system by using computers we still need some understandings of so-called simulation languages. Simulation languages are analytical tools which can be used to study the behaviour of a wide range of dynamic systems without the need for a detailed knowledge of computer procedures. The languages are designed to be simple to understand and use and they minimize programming difficulty by allowing the program to be written as a sequence of relatively self-descriptive statements.

Numerous different languages with acronyms such as CMSP, CSSL, DYNAMO, DARE, MIMIC and TELSIM, have been developed by computer manufactures, software companies, universities and others for wider application. Symbolic names are used for the system variables (the names being required to follow certain convention) and the main body of the program written as a series of simple statements based either on system equations or on block diagram representation of the systems. To these are added statements specifying initial parameter values and values of system constants and simple commands.

Statements controlling the running of the program are then automatically translated into a FORTRAN (or other high languages) program which is then compiled, loaded, and executed to produce a time history of the variables of interest in printed or plotted form. System constants and initial conditions can be altered and the program rerun without the need to retranslate and recompile.

To illustrate the general nature of a simulation language and the way in which it is used CSMP (Continuous System Modelling Program, a widely available FORTRAN based language developed by IBM). For example, using of FORTRAN (*) program to evaluate C(t) for the second order differential equation (3.9) below:

$$A\ddot{C}(t) + B\dot{C}(t) + C(t) = U(t) \qquad (3.9)$$

The heart of the program which uses the Euler approach to integration is the iterative application of the following three statements:

```
CDDOT I     =  /1.0 - C(I) - B* CDOT(I)/A
CDOT (I+1) = CDOT (I) + DT* CDDOT I
C (I+1)     = C(I) + DT* CDOT (I)
```

An exact program to solve the equation (3.9) is off course, more complicated. Here author would like to introduce an idea briefly.

The basic elements which appear in statements of such program are the following:

1- System variables (i.e quantities which may change in magnitude during a program run) represented by appropriately descriptive symbolic names
2- Numerical constants
3- The basic arithmetical operators +;-;*;** and bracket
4- Functions or functional blocks for more complex

(*) Source: "Marine Control Practice" D.A. Taylor

mathematical operations and

5- Levels, which are keyboards at the start of certain statements, to indicate the type of statement so that it is appropriately handled in the translation phase.

At the present time, due to the disadvantages of analog simulation such as high cost of computer, difficulties of problem scaling to avoid overloading of amplifiers and relatively limited accuracy, the digital simulation has been introduced to simulate physical systems days after days more popular.

3.2- Principle of Simulating a Marine Propulsion Plant

Above I have mentioned the background of the conceptual simulation which can be used to research behaviour between elements composed of one control system or to simulate real machines or systems for training purposes.

If we are now going back to the history of applied simulation techniques in the maritime field that an initial attempt at system simulation might deal with a heat exchange system such as that for piston water cooling on a diesel engine is an example. The techniques of simulation have not 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 one another to produce, in every respect, the complete range of activities that may occur during an engine room watchkeeping period.

So, the word "simulation" here can be distinguished by two meanings:

1- Simulation of a special device with respect to the operator's interface. This is a training simulator well known as ship-simulator, an engine room simulator etc.
2- Simulation of the behaviour of a technical plant with respect to the functions of time of process variables. This is a method to develop and to construct the components of highly sophisticated plant and complex systems of machinery and to obtain knowledge of the performance of such systems.

The part below will deal with how marine propulsion plants can be simulated as a training simulator used for education and training purposes.

3.2.1- Diesel Propulsion Plants Simulator

A complete propulsion plant simulator consists often of three main components:

a- An engine control room
b- A machinery space, and
c- An instructor's room.

A digital computer forms the heart of the unit and various dynamic models describe the various processes within the plant. These models can be interconnected in many ways and can be adjusted to vary the plant condition. The basic functions which link the components to each other are described in Figure 3.5.

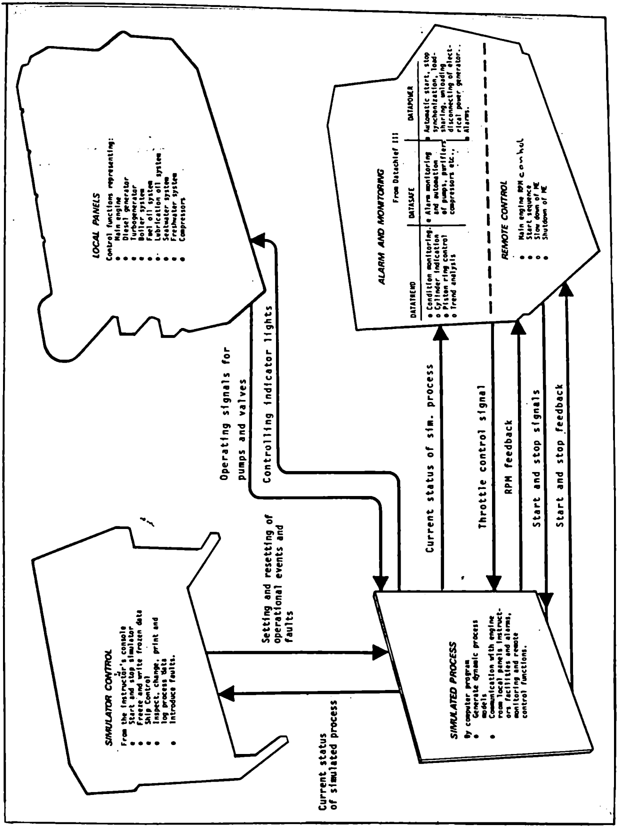


Figure 3.5 Basic Functions

Herein training or learning may normally be considered as a triangular activity containing the following elements:

1- The subject which is defined as "Diesel Propulsion Plant System", realized by "computer simulated process program", forms the heart of a simulator unit. It can be summed up as "Simulated Process".

2- The trainee and his educational aids. The trainee's meaning can be defined as either student, an engineer officer, or a chief engineer. Their "educational aids " are defined as training facilities consisting of an alarm- and monitoring system, alarm logging, condition monitoring, automation of electric power generation and load sharing, remote control of main engine and auxiliary machinery and a number of local panels representing engine room functions. Summed up as "Alarm/Monitoring and Remote Control".

3- The instructor and his educational aids. The concept of instructor; can be understood as a skilled teacher in the marine engineering field. His "educational aids" are defined as the instructor's facilities, comprising of controls for altering the behaviour of the different process models by introducing faults in components and subsystems to simulate the realistic running of a ship's machinery and equipment. This is summed up as "Simulation Control".

Now, the author would like to concentrate only on the computer simulated programs because good understanding of these guarante that later we can use and utilize efficiently simulator facilities for educational and training purposes.

As known before, to simulate an object the principle to be followed is:

Problem -- Mathematical Models -- Block Model -- Results

The process to be simulated is modelled using subroutines the so-called element program. An element program is a mathematical model of part of a process to be simulated, for instance, a diesel engine propulsion plant. A library of the element program would thus exist with models for the diesel engine propulsion plant components such as diesel engine, propeller, associated systems etc. Each element program must be given basic data: input and output variables, element constant. The linking between the different element subroutines is specified by means of data. The main physical dimensions and other characteristic parameters of the elements are given as input to the element subroutines.

Therefore, in terms of a diesel engine propulsion plant its models are modelized in the three levels: Basic Models, System Models and Plant Models. All models, independent of level, are interconnected software-wise.

1- Basic Models

A basic model is simply a mathematical equation describing the physical behaviour of a component. Each basic model represents a specific system component i.e a pump, a valve, a pipe, a heating element and so on.

Figure 3.6 illustrates a general basic model where the output variables /Y/ is the result of the input variable /X/ and the set model constant /H/.

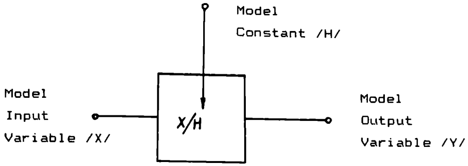


Figure 3.6 Principle of a Basic Model

For example, Figure 3.7 shows one system which consists of a pump, valves and a tank.

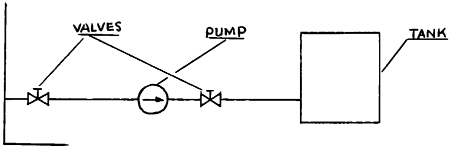


Figure 3.7 An Example of a System

We can simulate the system by means of basic models, within which every basic model is used to describe one element of this system. So, e.g to simulate the valve, firstly we have to know the input and output variables. In this case the output variable is a flow rate /Q/ from the valve and its input variable is the valve lift /X/. The relationship between the output and input variables can be described by the following equation:

$$Q = c*X*\sqrt{\frac{\Delta P}{\rho}} \qquad (3.9)$$

Where : Q- Output Variable
X- Input Variable
c- Flow coefficient / depends on the shape of valve, kind of fluid.../
Δp- Pressure difference
ρ- Density of a fluid

For the concrete valve of a system the required dimensions and features are given, then we can establish an appropriate mathematical model needed for the simulation purpose of a valve.

In a complete system where every element is already simulated, the interconnection of all elements can be solved by using the principle that the output variable of one basic model is normally used as an input variable to another. The model constant is thus a matter to set "the performance" or "the capacity of an element".

All variables and elements are identified by an index, thus making it possible to communicate with each of them in a computer system. A selection of the variables are considered as "critical" if passing certain limits i.e alarm and alarm limits.

Besides these, changing a model constant outside the "normal range", results in an abnormal output variable which in fact is the method used for simulating faults in the machinery.

Therefore, thruogh this information, a teletype and number of function pushbuttons, the instructor can perform almost unlimited manipulations on the process.

2- System Model

A system model can be understood as a model used to present a specific major part or function of any plant i.e fresh water system, fuel oil system and so on.

These models can be designed by using a variety of basic models.

3- Plant models

A plant model represents a complete diesel engine propulsion plant, averagely consisting of some 30 system models.

The principle of a diesel engine plant model includes the following systems:

- Single engine propulsion plant
- Single diesel engine
- Single stage, turbocharging system with intercooler
- Associated systems
  + Fresh water cooling system
  + Sea water cooling system
  + Lub. oil system
  + Fuel oil system and so on
- Boiler and steam system
- Diesel generator system
- Fixed pitch propeller or controlable pitch propeller.

The simulation of a plant model is based on a combination of all system models being needed to perform this plant model.

To make communication possible between particular system models, two things must be dealt with:

- Model variables
- Model constants

The model variable index consists of a letter describing the type of variable and an index number. To address the variable on the keyboard or the teletypes, only the index number should be used.

The model variables are by nature dynamic. Normally it will be of no use changing them manually, as this value will be replaced by the next calculation. However, the present value of tank level or air pressure variables are used for calculating the new ones. Changes to these variables could be useful.

The model variables are described as follows:

- Description of symbols

  G: Flow
  P: Pressure
  T: Temperature
  L: Level
  W: Viscosity
  V: Position
  Q: Torque
  E: Power
  N: Speed
  J: Electric variables / i,v,kw,kvar/
  H: Heat flux / heat energy/
  Z: Misc / salinity, water content, sensor signal/
  X: Trip codes / fault codes/.

- Description of units

GSW: Sea water flow unit
GFW: Fresh water flow unit
GMA: ME air flow unit
GMA2: TBCH air flow unit
GPW: ME piston cooling water flow unit
MHU: ME heat flow unit
SHU: Steam heat flow unit
PCT: Steam flow all:
FO flow, Oil boiler
Air flow, Oil boiler
Gas flow , Oil boiler
REL: " Related variables"
DG speed
DG power
DG torque
Active electrical load
Reactive electrical load

The model constants are denoted by the letter "C" followed by an index number. Only the constants normally manipulated by the instructor, are given model constant index. The rest are given a symbolic address. The model constants are coded as follows:

- Description of units

BAR - Bar over pressure
BARA - Bar absolute pressure
DGR - Degree Celsius
H - Hour
KCAL/G - Kilocalories per gram
KW - Kilowatt

- Description of Terminology:

FLOW CONSTANT:	Flow conductivity constant Increased value: Increased flow
DP CONSTANT :	Flow resistance constant Increased value: Decreased flow
PRESSURE CONSTANT :	Pump pressure at zero flow
PRESSURE DROP CONSTANT:	Drop of pump press.at full flow
HEAT TRANSFER COEFFICIENT :	Heat flow conductivity constant Increased value: Increased heat flow
HEAT TRANSFER RESISTANCE :	Heat flow resistance constant Increased value: Increased heat flow
HEAT LOSS CONSTANT:	Constant describing heat loss to surrounding. Increased value: Increased heat loss
TIME CONSTANT : Diff equation: Tp*Dx/Dt + x = 0 Sample time : Ts Time constant: 1-EXP(- Ts/Tp)	Process dynamic time scale constant. 0: Infinitely slow process 0.001: Extremely slow process 0.01: Very slow process 0.1: Medium slow process 0.3: Fast process 1.0: Instantaneous process

3.2.2- Simulating Diesel Engine

The diesel engine may also be referred to as a system model that represents both features of a diesel engine such as thermodynamic features and dynamic behaviour.

In general, a turbocharged diesel engine can be considered as a typical model which consists of a series of control volumes such as turbocharger turbine and compressor, engine cylinders, inlet and exhaust manifolds and intercooler. The principle components of a turbocharged diesel engine is illustrated in Figure 3.8.

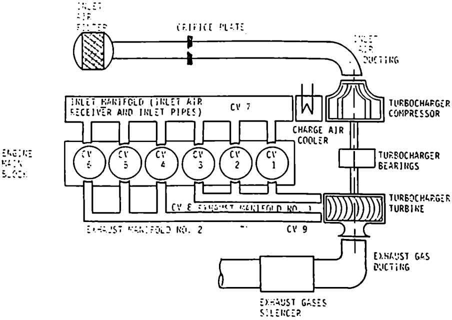


Figure 3.8 Turbocharged Diesel Engine

1- Simulation of Diesel Engine Thermodynamic Features

In terms of thermodynamic features of a diesel engine we can simulate the interactions of all components by standard thermodynamic equations i.e by means of equations representing the flow of mass, heat and mechanical work. It is really a "filling and emptying model which is able to predict engine performance from a detailed geometric description of the engine.

The structure of a simulation program of a turbocharged diesel engine that is constructed by T. Ruxton and Dr KS Hoong in their paper "Application and expert system to performance of marine diesel engine" is shown in block diagram form in Figure 3.9.

The mathematical model which describes the performance of the internal combustion engine contains the following basic models:

- Cylinder
- Exhaust manifold
- Inlet manifold
- Turbocharger
- The system of one or more valves per cylinder
- The air scavenging cooler.

All mathematical models of the components of a diesel engine are given in Appendix II.

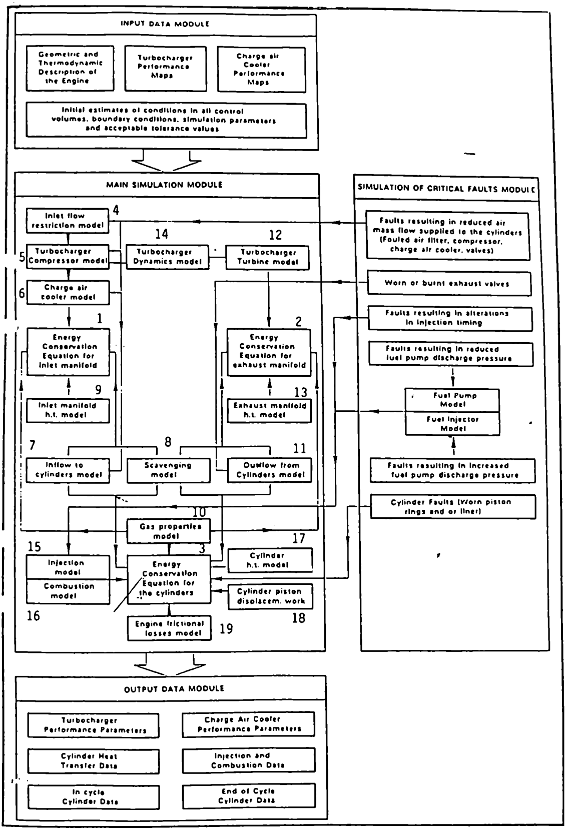


Figure 3.9 Block Diagram of Diesel Engine Simulation Program.

Sourse: "Diesel Engine Simulation Program" T.Ruxton and Dr KS.Hoong

To make a simulation of a diesel engine more accurate and match the sub-systems, some additional requirements are required:

- In terms of the cylinder, the working gas thermodynamic parameters must be the same at the start as at the end of the cycle.
- The inlet and exhaust manifold have to show the known mean pressure and exhaust gas temperature which are determined from experimental results.
- From the given inlet and outlet conditions, the thermodynamic parameters in the cylinder at any crank angle must be calculated and the predicted indicator diagram must have the same characteristic values as determined from experimental results, i.e compression pressure and max. pressure etc.
- The turbocharger's efficiency and air cooler's effectiveness must be determined in a way that allows the best fit between predicted and measured values.

Therefore, in fact to simulate a main diesel engine, we have to cover the following areas:

- The ME loop scavenging, FW cooled pistons and FW cooled liners/top cover.
- The cylinder space, piston, cylinder liner, injection valve and top cover.
- Mean exhaust temperature, after exhaust ports.
  It depends on injected amount of oil, air charge thermodynamic cylinder efficiency, jacket and piston FW cooling flow/temperature.

- From indicated mean pressure for each cylinder, total driving shaft torque can be computed. For the purpose of getting net main engine torque, the friction force should be considered.

For each cylinder of the main engine the model is shown in Figure 3.10

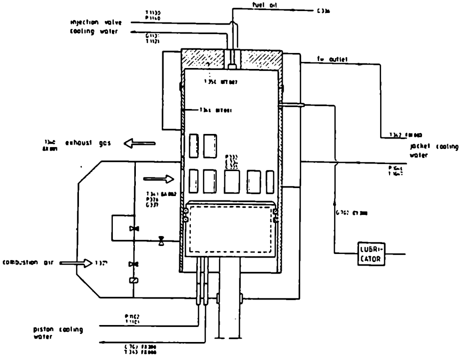


Figure 3.10 An Example of M.E Cylinder Model

In terms of the main engine turbocharger system, depending on the principle of utilizing of waste energy from main engine, the supercharger system is based on the constant pressure or impulse charging principle.

For instance, the main engine supercharger is based on the constant pressure charging principle. The model of the main engine turbocharger system is shown in Figure 3.11

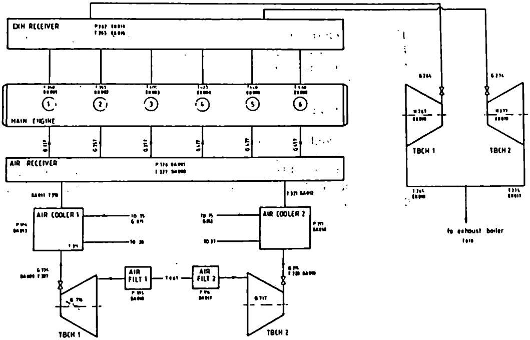


Figure 3.11 Model of M.E Turbocharger System

The main engine bearing system that includes the main journal bearing, crank shaft bearing, cross head bearing and a thrust bearing, is described in the model as seen in Figure 3.12

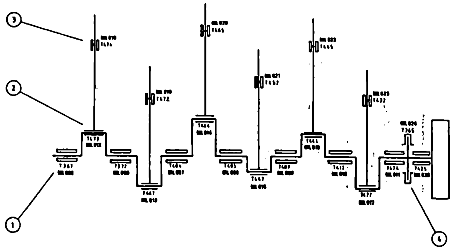


Figure 3.12 Model of ME Bearing System

The bearing temperature depends on cylinder power, oil flow, oil temperature and ambient temperature. All bearing temperatures will vary slowly to simulate change in the lubrication film. The variations are small and can be adjusted.

A dramatic effect is simulated at very high temperature. If the temperature of any of the bearing exceeds a certain limit, crank casing exploition occurs and the main engine will stop by emergency trip.

2- Simulation of Dynamic Behaviour of Propulsion System (*)

As can be seen in Figure 3.13 the ship propulsion system consists of the following components:

- Main engine
- Ship hull
- Ship propeller
- Propeller shaft

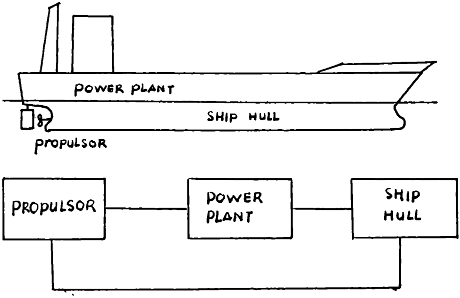


Figure 3.13 The Ship Propulsion System

For the purpose of simulating the ship propulsion system, it is necessary to know the specific characteristics of every component and the environment influencing on this system.

A basic principle to simulate the ship propulsion system is based on the equation that describes the motion of a ship in water. The well known equation used is Newton's second law of motion.

* Sources:-"Dynamic Simulation of Propulsion System"
Prof. Dr Ing W. Drote
-"Principles of Naval Architecture" J.Comstock
-"Dieselsim" System Manual-Norcontrol.

In terms of the ship, the motion equation can be described by the relationship between a ship speed and a force of acceleration:

$$\frac{dV}{dt} = \frac{1}{m} * F_a \qquad (3.11)$$

Where: V - Ship speed

m - Mass of ship (plus 20% for withdrawn water)

F_a - Acceleration force

The acceleration force Fa is the difference between propeller thrust Tp and the ship's resistance R. The later is a function of speed v.

$$F_a = T_p - R \qquad (3.12)$$

$$R = R_n \left[\frac{V}{V} \right]^{\alpha} \qquad (3.13)$$

R_n and V_n - Nominal values of resistance force and ship's speed / due to the working point often closed to the nominal working point, mostly the rated values will be taken as nominal values/.

- An empirical coefficient, about 2

For simulation purposes it is useful to normalize all variables. In other words, all variables will be considered as ununit variables. This means all variables (except time) are to be divided by their nominal values. So, the equations from (3.12) to (3.13) will turn into:

$$\frac{d}{dt}\left(\frac{V}{V_n}\right) = \frac{F_n}{V_n} * \frac{1}{m} * \frac{F_a}{F_n}$$

indicating normalized variable by a comma, it is

$$\frac{dV'}{dt} = \frac{1}{T_{as}} * F' \quad ; \qquad (3.14)$$

where: $T_{as} = V_n/F_n * m$

The term T_{as} is the time constant of a ship or acceleration constant which characterizes the acceleration features of a particular ship. The larger is the ship the bigger is the acceleration constant. So, introduction of the ship's time constant makes it possible to describe all ships in a small segment of data. See Table 3.1

Table 3.1 Data of Ship's Acceleration Constant

High powered ships	Tas /s/	Low powered ships	Tas /s/
Frigate	20	Tanker	1200
Icebreaker	200		

a- Main Engine

The dynamic model,(*) used for the main engine is illustrated schematically in Figure 3.14.

A program is used to develop propeller torque from inputs of ship speed, engine speed and propeller pitch (which may be from a controlable pitch propeller). The inputs to the dynamic engine follow:

- Environment data
- Conditions parameters
- Fuel data
- Engine constants
- Position of pitch propeller
- Position of rpm propeller
- Ship speed

(*) Source: "Dieselsim Manual"- NORCONTROL

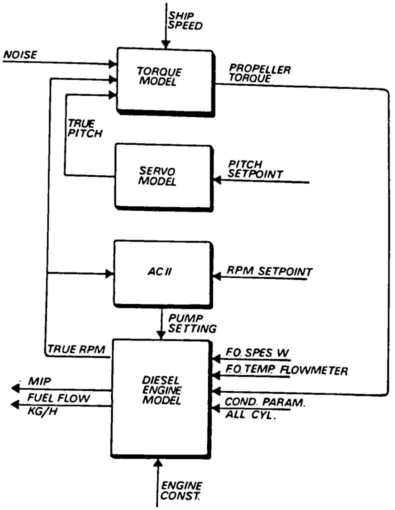


Figure 3.14 Principle of a Dynamic Engine Model

In the model, the actual rpm is calculated due to the fuel pump setting and propeller torque as follows:

$$\eta_e * m_f * W_l = n * M_e \qquad (3.15)$$

Where: η_e - Engine thermal efficiency

$\dot{m}_f$ - Fuel mass flow

n - Engine revolution

M_e - Engine moment

W_l - Low caloric value of a fuel oil

Then an engine revolution can be calculated as follows:

$$n = \frac{W_t * \dot{m}_f * \eta_e}{M_e} \tag{3.16}$$

In fact, the efficiency is approximately a constant, the fuel rate is approximately proportional to the fuel rack position F and the speed of engine (n), so it results from (3.36) as an approximation for given caloric value of fuel.

$$A*F*n = n*M_e$$

Where: A- engine constant: $A = \frac{z*\dot{m}f*\eta_e*Wl}{\delta}$

$$\dot{m}_f = \frac{z*n*m_f}{\delta}$$

z - number of cylinders

m_f - Fuel mass injected into cylinder per engine cycle

δ - Number of rpm/s (1 for 2-stroke engine, 2 for 4-stroke engine)

After normalizing, it gives:

$$M' = F' \tag{3.17}$$

If taking effect of environment influences such as friction forces, ambient conditions, the relationship between engine torque with engine speed and fuel rack position can be described as follows:

$$M_e = a*F' + b + cn' + d*n'\text{^}2 \tag{3.18}$$

Where: a,b,c,d- constants

This equation takes care of the efficiency within the full range of operation of almost all diesel engines with an accuracy of 1%.

To simulate all engine components, a separate model is used for every cylinder condition and operates in conjunction with the air intake and exhaust system. The model uses individual inputs from all engine cylinders and these will vary according to the engine operating conditions. All the various parameters will have dynamic responses as running conditions change. Fault conditions may be introduced into a specific cylinder and the various parameters will be realistically affected.

b- Ship Propeller

If a ship is built with a constant pitch propeller there are three methods of modelling:

- The use of torque and thrust coefficients Kq,Kt
- The use of the torque and thrust indices Cq,Ct
- The use of "Robinson functions"

Resulting from the propeller analysis it can be concluded that the two first methods used to model the propeller characteristics do not give enough accuracy of required results if the ahead-astern manoeuvre shall be analyzed or when we need to calculate precisely the values of the torque and thrust. Therefore, for a long time the Robinson functions have been in use as a method to describe propeller thrust and torque and the influence of wake and thrust deduction in a more global manner.

Typical Robinson functions are shown in Figure 3.15 with an accuracy sufficient for simulating purposes. These functions can be described by rational functions.

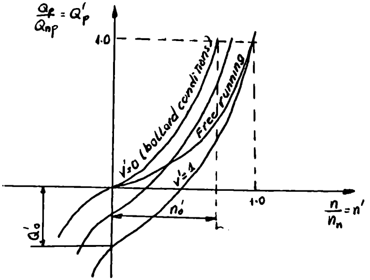


Figure 3.15 Robinson Functions

If one chooses second order functions there is in the case of zero ship speed:

$$Q_p'\ (V=0) = \frac{1}{n_o'^2} * n' * |n'| \qquad (3.19)$$

and in the case of nominal ship speed:

$$Q_p'\ (V=1) = (1+Q_o') * n' * |n'| - Q_o' \qquad (3.20)$$

Linear interpolation between both these boundary cases gives the influence of ship speed:

$$Q_p' = Q_p'\ (V=0) - [Q_p'\ (V=0) - Q_p'\ (V=1)] * V' \qquad (3.21)$$

In this simple form only two ship's specific numbers are necessary to describe propeller torque as a function of number of revolutions and ship speed. These are:

n_o' – number of revolutions when the propeller is operating at nominal torque at zero hip speed (bollard condition), the value of no is 0.65

Q_o' - torque of the propeller when the number of revolutions is zero (propeller braking condition) and the ship is running with nominal speed, the value of Qo is between 0.4 (tanker) to 0.8 (frigate).

In fact, the normalized propeller thrust T_p' is equal to the propeller torque and

$$T_p' = Q_p' \tag{3.22}$$

In the case of a ship which is equipped with a variable pitch propeller it is more complicated to create a propeller model because the thrust and torque of the controlable pitch propeller are functions of three independent variables:

- The number of revolutions n
- The ship speed V
- The pitch ratio H/D

The remarkable difference between the constant pitch propeller and the variable pitch propeller is that the thrust and torque of the variable pitch propeller are not proportional and that the operating range of advance coefficient is limited to positive values. Due to the different values of the variable angle between propeller blade and propeller axis and therefore of the difference direction of lift and drag forces in respect to the propeller axis, the advance coefficient in accordance with equation (J=V/n) of the operational range of propeller speed is between 70% and 100%. Ship speed in astern direction is not taken into account.

So, to create a mathematical model of a variable pitch propeller, Prof W.Droste showed that it is a better solution to start from the angle between the water speed in respect to the propeller blade and the angle of the blade itself. The situation of the angles, speed and forces in respect to the propeller blade is shown in Figure 3.16.

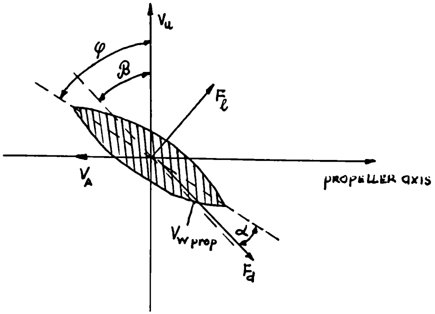


Figure 3.16 The Angle, Speed and Force in Respect to The Propeller Blade.

V_u - Rotational inflow velocity

V_a - Advance speed

F_d - Drag force

V_w - Drag speed of propeller

F_l - Lift force

β - Angle between water speed and propeller blade

φ - Pitch angle : $tg\varphi = H/D*1/\pi$

α - Access angle; $\alpha = \varphi - \beta$

The lift force F_l and the drag force Fd can be calculated by the following formulas:

$$F_l = A*\frac{\rho}{2} * C_l(\alpha)*(V_a^2 + V_u^2) \qquad (3.23)$$

$$F_d = A*\frac{\rho}{2} * C_d(\alpha) * (V_a^2 + V_u^2) \qquad (3.24)$$

Where: A- Area of plane form of section for rectangular shapes

ρ - Density of water

C_l- Lift coefficient

C_d- Drag coefficient

Hereof follows

$$T = (F_l \cos\beta + F_d \sin\beta)(1-t) \qquad (3.25)$$

$$Q = (F_l \sin\beta + F_d \cos\beta)(D/2) \qquad (3.26)$$

Where: T- Propeller thrust

Q- Propeller torque

t- Thrust deduction coefficient; $t = \frac{T-R}{T}$

Normalizing of these equation gives the following new forms:

$$T = b_f [C_l(\alpha)\cos\beta + C_d(\alpha)\sin\beta][\frac{a^2}{a^2+1} * V'^2 + \frac{1}{a^2+1} * n'^2] \qquad (3.27)$$

$$Q = b_m [Cl(\alpha)\sin\beta - C_d(\alpha)\cos\beta][\frac{a^2}{a^2+1} * V'^2 + \frac{1}{a^2+1} * n'^2] \qquad (3.28)$$

Where:

$$a = \frac{V_{na}}{V_{nu}} = tg\beta_n = \frac{V(1-w)}{n*0.7\pi D}$$

$$b_f = \frac{1}{C_l(\alpha_n)\cos\beta_n + C_d(\alpha_n)\sin\beta_n}$$

$$b_m = \frac{1}{C_l(\alpha_n)\sin\beta_n - C_d(\alpha_n)\sin\beta_n}$$

Very often on ships designed for merchant purposes

β_n = 20.5 then $tg\beta_n$ = 0.37

$C_l(\alpha_n)$ = 0.45

$C_d(\alpha_n)$ = 0.02

b_f = 2.3

b_m = 7.2

So, the approximate mathematical model used to simulate a controlable pitch propeller is:

$$T' = 2.3\,[0.94C_l(\alpha) + 0.35C_d(\alpha)][\,0.12V'^2 + 0.88n'^2] \quad (3.29)$$

$$Q' = 7.2\,[0.35C_l(\alpha) - 0.94C_d(\alpha)][0.12V'^2 + 0.88n'^2] \quad (3.30)$$

c- Rotating Part of a Propulsion Plant under Manoeuvre conditions

In the investigative process of a propulsion plant, one of the conditions that has to be emphasized is the manoeuvring condition, because, under manoeuvring conditions, the propulsion plant always works unsteadily in terms of heat exchanged and the mechanical stress of all components.

For the purposes of creating a mathematical model, the initial condition that shall be accepted is a fact that under manoeuvring conditions it is not necessary to take care of the twisting of the propeller shaft or the crankshaft. So all moments of inertia may be joined together into a total moment which embodies propeller, withdrawn water, shaft rotating parts of the engine and the influence of the reciprocating pistons. If there is a reduction gear in the propulsion plant, torque, speed and moment of inertia is to be reduced to the conditions at one side of the gear.

The speed that means the number of revolutions of the engine results of an integration of the accelerating torque:

$$M_e - Q_p = m_r * \frac{dw_d}{dt} \qquad (3.31)$$

Where: M_e - Engine torque

w_d - Angular frequency of rotation engine

m_r - Total rotating mass

After normalizing we receive:

$$M_e' - Q_p' = T_a * \frac{dn'}{dt} \qquad (3.32)$$

$$\text{Where: } T_a = m_r * \frac{2\pi n_n}{M_{en}} \qquad (3.33)$$

The expression T_a is the acceleration constant of the rotating parts. It can be calculated by equation (3.33) where n_n - nominal value of engine revolution per second; M_{en} - nominal value of engine torque.

d- Structure of The Complete Propulsion Plant

The mathematical models of all components performing in the propulsion plant are given above. So, to simulate the plant is only to be linked together just by assembling the appertaining program sections. The structure of the complete propulsion plant is described in Figure 3.17.

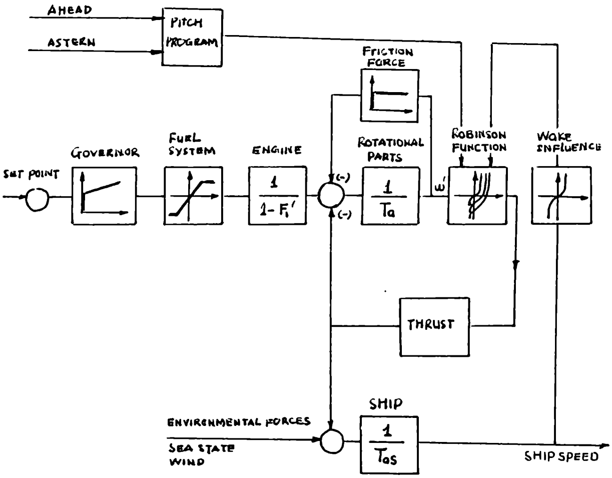


Figure 3.17 Structure of Propulsion Plant

This structure of engine-propeller- ship hull can be simulated in a PC by using the BASIC language or FORTRAN. However, in a realistic simulator of a ship propulsion plant the following features must be considered:

- The basic ship speed response constant is correctly modelled dependent of load condition. By the push button "Fast Ship" the instructor can change the apparent speed response depending on the required ship's speed.
- The total friction is modelled as a mixture of static and dynamic friction. Accelerating propeller torque is corrected for internal main engine friction and for thrust bearing and stern tube friction. At very low RPM the friction increases relatively much.
- The main engine should be put on turning gear and flushed with LO for 5 minutes before starting. This ensures that all the bearings are well lubricated at the start.

3- Simulation of Faults

A further specific objective of a simulation program is the modification of a diesel engine simulation program to enable the performance of an engine to be predicted when a number of engine faults are introduced.

The simulation program of faults will be capable of determining various performance parameters under normal healthy conditions and also under fault conditions.

The overall methodology used in the program development is illustrated in Figure 3.9. The simulation under normal conditions is shown by the three modules namely: input data module, main simulation module and output data module.

An additional module, simulation of critical faults, is introduced to represent the mathematical simulation of engine faults. This module consists of a series of mathematical models derived to represent various engine fault conditions. Examples of these conditions are:

- Faults resulting in reduced air mass flow to the engine
- Exhaust valve faults
- Fuel injection faults
- Faults resulting in reduced and increased fuel pump discharge pressure
- Cylinder faults.

In fact, the simulation of engine faults is based on changing the model constants over the normal range. With the simulation program running under normal conditions the critical fault module is ignored and the output data module produces the relevant performance value for a healthy engine. When the program is run to simulate a fault condition on the engine, the critical faults module is activated and specific mathematical models of the main simulation module reference appropriate mathematical models of the fault under consideration. The specific routine of the fault condition will modify the coefficient and or parameters of the required main simulation module models.

In a real engine simulator, faults can be introduced in three different ways:

- Single faults, by operating the "SETFAULT"-function
- Series of faults in predetermined time sequence, by operating the "FAULT SEQUENCE"-function.
- Series of faults randomly selected from the fault table and introduced by operating the "MONTECARLO"-function.

The setting fault system is located in the instructor room. Each fault has an assigned number on a "Fault code". When a single fault is set, the content of a memory cell is changed from its normal value to a fault value. The fault system data are collected in two major computer tables, the "FAULT DATA TABLE" and "GROUP DATA TABLE". All faults can be reset by instructor command "Reset Fault", or by student command "Reset" on engine control room teletype.

3.2.3 Simulation of Associated Systems

As mentioned above, the diesel engine propulsion plant is composed of about 30 different systems such as fresh water cooling system, sea water cooling system, main engine lubricating oil system, fuel oil system and so on.

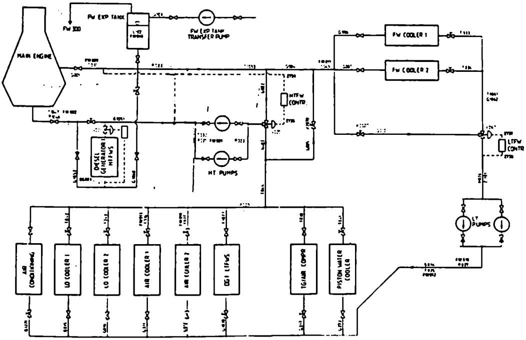
The particular associated system can be simulated on a base that the pipe network of a system is modelled by using the physical laws of continuity and conservation of energy (Bernoulli equation) which means that the flow rate into a junction is equal to the flow rate out of a junction. In addition, the summation of head losses around a closed loop will equal zero, when beginning and ending at the same point. Frictional head losses are calculated by appropriate exponential friction formulas to be satisfied for each pipe. That is, the proper relation between head loss and flow rate must be maintained for each pipe. Further, the program includes additional losses due to pipe line bends, inlets, elbows valves etc.

In fact, each associated system model includes

- system functions and operating procedure
- a flow/ tube type model drawing including variable

and alarm points
- applicable local panels
- model variable
- model constants
- fault codes..

One example of an associated system is shown in Figure 3.18. This is a fresh water cooling system.



3.18 **Model Drawing FW Cooling System**

The fresh water cooling system consists of two main loops , high temperature loop (HT) and low temperature loop (LT). The LT and HT water is cooled by sea water.

To make the simulated system closer to real life it is necessary to modify it by including the following features:

- The general pressure level in the fresh water system is given by the water content in the fresh water expansion tank.
- There is a constant consumption of fresh water, because of leakage and evaporation. The expansion tank must be filled periodically.
- In bad weather the unsteady expansion tank level is simulated and the false alarm may arise.
- The effect of cavitation is modelled for the pumps at abnormally low suction pressure and/or high water temperature. The pump discharge pressure will drop.
- A low water level leading to low pressure generally in the fresh water system, especially the water pumps are apt to cavitate and the main engine cooling is reduced.
- If the water level drops below "Top Cover Level" the heat transfer from cylinder liners/top covers will gradually decline to zero. This leads to dangerously high liner and exhaust gas temperature.

Figures 3.19 and 3.20 show the examples of local panel fresh water system and local panel miscellaneous valves/pump respectively.

For the other associated systems, the simulation process is carried out in the same way however, we have to take care with particular features of each simulated system to make them more realistic.

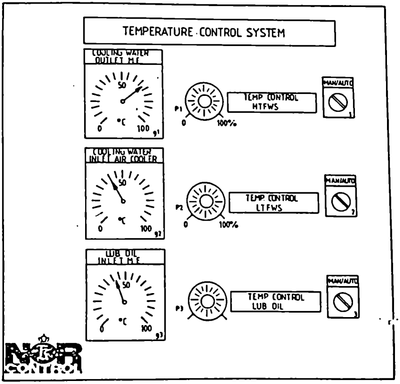


Figure 3.19 Local Panel Fresh Water System

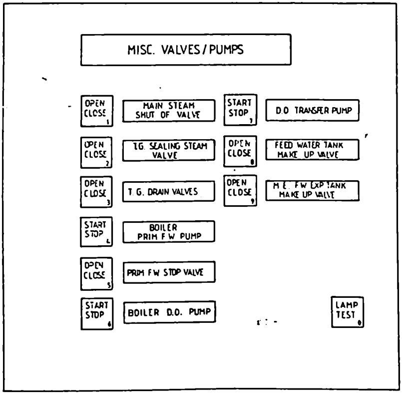


Figure 3.20 Local Panel Miscellaneous Valves/Pump

3.3- Controller Models

For the purposes of the diesel engine propulsion plant automation, due to the all units in an engine room replaced by the integrated digital dynamic mathematical models, the controllers must be modelled by means of proper mathematical equations.

Usually, the controllers are modelled as PID controllers/ proportial-integral-deviatial controller/ because, such kinds of controller have universal features that are very easy to perform appropriate characteristics on for controlling purposes such as P-characteristic, PI-characteristic etc.

A model of these controllers(*) is based on the standard mathematical equation:

$$y + T_3 \frac{dy}{dt} = k*[e + \frac{1}{T_1}* \int edt + T_2 * \frac{de}{dt}] \qquad (3.34)$$

Where: y- Controller output signal

e- Deviation signal; e=(setpoit)-(feedback signal)

k- Controller gain

T_1 - Integration time

T_2 - Deviation time

T_3 - Deviation brackoff time

The characteristic of this controller can be described by a function the so-called transform-function that characterizes the relationship between inputs and outputs of controllers.

(*) Sources:-"Automation and Control for Marine Engineer" by Virgil Cox.

- Dieselsim Manual-Norcontrol.

By using the Laplace's transforms, equation (3.34) can be handled in another form where the solution for variable takes place in terms of s and the values obtained are inversely transformed:

$$Y(S) + T_3 * S * Y(S) = k[E(S) + \frac{1}{T_1 * S} * E(S) + T_2 * S * E(S)] \qquad (3.35)$$

When we set variable $x = (T_2 / T_3) - 1$; x- deviation factor Thus the transfer function of PID-controller is the follow:

$$G(S) = k * \frac{(1+T_1)\ [(x+1) * T_3 * S + 1]}{T_1 * S * (T_3 * S + 1)} \qquad (3.36)$$

Plotting in the S-plane, the PID-controller characteristic can be seen in Figure 3.21

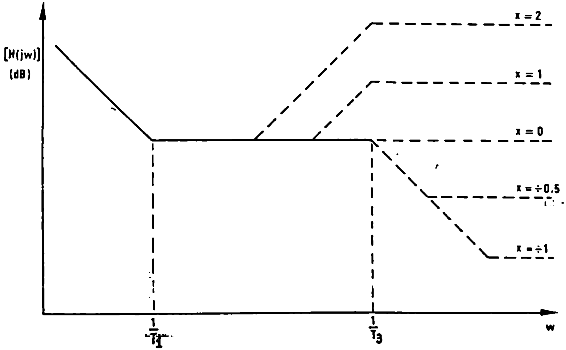


Figure 3.21 PID- controller Characteristic.

Depending on the adjusted value of x, the PID-controller can vary in form as follows:

x>0 - PID controller action with high frequency cutoff

x=0 - Pure PI controller (deviation action avoided)

-1<x<0 - PI controller action with high frequency cut off

-2<x<-1- PI controller action with signal transport delay.

According to the NORCONTROL information, in the range -2<x<0 the controller can activate as pure Pi controller used to control the process looklike too small I/P converters, low control air pressure, long air control pipe.

3.3.1- Controller Loop

In general, the single controller loop is composed of the following parts:

- Controller
- Actuator
- Process
- Sensor or measuring element

The basic PID controller can improve its control performance by including one or several so-called "forward signals". The standard PID controller loop is shown in Figure 3.22

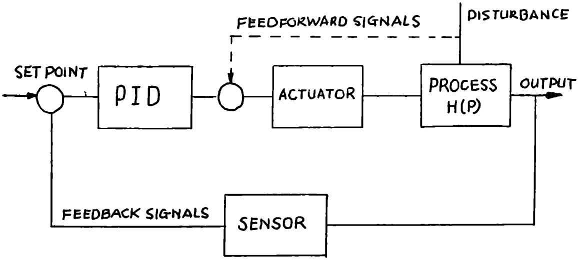


Figure 3.22 Basic PID Controller Loop

So far, process control has been introduced using a single loop control, it is sometimes necessary to achieve statisfactory control by further introducing a multiloop control system called "cascade control" that can be seen in Figure 3.23

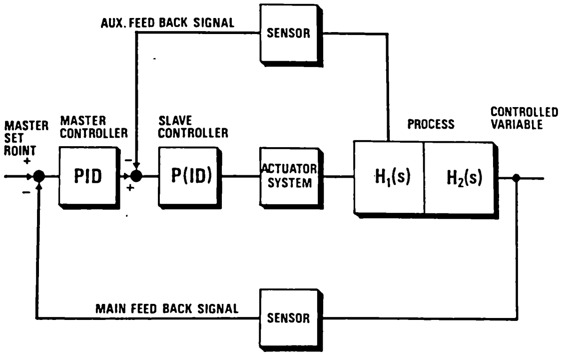


Figure 3.23 Multiloop or Cascade Control Loop

In this control loop, there are two controllers: a master and a slave. The slave controller measures and controls the front part of process, while the master controller checks the controlled value of all process and sends correction signals as a set point command to the slave controller. In a complete slave controller loop may be considered as a correcting unit for the master controller.

With the cascade control arrangement a dynamic process can establish its own stability more quickly if any disturbances influence on this process. In fact, the slave controller will usually have only P or possibly PI actions.

3.3.2 Standard PID Controller Loop for Simulation Purposes

For the purposes of controlling the controlled variables such as FW temperature outlet ME, LO temperature outlet ME, FO temperature etc, although there are different dynamical controlled process all control loop systems have the same actuators-controlvalves. In accordance with NORCONTROL instructions and Automation and Control for Marine Engineers, the valve movements are modelled as a linear first order process:

$$T \cdot \frac{dv}{dt} + v = u \qquad (3.37)$$

Where: v- Valve movement

u- Control signal

T- Effective valve time constant (sec)

These movements can be described in Figure 3.24

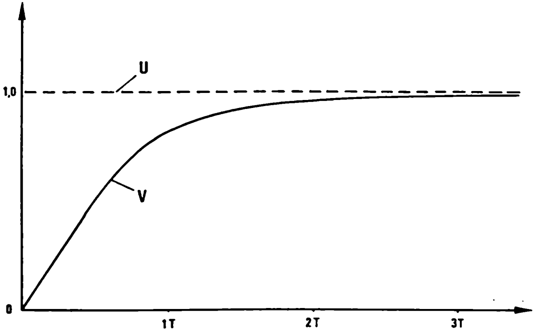


Figure 3.24 Valve Movements

The speed of the control valve is dependent on air supply pressure. This phenomena can be simulated by increasing the effective valve time constant (T) at reduced service air pressure.

For computional reasons the valve time constant is described as a non dimensional unit (x) between 0-1 and can be adjusted as a model constant.

$$x = 1 - EXP(-TS/T) \tag{3.38}$$

Where: TS- Sample time (sec)

x - Time constant parameter

T - Valve time constant

Then, the standard PID controller loop system that is used to simulate the automatic-controlled systems of a diesel engine propulsion plant, is shown in Figure 3.25.

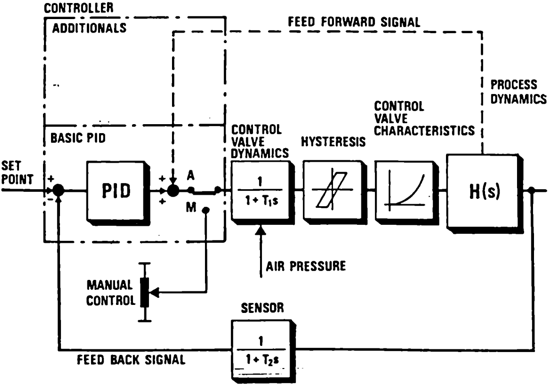


Figure 3.25 Standard PID Control Loop

On the basic of such a principle, in the engine room simulator the NORCONTROL company has arranged automatic loops for instances for the fresh water cooling system as follows:

In this system there are three different modes possible

- Control of fresh water temperature inlet ME
  This is a normal control setting.
- Control of fresh water temperature inlet ME (outlet fresh water pump)
- Control of fresh water temperature inlet ME by using a double loop or cascade loop: the output from the external hardware controller is then connected to the set point input of the software controller, the later controlling the FW temperature inlet ME. In this case the hardware controller plays the role of the master and the software controller slave. The FW mixing control valve is considered as a fixed and linear characteristic. The temperature sensor after FW pumps used at ME inlet control has no time lag or ideal sensor.

The arrangement of FW temperature controller can be seen in Figure 3.18. The local panel of FW temperature control loop is shown in Figure 3.26. On this local panel there are temperature indicators, a scale used to adjust the controller gain (x) and the switch changed over from MAN to AUTO function.

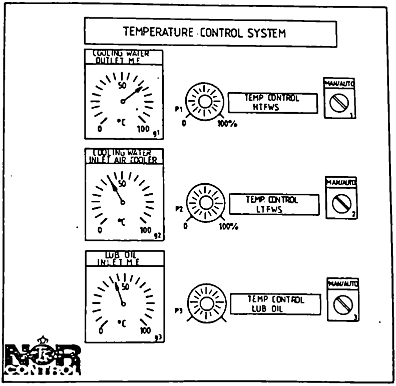


Figure 3.26 Local Panel FW Temp. Control System

3.4- Computer System

In part (3.2) the author has mentioned the mathematical models of some components performed in the diesel engine propulsion plant. For the purpose of simulating the mathematical models are programed on a computer in FORTRAN and ASSEMBLER languages. The next step is the computer model and the operating program which are stored on flexible disks. They are then put into the computer system each time a simulation is to be run. Also, the instructor is able to stop a simulation at any time and add, change or store current data in the disks.

4.3.1 Computer Hardware System

In figure (3.27) the computer system is illustrated in general. The computer hardware system may be used for a wide range of applications. However, the first purpose is to perform the man-machine communications system.

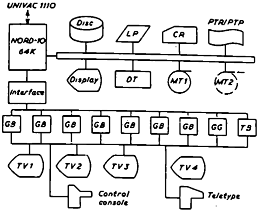


Figure 3.27 The Computer Hardware System

The components of the computer hardware system are briefly explained below:

a- Computer and peripheral hardware

- A digital computer has some analogue, digital input and output channels. Its capacity is about 100 kb (depending on complexity of a simulator).
- Disk system
- Magnetic tape station (MT1 and MT2)
- The paper tape reader and punch (PTR,PTP), card reader (CR), line printer (LP).

b- Computer communications system

- Simigraphic buffers (GB)
- Graphic buffer (GB)
- Tracker ball (TB)
- The colour display.

Thanks to the computer system, the element models can be interconnected in many ways to perform a plant model and then be adjusted to vary the plant conditions adequately for the training purposes.

3.4.2 Types of Signals Used in The Communications System

For the purposes of simulation there are two types of signals used in simulation systems: analog and digital. If the signals in to and out of one system are continuous signals then these signals are called analog signals. On the other hand if the signals in to and out of one system itself can be only in two different states identified by two voltage levels or two current levels, the signals then, are called digital signals.

a- Analog Signals

The levels or magnitude of analog signals may vary continuously with time, that is, the amplitude of the signal may assume any of an inifite number of values between some maximum and minimum limits.

In automation systems like an alarm and monitoring system analog signals are very often used. Each of the analog signals are sampled with specified intervals. All the analog signals are divided into groups which are scanned at certain intervals. The intervals are related to the need for update values, and to the speed of change in a process. In order to detect instrument failure, rate failure or process alarm, the measured value is compared to a set of limits which describes the particular sensor.

If the measured value is found to be outside the limits of a process, an alarm for process failure is given. The process failure alarm is recognized by the text HIGH or LOW. The alarm remains until the process variable returns within limits at which time a return- to- normal message is given.

The analog signals are used in a monitoring system shown in Figure 3.28

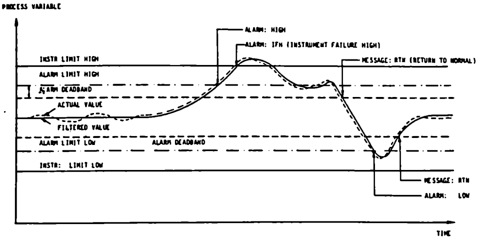


Figure 3.28 Analog Signals

b- Digital Signals

The digital signals used in simulator systems have only two possible levels: 0 and 1. Therefore, they are binary signals. If the signals are represented in numerical form, then one of the levels is a value of "1" and the other a value of "0", the two values in the binary (base 2) system. Digital electronic circuits operate on voltage levels, but the voltage levels represented by a 0 or 1 in one system may be different from the voltage levels represented by a 0 or a 1 in another system.

In alarm and monitoring systems both signals may be used: analog and digital. In the case of the digital signals, each binary signal is sampled several times each second, and a change of a state to an alarm condition will turn on a horn and start an alarm group lamp flashing.

In a computer system we use the digital computers. If some sensors or actuators generate or use analog signals, the signals can be converted into binary signals by using so-called analog- to- digital converters. In the opposite case, we can use a digital- to -analog converter if it is required.

The principle of using the binary signals is shown in Figure 3.29

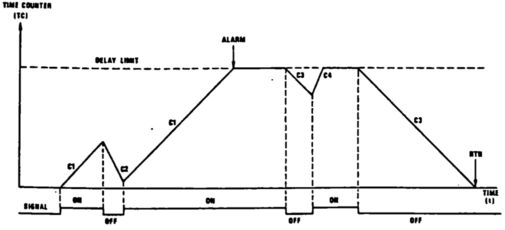


Figure 3.29 Binary Signals

3.5 Training and Instructor Facilities

The principles of simulating an engine room simulator and some mathematical models needed to perform plant systems are mentioned above. However, to complete an entire engine room simulator we have to study more about the machinery equipment, control room equipment and instructor's equipment.

3.5.1 Machinery Space Equipment

The machinery space in a real ship's engine room is usually located on different flats and widely distributed. The simulate aspect various control panels are provided in the simulator machinery room.

All the equipment of an engine propulsion plant has to be provided with local panels. Also included are a temperature control panel, starting air and control air compressor panel. The local panel of each piece of equipment has its own mimic diagram, for example, the main engine panel has a mimic diagram and several reset push-buttons. These buttons represent different engine faults and when operated, simulate the correction of the fault by overhaul or repair. The panel also represents the possibility of adjustment of the fuel rack position for each cylinder. For instance, the main engine mimic diagram is shown in Figure 3.30. This is constructed by NORCONTROL company.

3.5.2 Control Room Equipment

In the control room equipment there is a control console, a teletype and an electric switchboard. The control console is often constructed on the base of an integrated alarm and the monitoring system. It usually includes the following panels:

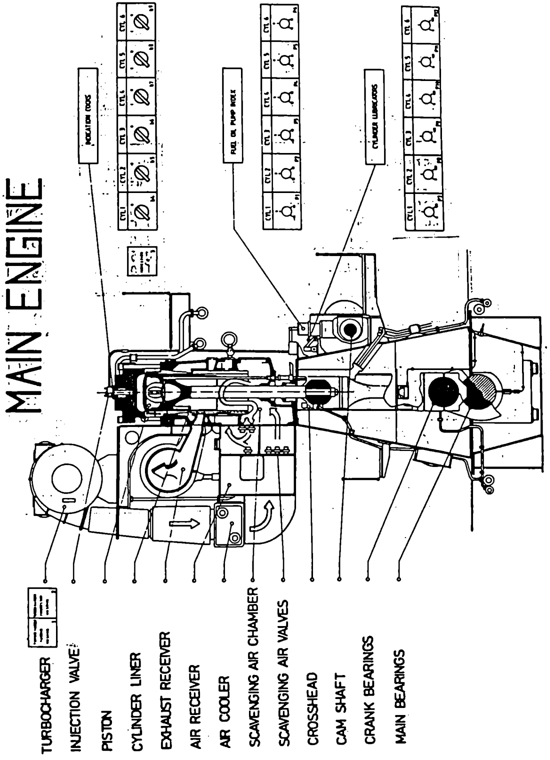


Figure 3.30 Local Panel Main Engine

- An alarm panel
- A communication panel
- A remote control panel, and
- A main engine manoeuvring panel

Like a really high-automated engine room, it enables trainees to operate (starting, stopping, changing of a working condition or synchronizing of generators) fully-automatically all the equipment and systems of an engine propulsion plant. Furthermore, a teletype is also used for logging all alarms and any parameter changes that have been made.

An example of an engine control room is shown in Figure 3.31.

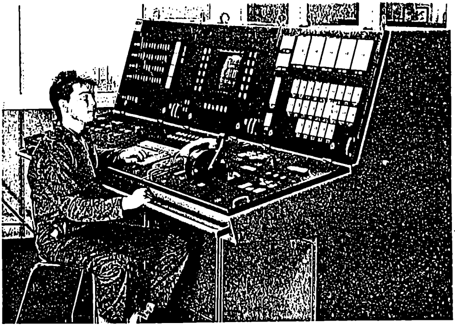


Figure 3.31 An Engine Control Room

3.5.3 Instructor's Equipment

The instructor's console contains a bridge control unit and a simulation communication system.

The bridge control unit enables the instructor to exercise remote control of the main engine as a "bridge officer". From an other section (a simulation communication system) the instructor may perform simulation control, general system communications, entering faults, setting and changing operational and ambient conditions, developing and testing training programs, freezing and storing of current situations.

Figure 3.32 shows the instructor's facilities composed of the bridge control unit, the simulation communication system, the display unit and so on.

The instructor's console

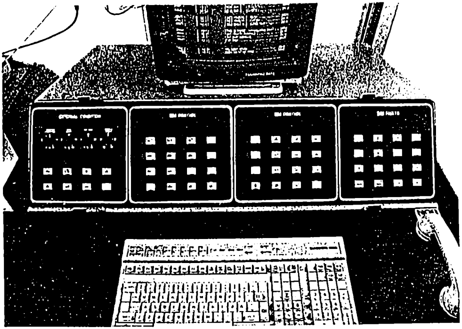


Figure 3.32 Instructor's Facilities

CHAPTER IV

TYPICAL ENGINE ROOM SIMULATORS

IV- Typical Engine Room Simulator

In the earlier chapters, the basic principle of simulation has been introduced. Since the arrival of the conceptual simulation, it has been developed in many countries as a tool for researching, designing purposes and for creating training devices.

For training purposes, the training devices such as radar simulator, ship handling simulator and engine room simulator have been developed rapidly in Norway, Japan, the U.S.A the Netherlands and Germany.

Although the training simulators have been developed in one country or elsewhere, they have been designed with a capability which makes it possible to compress situations normally encountered through many years of experience into a few weeks and also to provide experience to guarantee future safe operations.

In the part below, the author would like to recommend some typical engine room simulators around the world and make certain assessments.

4.1 Dieselsim- Norcontrol

The Dieselsim is an engine room simulator which has been designed and developed by a well-known company in the world: Norcontrol. The Dieselsim is a modular dynamic real time computerized simulator in which have been built up the mathematical models of marine power plants and in which appropriate devices for adjustment and display have been set up to simulate various operating conditions of ship power plants.

As a comprehensive training package we can use it to teach the logical way to fault finding, to train the operation of machinery and equipment in normal and abnormal situation without danger to life or equipment. Furthermore to allow the instructor to assess the degree or level of understanding of the trainees.

4.1.1 Dieselsim Room Layout

Dieselsim has a layout and instrumentation typical to that of a modern vessel and is normally arranged over three separate rooms:

- The engine control room
- The instructor's room and
- The engine room, see Figure 4.1

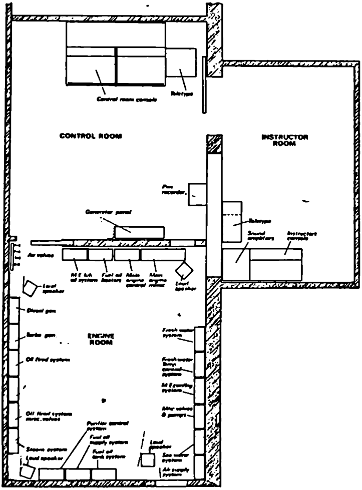


Figure 4.1 Dieselsim Room Layout

The two first items, the engine control room and the instructor's room are almost equipped with standardized and advanced commercial ship automation and control systems slightly modified to be able to interface to the specially designed simulator hardware.

4.1.2 System Configuration

The overall plant arrangement is shown in Figure 4.2

a- Instructor's Room

- Simulator console
- Autochief II manoeuvring console
- Teletype
- Sound amplifier

b- Engine Room Control

- Data Chief III console
  + Operating panel
  + Computer
  + Interface electronics
  + Floppy disk unit
  + Power supplies

- Teletype
- Pen recorder
- Electronic regulator
- Generator and synchronizing panel
- Misc. electronic consumer

c- Engine Room

The engine room consists of the following local panels:

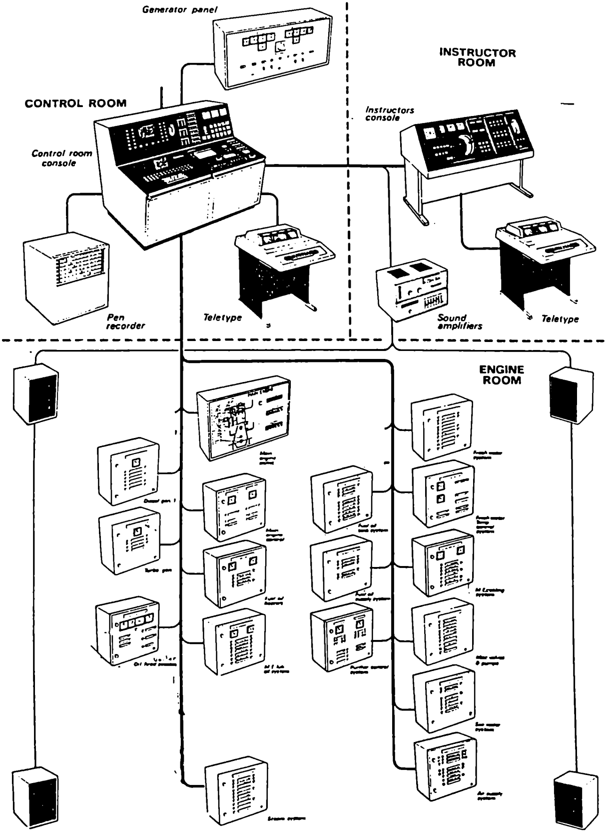


Figure 4.2- Overall Plant Arrangement

- Main engine mimic
- Main engine local control
- Aux. fresh water system
- Main engine LO system
- Sea water system
- Misc. valves and pumps
- Air supply
- Diesel generator I
- Turbo generator
- Steam system
- Boiler control system

4.1.3 Automation System

The Datachief III is chosen and slightly modified to interface the diesel engine plant as an alarm, monitoring and remote control system. The Datachief III can be simplified and described by the block diagram in Figure 4.3

A description of Datachief is enclosed, and it must be noted that some of its functions are not implemented on the diesel engine plant simulator. In fact:

In Data trend: The simulation of future condition and simulation of maintenance is not implemented.

In Data safe: The separate back-up system is not implemented

Figure 4.3 shows that the functions of the Datachief III system are:

- Datasafe

- Datapower
- Data trend
- Autochief II

DATACHIEF III

DATASAFE	DATAPOWER	DATATREND	AUTOCHIEF II
• Alarm/monitoring • Control of pumps purifiers and compressors • Logging • Calling and communication	• Black-out and power consumption control • Synchronizing and loadsharing • Automatic start/stop of auxiliary engines • Alarm monitoring • Logging	• Condition monitoring • Electronic cylinder indication • Maintenance prediction • Bad condition alarms	• Main engine remote control • Engine protection

FLOPPY DISK	TELETYPE
• Read system progr • Freeze/write present process situations	• Log alarms, messages and changes

Figure 4.3 Datachief III Block Diagram

For operation purposes, there are the main console panels which consist of four parts, from which every part of the functions can be operated.

4.1.4 Diesel Engine Plant Model

The engine plant models, form a complete diesel engine plant. The diesel engine plant consists of a diesel engine and all sub-systems which are associated with the diesel engine. The principle of this diesel engine plant model is shown in Figure 4.4.

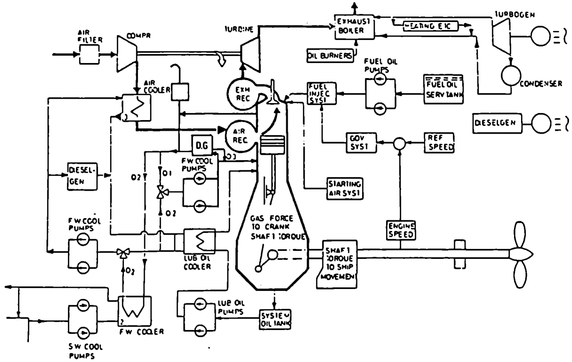


Figure 4.4 Diesel Engine Plant Model

In the diesel plant models the main engine is modelled as a slow speed, turbocharged diesel engine with the following data:

Type: RND90NC
Cylinder Bore/Stroke: 90/167 cm

Number of cylinders:	6
Max continuous shaft power:	15MW
Engine speed:	114RPM
Mean effective pressure:	11.8bar
Mean indicated pressure:	12.8bar
Scav. air pressure :	1.7bar
Scav. air system :	Loop scavenge 1 exhaust receiver 1 air receiver 2 turbochargers
Constant pressure TBCH	
Cooling system:	FW cooled cylinder liners/top covers FW cooled piston FW cooled injection valves

The simulation models are based on real time programming and are thereby able to replicate the dynamic behaviour of the engine room propulsion plant and all its different parameters as well as the interactions between the sub-systems of a diesel plant.

4.1.5 Instructor's Facilities

The instructor's operating console is composed of two sections:

- The Autochief II maneouvring panel and
- The main communication section, enclosing a teletype, and the sound equipment.

The functions of the instructor's facilities are explained briefly as below:

a- Simulation Control

The simulation control function enables the instructor to:

- set the speed of the ship to zero by activating "stopship" push-button
- reduce the acceleration constant of the ship (time constant) next to zero by activating "fast ship"
- perform the main engine running and still keep all tank levels fixed as the moment of pushing "steady run"
- introduce regularly a set of "normal" value into the simulator by pushing:
  + fixed process
  + fast process
  + emergency run.

b- Communication

Except the general communication functions, from the communication console the instructor can:

- perform the behaviour of the different mathematical models by changing the "model constants" and address on teletype to a model constant identification number
- inspect any of the model variables in the simulator by initiating the "model variable-button " and identify a model variable number on teletype
- change signal groups by pushing the "change recorder signal-button"
- perform repair"condition" by pressing the reset fault permit-button.

c- Creating of Faults and Deterioration

A number of faults and deteriorations can be performed in the plant individually or as preprogrammed group of faults:

- Single faults are set one by one pressing the "Set Fault" button and selecting proper fault number from the "Fault Index Table"

The actual fault selection is made from the teletype keyboard

- sequential faults consist of four preprogrammed sets, each having 8 faults, the proper fault group is selected by pressing "execute fault SEQ"-button

- the rate of components wear can be accelerated by initiating the "Progress Wear"-button

- random generation of faults can be initiated by the "Monte Carlo"-button.

d- Resetting of Faults

Resetting of faults can be done either by:

- Pushing the "Reset Fault"-button on communication panel or
- Pushing the "Reset Fault Seq"-button on the communication panel to reset all the fault in one preprogrammed sequence.

When a reset-action of fault is made, then three kinds of message are printed on instructor's teletype:

- Correct fault location
- Incorrect fault location
- Correct fault location is made, but the preparation for repair is not completed.

e- Logging of Events and Alarm

- The "Event Log"-function can be selected to the engine control room teletype or the instructor room teletype. The selected teletype logs starting and stopping of pumps, opening and closing of valves etc together with a current print of time.
- The "Alarm Log"-function can be selected to the engine control room teletype only or to both teletypes.

4.1.6- Available Training Programs for Trainees

The engine room simulator is designed for:

a- Training junior engineers in basic engine room operation

- to meet a control room arrangement that is realistic and as up-to-date as the most modern ship.
- to prepare for getting under way
- to manoeuvre to open sea and to harbour-Operation of the generators including start-up, synchronization and load-sharing
- to finish with the engine.

b- Senior/ Chief engineers are drilled at the advanced level

- emergency operations and trouble shooting
- by using the engine, the engineers are trained to face serious problems such as:

  + 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?

- Studies of process optimizing and fuel economy:
In the case of optimizing process the trainees have the opportunity to survey the total consequence of different methods of saving fuel and conserving energy. Furthermore, the simulator still enables the trainees to link their experiences achieved through so many years at sea to engineering theory.

4.2- Mitsubishi Diesel Plant Simulator

This simulator is designed and developed by the well-known company: Mitsubishi Heavy Industry, Nagasaki, Japan. Several sets are equipped at maritime academies around the world such as at the Australian Maritime College, and Japanese Maritime College.

4.2.1- Overview of The Plant

The simulator models are based on the behaviour of an 18kw slow speed diesel engine equipped in a 120,000 DWT oil tanker. For training purposes the behaviour of the ship can be performed, given the standard models, by adjusting the model constants. The plant of the engine room is described in Figure 4.5.

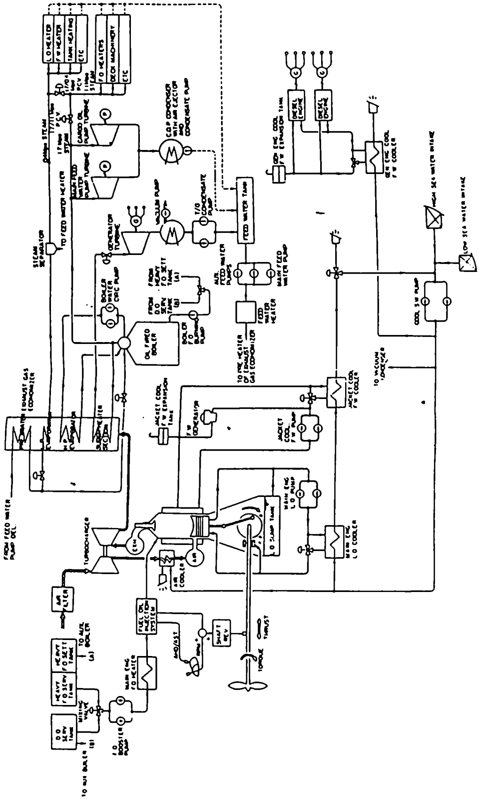


Figure 4.5 Mitsubishi Diesel Plant

4.2.2- The Computer System

The computer system was designed on a base of a PDP-11/34A with 248 kb of user accessible memory. The operating system and utilities being RSX11M with a FORTRAN IV and compiler. The computer system configuration is illustrated in Figure 4.6.

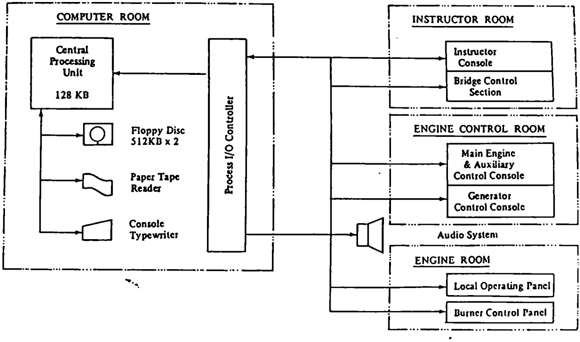


Figure 4.6 Computer System Configuration

4.2.3- Instructor Control Program

In the instructor's room there are the following facilities:

1- Up to 40 operational read/ write files
2- Up to 316 engine faults, which can be created singly

or in groups of 8, with a programmed performation sequence and student action initiated cancellation.

3- Up to 6 channels trend recording using a pen recorder

4- Fire time scales

5- A logging facility which can record operational actions and an alarm annunciation and recovery

6- Compression and out of phase indicator diagram print out

7- Time slice of process data.

4.2.4 Hardware Equipment

The Mitsubishi company has arranged the engine room simulator in five spaces:

1- The computer room, including the input and output devices, 672-digital and 100-analogue channels

2- The "engine room", in which there is a large mimic panel on which valves, pumps and generator prime movers are operated, and manual controller outputs can be manipulated

3- The control room where there are a real machinery control console, an electrical power distribution panel, a V.D.U. an alarm logging and indicator diagram printer.

4- The instructor room which consists of the system control terminal, a process monitoring V.D.U a real bridge control panel and a small panel that allows the instructors to run the control programs by push buttons.

5- An off-duty room which doubles as small classroom fitted with an accommodation alarm unit from a ship.

4.2.5- Available Course Development

According to the company-maker's recommendation, by using this simulator the themes of training courses can be demonstrated as follows:

- Learning of system behaviour. It is suggested that any one /after learning/ interfacing with a plant should be able to understand its behaviour at a appropriate level.
- Practising of operational techniques regarding advanced engine room, its propulsion plant and automation systems require proper human activities in certain combinations and sequences. The operational techniques have to be practised as much as possible in different level requirements of trainees.
- Management of system failure, it is likely to train the students regarding the rules of decision-making based on various kinds of information. Therefore, it is considered as the control learning theme of a plant simulator.
- Other educational uses: a thermofluid system, a ship manoeuvring system and an examination aid.

4.3- The Marine Engine Room Simulator at TNO DELFT

The marine engine room simulator has been designed and developed by Exxon International Company (Tanker Department) and Exxon Research and Engineering in cooperation with the institute for Mechanical Construction of the Dutch Organization for Applied Scientific Research (TNO).

The simulator was built for this reason that a training aid was needed in order to ensure safe and efficient operation of increasingly complex marine propulsion plants and their associated system, especially large-modern turbine propulsion systems.

The engine room simulator that was simulated in the base of a turbine propulsion plant fitted on a large tanker, can described as follows:

4.3.1- Simulated Machinery Installation

The engine room simulator dynamically models the steam turbine propulsion plant of the TT "ESSO WILHELMSHAVEN", a crude carrier of 250,000 DWT. The machinery installation has the following characteristics:

- 24,000 kw eross-compound General Electric main steam turbine with four bleeds and bridge control capacity. 80 rpm at maximum continuous power.
- Single Babcock & Wilcox Marine Radiant main boiler equipped with two economizers, a rotary generative gas air-heater and two electric motor-driven forced-draft fans. Steam production is 110tons/h at 64 bars and 513 C.
- Single auxiliary/emergency boiler whose steam production is 30T/h saturated at 18 bars.
- One main turbo-alternator of 1100 kw
- One standby diesel engine driven alternator of 900 kw.

- One emergency diesel-driven alternator of 275 kw with automatic starting system.
- Central control room for remote alarm monitoring and control of machinery.

The boilers were constructed to be controlled by the Askania control system. Turbine control is by Siemens and the system control by Leslic.

The simulation model was designed to simulate the following items:

- The main steam, condensate and feed system.
- The electrical generator and distribution system
- The boiler air/gas and fuel systems, and
- The supporting lub. oil and sea-water system.

Due to the required-reasonable size and level of complexity, some kinds of machinery have not been simulated such as cargo pump turbine, firefighting system. Therefore, an overview of the simplied scheme of the simulated propulsion plant is shown in Figure 4.7

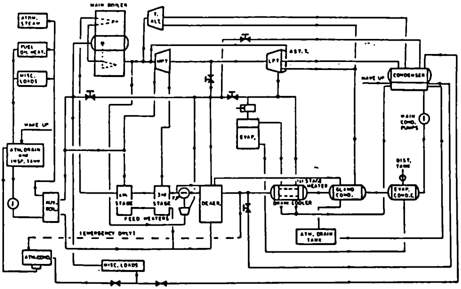


Figure 4.7 Turbine Propulsion Plant

4.3.2- Simulator Layout

The engine room simulator facility is composed of:

- A control room
- An "engine room"
- An instructor's cabin
- A lecture room
- A digital computer programmed with the mathematical models of the power propulsion plant.

Figure 4.8 shows the simulator lay-out

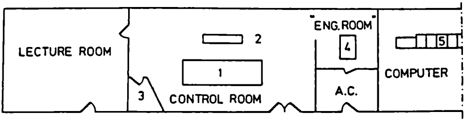


Figure 4.8 Simulator Lay-out

1- Main instrument console
2- Electrical switch board
3- Instructor's cabin
4- Computer

The CONTROL ROOM where the main instrument console is situated is equipped with the main propulsion control and the other instrument console plus the electrical switch-boards.

In the ENGINE ROOM there are three "local" panels which are in the form of mimic diagrams corresponding to the elements of the propulsion plant. They are used to allow the trainees to carry out some exercises e.g reading of indications, making of trouble-shooting like in a real engine room.

In the INSTRUCTOR's CABIN the simulation process is controlled through a CRT display with keyboard, through the keyboard, connected to the computer, to allow the instructor to

- Perform initial conditions
- Start and freeze the simulator
- Create an existing process condition into disk storage
- Change the performances of the individual component by changing of the model constants
- Introduce the failures, malfunctions as single acting or group
- Give a command as a bridge officer

The LECTURE ROOM allows the trainees to prepare and analyze the exercises on the simulator.

The COMPUTER CONFIGURATION is composed of the hardware and software.

- HARDWARE: The computer used is an EAI PACER 100. It is a general purpose type with the following features:

  + Memory disk 32k (16 bit word length)
  + Disk system
  + Graphic display terminal
  + Line printer

+ Card reader

+ Real time clock

The computer has a 64 analogue input channels, 192 analogue output channels and a 288 digital input-, output-channels.

- SOFTWARE: The mathematical models of the power propulsion plant have been programmed on the computer in FORTRAN and in ASSEMBLER languages. The process is modelled on a base of so-called subroutines (General principle mentioned in item 3.2).

An overlay technique has been applied to accommodate a 50k model on the 32k computer, not taking into account utility routines for print outs, instructor's interface etc.

4.3.3- Available Training Course Development

For the education and training purposes, the training simulator courses can be organized to achieve the following objectives:

- To help the students and marine engineers to complete their knowledge of steam propulsion plant principles.
- To improve marine engineer's professional skill in the safe and efficient operation of complex steam propulsion machinery and systems in accordance with requirements of different levels.
- To provide an opportunity for the trainees to drill themselves in the making of trouble-shooting and facing with machinery operation in abnormal conditions.
- To improve operating practice in order to conserve energy.

- To provide a good facility for other objectives such as contribution to a faster transfer form diesel engine to steam turbine operation and to the training of nautical personnel for dual licensing and so on.

4.4- General Assessment

Above the author has mentioned the simulation principles and engine room simulators among great number of them that are installed around the world. Based on the analysis of these simulators and other information gathered by the author that author can not have opportunity to mention here due to the limitation of the dissertation. Thus the author would like to summarize as follows:

1- All the engine room simulators have been designed and developed on a basic of a real engine room with very high-power propulsion mover e.g Dieselsim Simulator with diesel engine power 15MW, Mitsubishi Simulator with diesel engine power 18MW etc. The reason for this is to provide an opportunity for trainees to be familiarized with very a large engine room , then they can easily manage an engine room of smaller scale in their realistic jobs.

2- The process of the propulsion plants are modelled by using subroutines which are classified on the basic models, the system models and the plant models. Each basic model is used to model a component of the process, then all combined basic models can perform the proper system models or plant model. The computer system used is a digital computer with a memory from 20 kbytes to 35 kbytes. The input and output channels used are both kinds: digital and analog channels.

3- The engine room simulators are designed primarily for training application (The objectives of these are already mentioned in the available course development of the engine room simulator) however, it is enriaged it may also be used for research purposes e.g

- effect of hull fouling on the propulsion plant performances,or
- the human operator during fault management.

4- The engine room simulator of the Norcontrol (Dieselsim) and the Mitsubishi engine room simulator are very similar to each other. Both the engine room simulators are built up on the basic of the diesel engine room but can also be used to train the trainees on the oil-fired boiler and the steam turbine. The simulators have been simulated almost as a real engine room for training purposes and their advantages are obviously mentioned in the above parts.

5- Besides the advantages of the engine room simulators there are some negative points in the structure of simulators and for the training purpose as follows:

- The mimic diagrams of the diesel engine and its components or the machinery and equipment are so simple that they look like the technical schemes which are very difficult for the students who for the first time, have the opportunity to learn how to operate the engine room machinery and systems.

- In constructed structure of the simulators there are some items which are not so logically designed e.g the probability of diagnosing a scavenging fire within 5 minutes is very much greater than that for a cracked cylinder liner (Mitsubishi Simulator) or there is found logical design at the Dieselsim simulator when the diesel engine runs at 102rpm, fuel indication at 94% and the maximum combustion pressure (Pmax) at 130bars, then the load is increased, the diesel engine is decreased in its revolution to 98rpm, the fuel oil supply is increased to 98% but, instead of increasing the Pmax, in fact it is decreased to 124 bars (Dieselsim at the Nantes Maritime College in France).
- Very often the participants had not fully appreciated the systemic nature of control theory or could not relate the theory to the operational task e.g the controller's outputs are available to participants , as a process variable but have been almost universally ignored as a diagnostic aid. Participants wait until a process alarm is generated, which is some time after the controller output has reached its limit.

Therefore, considering this information about different types of the diesel engine room simulators, it is very helpful for our Maritime University to decide to choose a diesel engine simulator for training purposes /see chapter VI/.

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CHAPTER V

RECENT EXPERIENCES WITH ENGINE ROOM PERSONNEL ON SIMULATORS

V- RECENT EXPERIENCES WITH ENGINE ROOM PERSONNEL ON SIMULATOR

Within the past few years a number of engine room simulators have become available and they have quickly been accepted as invaluable tools for the training of engine room personnel. Assessing the training functions of an engine room simulator, almost all the training centers have the same opinions that the engine room simulators can provide a most valuable and flexible means of carrying out professional training and research, and in the future the simulators can be used as a part of the examination process for the award of certificates of competency. However, simulators are not able to perfectly represent the real-world. Therefore, depending on the degree of sophistication of the simulator, the results of interaction between the human and the machine and the operating environment, the efficiency and the effectiveness of the used engine room simulator to train engine room personnel are different. Because of this, in this chapter the author would like to analyze the positive and negative features of an engine room simulator for training purposes.

5.1- Advantages of An Engine Room Simulator (ERS) in Training Areas

When analyzing the marine engine simulator for teaching, we have discovered many special merits of the simulator such as the economy and safety features, the repeatibility of training of the students, improving the ability of students to analyze and remove the faults, the possibility of special training and research e.t.c.

So, the some advantageous characteristics of the marine engine simulator for training purposes can be summarized as follows:

5.1.1- Low Cost of Simulator Training

The engine room simulator very often has no large and complicated mechanical equipment. As we know, the engine room simulator costs about a half million dollars (U.S) and only consumes very little electric energy for its computer (about 2.5kw). So using a simulator not only saves a large sum of initial investment, it also does not consume large amounts of fuel, steam or electrical energy. Moreover, the daily maintenance costs are greatly saved.

Furthermore, a training simulator provides the means by which different training situations, operational scenarios, fault or emergency conditions, may be programmed for training purposes without incurring the cost associated with putting a ship to sea, or other involved units or personnel.

It is evident that the training of seafarers by using such simulated propulsion plants is much cheaper than that carried out on real ships. The same opinions were concluded at the 5th Ship Control System Symposium (SCSS) in 1978 in U.S.A that the cost of a simulator only equals 1/8 to 1/10 of that of real ships.

5.1.2- Repeatibility of Training

We can train the trainees in all kinds of operational training on the simulator exactly as on the real equipment. It is safe and reliable, and can be done repeatedly. Some items often used in operational training are:

1- Operation of The Main Engine Remote Control Equipment

The automation systems and equipment are designed exactly the same as that on board ships. The automation systems are composed of three parts: bridge, engine control room and engine room.

For training purposes, the trainees have the opportunity to become familiar with modern automation systems and equipment. They can also practice on how to operate the main engine remote control equipment, to change over the three manoeuvring positions of the main engine and to start up, synchronize and load-share the generators as in the real engine room.

2- Main Engine Basic Operational Training

The objectives are to give the students knowledge of the various modes of operation of the main engine . The exercises may include:

- Preparating for getting underway
- Manoeuvring to open sea
- Manoeuvring into harbour
- Finishing with the engine

The main engine stand-by, "at sea" manoeuvring and "at harbour" procedures of the simulator are the same as that on board ships. So, it is very effective for the students to learn all the procedures on the simulator by repeatedly practising.

3- Training for Correct Operating of The Equipment

All the associated systems and equipment in the engine room have also very complicated operating sequences. Being familiar with this sequence for each piece of equipment is also important for the development of correct operating by the engineers. For instance, the purifier, boiler, turbo-generator, diesel generator etc can all be simulated for training purposes.

4- Training for Duty in The Engine Room

The watchkeeping function in an engine room is a main task of the marine engineer. Due to the random changing of the operating parameters and the liquid levels, the watchkeeping engineers have hourly to face critical situations. According to what is shown by the alarms or watch-keeping engineer's recognition, he might have to do,e.g the following work:

- Fill the fresh water expansion tank
- Make up water to the purifier water tank
- Make up lub.oil to the lub.oil tank
- Change the filters
- Adjust the temperatures, pressures etc.

Furthermore, he has also to monitor the main engine and various thermal parameters, then analyze the combustion and injection information of each cylinder by the indicator diagrams.

In addition, when sailing at changing sea conditions the condition of the main engine and the other equipment will also change correspondingly. Then of course, the watch-keeping engineer has to act so that all the systems and equipment safely. It is fortunate that by the engine room simulator the trainees may be trained to meet all these requirements.

5.1.3- Drilling in Trouble Shooting

For advanced operational training, a number of questions has to be answered, for instance:

- How will an engine side crew operate together when abnormal situations develop? or
- How can faults within the systems be traced and corrected?

Questions like these may be answered through simulation of component break down and abnormal situations. Every engine room simulator has more than 400 faults programed into its software. The instructor can push the "Set Fault" push-button on the control panel and use the keyboard on the TTY to send the fault code into the computer, thus the fault will be displayed on the control box and on the control console. According to the conditions displayed, the trainees at the control console and in the engine room can check the various parameters and analyze them to determine the cause of the fault and propose an appropriate method to remove the fault.

Besides more than 400 programed faults, the instructor may update the various model constants or by a means of fault combination, he can artificially make up many faults.

Through analyzing and removing the faults, the students can further understand the use of the various power plants and the connection between them. They can also learn what is required for them in the future job on board ships.

5.1.4- Acceleration of Damage Processes of The Machinery

As known, the deterioration process of some machines and equipment happens very slowly, and cannot be felt in a short time. For instance, the wear of the piston rings and bearings are calculated in numbers of thousand of hours. But, on the simulator serious wear can be demonstrated in a very short time. Such demonstrations give students a good chance to understand how the wear of the piston rings has impact on engine performances and the capability of the used piston ring wearing system to diagnose engine health.

5.1.5- Special Training in Critical Situations

Some critical situations such as malfunctions, faults or dangerous accidents which cannot be demonstrated on real ships, can be easily simulated on the simulator. For instance, emergency stop of the main engine, emergency running of the main engine, scavenge air box fire, piston seizure, lost propeller, heavy hull fouling, electric power supply black out etc, can all be repeatedly simulated for training purposes.

In terms of the heavy hull fouling, then the various problems will be displayed: decreasing the ship's speed, raising the exhaust temperature, increasing the cylinder liner temperature and cylinder head. When the ship propeller is lost, the main engine is over speed but, the speed governor adjusts the fuel valve and the engine speed returns to normal while the ship's speed decreases gradually due to the ship's inertia.

It is obvious that such training gives the trainees the opportunity to learn something that can be met in real life but not easily demonstrated on a real ship for training.

5.1.6- Special Studies

As we all know, the engine room simulator is designed so that relations between the simulator operation parameters are random. Therefore, we can carry out some studies of several special problems on the simulator. This way it is more economical, more convenient and safer than doing it on a real ship. For example, the selection of the optimum economical speed of main engines in different sea conditions, the effects of various kinds of fuel oil on the main engine performances, the improvements related to feed forward and cascade control etc, can all be tested on the simulator and thus yield valuable conclusions.

5.1.7- Other Developmental Applications

Due to the complexity and connectivity of the modelled plant, in addition we can utilize the engine simulator for other educational uses

1- To study thermodynamics

The subject of "thermodynamics" however, it is split into components, is always an important element in the education of marine engineers. In the Australian Marine College, the simulator has successfully been used for:

- First law analyses- of the familiar type
- The less familiar second law analysis, in term of the rate that the plant is creating entropy.
- The explanation and testings trajectories on a turbo-charger map. This is particularly effective learning as students deliberately drive the turbo-chargers across the surge line by introducing different combinations of supply and demand side system faults into the models.

2- As an examination aid

In some training centers around the world, the engine room simulator has been used for testing the marine engineer's ability to be awarded the watch-keeping certificates of competency. The results of these were concluded as excellent.

To do so, the appropriate examination plan must be constructed. For instance, the students should be asked to present a brief state of the plant, then to take over the watch. The examiners then observe the student's behaviour and ask for explanations of such behaviour in response to simple malfunctions.

Of course, such functions of the simulator is still not used so often. It needs time to prove itself. We hope the engine room simulator will be adopted as the examination aid in the future on a world wide scale.

5.2- Some Lessons From Used Engine Room Simulators for Training

In part 5.1 the author has mentioned the vast application of an engine room simulator for training and in appendix C several training programs on simulators at different training centers around the world are recommended. After analyzing the training programs the author would like to conclude that:

- All the training programs are concerned with training students, junior marine engineers, chief engineers and the deck officers.

- The simulator training can be divided into two parts. The first part is devoted to learning e.g the lay-out, function and operation of simulator, while second part comprises the trainee's work with the special studies such as fault finding, diagnose process, fuel economy etc.
- It has been found that those who were trained on the simulator when they were students, have later better results than the others who have never been trained on it. Ideally the sooner this training is given in the carrier the better, but not until the student has some knowledge. It is preparable to give the training at this pre-sea stage so that the students are pre-trained in such procedures as testing of gear and can become a more useful member of the ship's staff more quickly.
- Training engineers during a short course of 7 to 10 days in the actual use of the simulator is a problem for all grades of engineers due to the very sophisticated equipment so, the familiarization step is very important one and in some cases it needs a lot of times for this step. Therefore, the instructor

should develop certain techniques reducing the familiarization time.

However, the simulator training is always accompanied with a number of problems:

- Choice of training media
- Preparation of training program
- Prerequisition of trainees
- Transfer of knowledge and skills during the training period
- Evaluation of trainee's understanding

Because of this, from the experiences of the mode course 2.07 (IMO) and some training centers who have pioneered the simulator training for long time, the author would like to summarize some experiences in training of the marine engineers by using the engine room simulator.

5.2.1- Choice of Training Facilities and Equipment

The choice of training facilities and equipment is a very important task after deciding to buy the simulator for training in a training center. This choice may range from the use of manuals and classroom teaching on the one hand to the use of whole task simulators or the complexity of a simulator on the other hand.

In fact, the simulator itself should be based on the engine room of a modern merchant ship, with its main unit being a dynamic real time computerized slow-speed main propulsion turbocharged diesel engine which incorporates a waste-heat steam boiler producing steam for turbo-generator. The engine room should be equipped with suitable auxiliary machinery and associated equipment, modern automation systems and related instrumentation adjacent to them. There should also be a separate room from the simulator spaces for lecture briefing which gives trainees good facilities to precede exercises and debriefing discussion.

5.2.2- Training Syllabus

The detailed training syllabus should be constructed in a learning objective format in which the objective describes what the trainee must do to demonstrate that the specific knowledge or skill can be transferred.

In order to assist the designer in preparing of a reasonable training syllabus, there are some recommended references: the IMO's references and publications (STCW Convention,1978, Model Course), national regulations, textbooks, technical instructions of the simulator, teaching aids and so on.

The content of a training syllabus depends on the trainees who have different learning objectives and initial knowledge or skills. For example, the syllabus content to train the chief engineers is different to that to train the engineer officers or students.

Furthermore, it should have more procedural training characteristics than a dedication to a particular type of engine due to the trainees then going to serve on different types of ships.

We should also remember that poor preparation is a sure way to close the interest of the trainees. It is evident that effective preparation of a training syllabus makes a major contribution to the success of a lecture.

5.2.3- The Instructor's Role

The instructor is the key to the effectiveness of simulator training and he has two main roles. One is to operate the simulator and represent the various outstations on the ship, and the other is to conduct the trainees in implementing their exercises and monitoring their progress including final evaluation.

Therefore, we have found that the instructor in charge should hold a merchant chief engineer certificate and should have experience in the operation and control of the engine room of a modern merchant ship as well as the training and experience necessary for using an engine room simulator as a training aid.

Furthermore, to operate the simulator effectively the instructor should also understand throughly the simulator itself and he could have the capability to manage the simulator in incidental cases e.g when the simulator's elements break down etc.

It is obvious that the instructor plays an extremely important role in carrying out the simulator training course effectively. We all know, poor teaching cannot be improved by good accommodations or advanced equipment, but good teaching can overcome any disadvantages that poor accommodation and lack of equipment can present. So, in every training center, the preparation of the instructor is always a priority that must be dealt with.

5.2.4- Entry Standards

Due to the short time of the simulator training course, about one or two weeks for each course, and the very sophisticated equipment, the entry standards should be established for the trainees. If in one trained group there are different levels of the trainees, the instructor cannot conduct the group to study effectively, thus the trainees who have a high entry level will get bored and those who have a low level entry may not follow the course. Therefore, the entry standards may be constructed on the basic of the course content and the international and national requirements for the certificates of competency.

If entry standards will not be met by the intended trainees intake, those entering the course should first be required to complete an updating course to raise them to the stated entry level.

5.2.5- Delivery

The main training components in the course are the practical exercises carried out under supervision on the simulated engineering plant. However, it is necessary to brief and discuss important aspects of the exercise before each exercises begin.

As far as possible, the instructor briefing trainees for the exercise should use practical examples involving real shipboard equipment and systems, referring to diagrams, lay-out plans, technical drawings and other related technical documents to supplement and reinforce the briefing.

5.2.6- Evaluation

The evaluation function includes those tasks which are concerned with appraisal of the trainee's performance and making decisions about a trainee's qualifications and recommendations for future training. The task involves the summarization (and processing) of data on performance as well as comparison with a reference standard. Many institutions have discussed under the evaluation tasks and they have conclud that to evaluate a student's performance the instructors are required to evaluate performance not only based on the printing out of selected data but also on notes or their recall of performance.

Although the engine room simulator is appreciated as a very good teaching aid for training marine engineers, it cannot cope with whole training requirements due to the simulator not being designed to substitute the real thing on board ships. So, to be more effective, the simulator needs to be designed as an integral part of the training system and not a piece of hardware which is produced separately from the training system. For instance, the engine room simulator and the ship handling simulator should be linked together and then perform the integral bridge-machinery simulator. In my opinion, it will be more useful to train both deck and engineer officers or even dualpurpose seafarers.

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CHAPTER VI

THE IMPLEMENTATION OF AN ENGINE ROOM SIMULATOR TRAINING COURSE AT THE VIETNAM MARITIME UNIVERSITY

VI- THE IMPLEMENTATION OF AN ENGINE ROOM SIMULATOR TRAINING COURSE AT THE VIETNAM MARITIME UNIVERSITY

The Ministry of Transport and Communications has planned to acquire an engine room simulator to be installed at the Vietnam Maritime University in Haiphong. This plan is to be carried out in the following stages:

Stage 1: Until Jan. 1992.

- The Ministry drafts the legal framework for simulator training and certification to all chief engineers and engineering officers of the Vietnam Maritime Fleet

- Selecting engine room simulator instructor team. They all have to attend an advanced English course, computer course and to learn the theory of E.R.S.

- Selecting type of engine room simulator.

Stage 2: Until June 1993

- Sending E.R.S team to study and train on simulator training at E.R.S manufacturer.

- Acquiring an engine room simulator.

- Assembling an engine room simulator and preparing teaching and teaching aids.

- Completing textbook "E.R.S manual".

- Instructor team will train itself and design exercises for the simulator training course.

- Preparing E.R simulator handouts for trainees.

Stage 3: From September/1993

- Operating first E.R simulator course for chief engineers and engineering officers.

- Teaching E.R simulator principles to 4th year marine engineer students at VMU.

- Developing more training programs to complete all engine team procedures and for research purposes.

Stage 4: From September/ 1994

- Running separate E.R simulator courses for
  + Chief Engineers (first and second class)
  + Engineer Officers
  + Marine Engineering Students
  + Deck Officers
  + Marine Engineering Superintendents

6.1- The Selection of E.R Simulator Equipment

The engine propulsion plant simulator is the basic equipment. It shall comply with the specification approved by the Rector of VMU and the Ministry of Transport and Communications. The Mitsubishi (Japan) engine room simulator has been selected by them. The reason for choosinge such an engine room simulator is that it is convenient to transport the equipment and economical to maintain and repair the E.R. simulator in the future. The chosen engine room simulator is based on the modern engine room of a 120,000 DWT oil tanker. The main engine is an 18MW low speed, turbocharged diesel engine which incorporates a waste-heat steam boiler supplying a turbo-generator. The scheme of this engine room is illustrated in figure 3.36.

6.1.1- Equipment in Simulator Room

Except for the main equipment of the simulator itself, the training facilities for students are also needed. The training facilities should be based on a modern control room concept with at least three workstations. Each workstation should consist of:

- a colour graphic display unit for picture presentation
- an operation keyboard for commands
- a visual display unit with keyboard
- one printer for all the workstations
- in addition there needs also some scheme relevant to the engine room simulator, engine logbook, etc.

The training facilities configuration is shown in Figure 6.1.

6.1.2- Equipment in The Classroom

The classroom should be equipped with an overhead projector and blackboard for teaching the theoretical part and the simulator briefing. The teaching equipment plays an important role in helping the instructor to implement exactly his teaching plan for the simulator training.

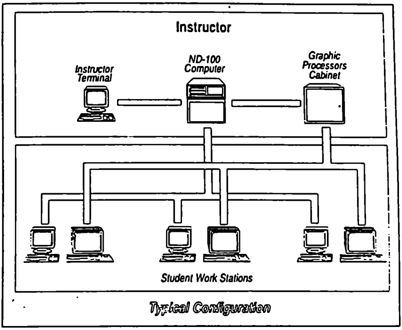

Figure 6.1 Typical Configuration of The Training Facilities

6.1.3- Textbooks

The simulator training that has been planned for the VMU is a new concept in the teaching process. Because of this the textbooks concerned with the simulator training are urgently needed for self-study purpose while the trainees are attending the courses. There are very few books written on engine room simulation and most of them are written by foreign authors. This makes it difficult for many Vietnamese participants to fully understand the engine room simulator. Therefore, it is necessary to prepare a proper E.R.S book. The author can recommend some good books and a lot of articles written by experts on the engine room simulator such as " Marine Control Practice " by Taylor, " A Machinery Space Simulator Based on A Micro-Processor" by R.Beam, J. Francis and S. Stallword (1985), "Microcomputer- based Simulation of Marine Propulsion System" by A. Fowler (1988). The experienced instructors will have to prepare "Engine Room Simulator Training" handouts for the participants.

6.1.4- Video Tape/Film

Video tapes or films showing different types of engine room simulators and simulator training sessions should be obtained for viewing. This will help the trainees to obtain some particular ideas of simulator training before they start to carry out the exercises.

6.2- The Instructors

As we all know, the instructor's role in simulator training is extremely important. The success of the participants and students depends to a great extent on the competence of the instructor. Therefore, preparing the instructor for the simulator training at the Vietnam Maritime University is considered as a first level of priority.

The engine room simulator team should consist of four instructors and one technician. In our case, the Rector of VMU has chosen four senior lecturers, three of whom hold the chief engineer certificate and one who has the second engineer certificate. They all are well qualified, well trained, dedicated and highly motivated. One more marine electronic engineer is chosen as the technician.

In accordance with our plan, the training team will then be sent to the E.R.S manufacturer (Mitsubishi, Japan) to attend the special E.R.S course for 3-4 weeks. They need to be trained in the operation and use of the hardware, software and capabilities of the equipment and how to carry out some of the difficult exercises in the engine room simulator. This is essential because if the instructors master the E.R.S training equipment then they will be able to design effective training exercises.

Before going to the E.R.S manufacturer for training, the training team has to study the engine room simulator principle according to the manufacturer's instructions, guidance and video tape. Thus the time devoted for familiarization can be reduced and the training team may have more time for other training tasks.

The maintenance of the simulator and peripheral equipment is very important for a successful engine room simulator course. So, the Vietnam Maritime University proposes the maintenance training for all the training team, not only for the technician. They should be trained by the E.R.S manufacturer in maintenance, fault finding and repairs. In addition, the technician should be trained particularly in electronics, computers, etc.

During the training course, the instructors need to keep detailed information regarding participants and their performance that will be necessary for statistical analysis. This data consists of:

- name, age, rank
- sea time
- types of ships worked on
- level of experience on the E.R.S

and the records of the performance:

- common, abnormal or novel manoeuvring of engine room machinery and equipment
- normal or abnormal mistakes
- types of exercises that the participant finds particularly difficult

Experience with simulator training shows that the effect of E.R.S training will improve when the instructors discuss all aspects of simulator training with practicians from all over the world through the MARSIM. If it is possible, the instructor team should be sent to different maritime colleges to visit and exchange experiences of simulator training with other experienced instructors.

6.3- Participants

The participants for the engine room simulator training course will be chief engineers, engineering officers, deck officers and marine engineering students of VMU. All participants must have a certain knowledge about the diesel engines and the diesel engine propulsion system arrangement. These requirements also apply to the marine engineering students. In our college, students who have completed the 7th term can start to learn on the simulator.

The engine room simulator training courses will be of 40 -46 hours duration for the senior marine engineer's training, 28 hours for the deck officers and 72 hours for the engineering students. These courses will be conducted frequently as per the requirement of shipping companies and other participants. In addition the VMU can conduct additional special courses such as:

- E.R.S training course for Navy Engineering Officers
- Special training course for marine superintendents
- Automation devices

The E.R.S training course at VMU can be divided into different orientations (applicable from September 1994)

- Chief Engineer and Second Engineer
- Engineering Officer
- Navy Engineering Officer
- Deck Officer including Master Mariner
- Marine Engineering students of VMU.

6.4- The Engine Room Simulator Training Program

The simulator training program is designed for gaining the knowledge and skill to the level of competency described in specific learning objectives which can be:

1- Updating the marine engineer's knowledge of modern diesel engine propulsion plant principles, to improve his professional skill in the safe and efficient operation of complex propulsion machinery.

2- To increase the watch keeping engineer's self confidence in handling all types of machinery, especially remote controlled equipment through "hands on" operation.

3- To provide an opportunity for the trainee to face certain critical situations that would be dangerous, difficult and exceedingly costly enact on board ship.

4- To improve operating practices in order to conserve energy.

5- To give the engineering students the opportunity to familiarize themselves with engine room equipment and arrangements and to help them to get some experience in short time for their future career.

The construction of a training exercise will mainly be based on the integration of theoretical knowledge with the necessary practical knowledge to adequately prepare the trainees. Consequently, the teaching method will consist of a series of lectures and practical demonstrations on the E.R.S and discussion. The pedagogical structure of designed simulator training courses is shown in Figure 6.2.

As we all know, depending on the trainee's requirements, every course must consist of the exercise modules at different levels. In Figure 6.2 the given letters A,B,C,D,E,F stand for the particular exercise module such as familiarization step (or simulator operation), operation training (line up procedures, manoeuvre procedures, at sea steady state) and theoretical studies including process study and component study. Meanwhile, the indexes (from 1 to n) stand for the level of the individual exercise module, the index is larger, the level higher. For example, due to the current requirement, the training course for marine engineering students needs more time to be devoted to familiarization than that for the chief engineers, but the less process studies and so on. Therefore, the training course for chief engineers may be composed of A1, B1, C2, D2 E6 and F5.

Therefore, due to the different levels, requirements of participants and studying time, a suggested schedule for the E.R.S training course at VMU is divided into 3 types as follows:

- For chief engineers
- For watch keeping engineers, and
- For marine engineering students.

EXERCISE MODULES

A	A1	A2	A3	A4	A5	A6	—	An	SIMULATOR OPERATION	FAMILIARIZATION
B	B1	B2	B3	B4	B5	B6	—	Bn	LINE UP PROCEDURES	OPERATIONAL TRAINING
C	C1	C2	C3	C4	C5	C6	—	Cn	MANOEUVRE PROCEDURES	
D	D1	D2	D3	D4	D5	D6	—	Dn	AT SEA STEADY STATE	
E	E1	E2	E3	E4	E5	E6	—	En	PROCESS STUDIES	THEORETICAL STUDIES
F	F1	F2	F3	F4	F5	F6	—	Fn	COMPONENT STUDIES	

Figure 6.2 The Pedagogical Structure

6.4.1 Schedule of Training Course For Chief Engineer

Duration: 6 days (1 week)

Number of Participants: 8-10 persons

This course is programmed especially to train the chief engineers who have many years of experience in operating the real engine room equipment and systems. The aim of this course is to update the chief engineer's knowledge in the operating procedures of modern equipment and to improve their understanding of the advanced automation, condition monitoring and diagnosis systems and in particular how to tackle some critical situations and how to operate the engine room equipment and systems efficiently and safely.

The suggested plan for the engine room simulator training course is based on IMO Model Course 2.07, the experiences of the simulator training of many maritime colleges all over the world and the recommended training courses of the engine room simulator makers. The time plan of this course and the conducted simulator training course are shown in Tables 6.1 and 6.2 respectively.

Furthermore, the Vietnam Maritime University has also designed some special courses required particularly by the shipowners who are interested in the saving of the fuel oil, maintenance of machinery and equipment, and in the influences of heavy fouling of the hull on the main engine characteristics or wearing of the machine's parts. The courses are:

- Fuel economy
- Fouling and wear

The details of those courses can be found in part 6.4.2.

Table 6.1 The Time Plan

Subject Areas	Hours	
	Lectures	Simulator
1- Introduction	1.0	
2- Familiarization with systems	1.0	3.0
3- Preparation for getting underway	0.5	2.5
4- Operating equipment and systems		8.0
5- Automation system description	1.0	1.0
6- Tuning and adjustments of governor and PID controller		6.0
7- Condition monitoring practice		3.0
8- Engine condition analysis	2.0	1.0
9- Trouble shooting	1.0	7.0
10- Effect of environmental conditions		3.0
11- Test: theory and simulator		3.0
12- Debriefing and recommendation	2.0	
	8.5	37.5

Table 6.2 The Conducted Simulator Training Course

Day	Time	Subject	
Monday	7.00- 8.00	Introduction	L
	8.00-12.00	Familiarization with systems	L&S
	13.00-16.30	Preparation for getting underway	L&S
Tuesday	7.00-10.00	Operation of auxiliary boiler, cargo pump and turbo-generator	S
	10.00-12.00	Manoeuvring to open sea and into harbour	S
	13.30-15.30	Regular watch routines	S
	15.30-16.30	Shutting down the engine	L&S
Wednesday	7.00- 9.00	Description of automation systems	L&S
	9.00-12.00	Tuning and adjustment of governor and PID-controller	S
	13.30-16.30	Tuning and adjustment (continue..)	S
Thursday	7.00-10.00	Condition monitoring practice	S
	10.00-12.00	Engine condition analysis	L&S
	13.30-14.30	Engine condition analysis	L&S
	14.30-16.30	Effects of environmental conditions	L&S
Friday	7.00- 8.00	Simulated fault system description	L&S
	8.00-12.00	Trouble shooting procedures	S
	13.30-16.30	Trouble shooting procedures	S
Saturday	7.00- 9.00	Summarization and discussion	L
	9.00-12.00	Test	S
	13.30-15.30	Test	S
	15.30-16.30	Debriefing	L

6.4.2 - Detailed Training Objectives for Chief Engineers

1- Introduction

- Objectives of the simulator training course
- Schedule for the course
- Documentation

2. Familiarization

2.1. Plant arrangement

- Description of the plant arrangement including the machinery, associated systems and equipment
- Description of how the machinery and associated systems and equipment are arranged and linked together to form the plant
- Description of the block diagram and the plant mimic diagram, comparison between them.

2.2. Instrumentation

- Description and listing of the instrumentation used in the engine room simulator to measure and indicate the necessary parameters
- Description of automation systems including the main engine control system, auxiliary control system and the alarm and monitoring system.

3. Operation of Machinery and Equipment

3.1. General procedures

- Observation and application of safe practice in all exercises
- Maintenance of recording procedures and normal operating conditions for each exercise.

3.2. Auxiliary machinery and systems

- Preparation start up, and putting into the normal operating conditions
  + the seawater cooling system
  + the freshwater cooling system
  + the compressed air system
  + the fuel oil system including the service tank, the fuel purifier, fuel pumps
  + the lub. oil system

3.3. Diesel engine generator

- Preparation, start up, and running of the diesel-driven generator
- Preparation,and synchronization of the diesel generators to operate parallel

3.4. Steam boiler

- Preparation, start up, and raising of steam to normal working pressure
- Putting of the steam boiler "on line" into the steam system

3.5. Steam driven turbo-generator

- Preparation, start up, and running of the steam turbo- generator
- Connecting of the turbo-generator to the main electrical system, applying control on
  + voltage
  + frequency
  + synchronization
- Carrying out of the load sharing between diesel and turbo-generator

3.6. Main propulsion diesel engine

-Carrying out of preparation procedure, including

+ Checking the sea-water cooling system through heat exchangers
+ Checking the fresh water cooling system through engine and heat exchangers
+ Checking the lub. oil circulation through engine and heat exchangers
+ Checking the fuel oil circulation through heaters to injection pump inlets
+ Confirming that compressed air is available for starting
+ Confirming that the engine cylinder lubrication is functioning
+ Turning the engine on starting air for one revolution with all indicator cocks opened

- Carrying out of starting procedures, including
  + Confirming all indicator cocks closed
  + Confirming fuel oil circulation
  + Confirming of bridge order for engine movement
  + Application of starting air for 3-4 revolutions
  + Moving fuel control to required speed position

- Setting up of the normal running mode and observes operating conditions, including +
  + Engine speed and power output
  + Temperatures of lubricating oil and cooling water
  + Temperatures of exhaust gas from each cylinder
  + Temperatures of engine exhaust gas at inlet and exit from turbocharger

+ Maintaining a check on fuel oil supply, lub. oil supply
+ Maintaining a check on fuel oil viscosity/temp.

- Manoeuvring to open sea and into harbour
  + Applies manoeuvring procedures and uses the control to obtain different power outputs
  + Applies recorder or logs all necessary engine parameters
  + Notes all important operational parameters for this power setting
  + Carries out fuel changing processes from the heavy oil into diesel fuel oil and vice verse

- Shutting down the engine room
  + Applies the engine shutting down process, including shutting down the main engine, the associated systems and machinery

4. Watchkeeping

4.1- Taking over and accepting an engine room watch

- Inspection of all operating units, noting operational conditions and any deviations from the normal mode
- Recording of engine telegraph indication, checking of engine control position and related speed
- Examination of the engine room log
- Receiving of report from the engineer officer in charge of the watch for the period of watch keeping now completed
- Entering in the engine room logbook any abnormal operational conditions noted during inspection

- If satisfied, accepts responsibility for the machinery space operation over the next period of watchkeeping

4.2. Watchkeeping routines and duties

Applies all watchkeeping procedures of the engineer officer

- Inspection of at regular intervals of all operational machinery and equipment, noting operating conditions and correcting any deviations from normal mode
- Checking of the levels, Temperatures of all engine room service tanks, transfers or fulfill up as necessary
- Checking of the electrical system voltage and load, and if there are two or more generators operating that the load is properly balanced
- Inspection of bilge and underfloor spaces and leering them as necessary, using the bilge pump and complying with any anti-pollution regulations
- Operation of the fuel oil and lub. oil purifiers as necessary
- Recording in the engine log book all information and data of the main engine and auxiliary machinery on the operating conditions.

4.3. Main engine operation

During the ship going to the open sea sometimes the watchkeeping officer also has to operate the main engine as necessary

- Application of manoeuvring procedures as mentioned before
- Entering in the engine log book all data pertaining to a particular case.

5. Automation and condition monitoring systems

5.1- Automation system

- The structure of the main engine control system
- The operating procedures of the control system

5.2- Condition monitoring

- Taking cylinder indicator diagrams
- Piston ring monitoring
- Metal temperature monitoring of cylinder liners and head covers
- Engine condition analysis
- Cylinder faults detection through the indicator diagram analysis
- Trend condition prediction of engine wear based on partial analysis

6. Trouble shooting procedures

The instructor demonstrates some faults and then students try to locate, trace and apply remedial action for the following malfunctions and faults:

- Fuel injection timing (early or late)
- Scavenge space fire
- Overheated main bearing
- Lubricating oil circulation pump failure
- Lubricating-oil filters choked
- Bilge spaces flooding

7. Tuning and adjustments of governor and PID controllers

- Application of the principles of tuning and adjustments of the governor and PID controller
- Demonstration of adjustments on governor
- Demonstration of adjustments on PID controller

8. Effect of environmental conditions

- The effects of cooling water temperature on the main engine characteristics
- The effects of the ambient conditions like the air temperature and humidity on the combustion characteristics of the main engine.

9. Fuel economy - 4 days (24h)

- The background of fuel saving during operating a ship
- Demonstration of fuel saving on simulator
  + Optimum fuel consumption on a "time charter party"
  + Optimum fuel consumption on a "voyage charter party"
  + Optimum ship's speed in case of limitation of fuel oil storage.

11. Fouling and wear - 4 days (24h)

- The background to fouling of hull and wearing of the machine's parts (liners and piston rings)
- Demonstration of serious wear on the piston rings on the simulator
- Demonstration of hull fouling and the various problems caused by heavy hull fouling on the simulator.

6.4.3- The Training Program for Engineering Officers

The training program for engineering officers on the engine room simulator is also conducted during a week of about 40-44 hours. It is very similar to the training course for chief engineers but it devotes more time to the watchkeeping training and less to the process studies

The training course is designed based on of the following subjects:

- Introduction of E.R.S
- Familiarization
- Preparation for getting underway
- Operation of main and auxiliary machinery
- Watchkeeping routines and duties
- Automation system, condition monitoring and diagnosis
- Trouble shooting procedures
- Summarization and discussion
- Test and evaluation
- Debriefing

The details of these subjects can be seen in the items 1, 2, 3.2, 3.5, 3.6, 4, 5, 6 in table 6.4.2.

6.4.4- The Schedule of the Training Course for Marine Engineering Students

As is known, students who have been trained on the simulator have only a certain theoretical knowledge of the diesel engine and the engine room arrangement. Therefore, the training course for them should be programmed so that they can observe efficiently the operational knowledge and skills of engine rooms. To do so, the simulator training course should be conducted in two periods. The first period of the simulator training course is carried out before the students go on a 6-month sea practice, and the second will be conducted after the sea training.

The first period of the simulator training course will be carried out in the 8th semester, in which the students will be trained on the simulator for 36 hours, from 3 to 4 hours per a week. After completing this period, the students will be able to serve as the marine engineering cadets onboard a ship. The second period will be implemented in the 10th semester, after the sea practice when the students may have had certain experiences on the operation of a real engine room's machinery and equipment. Therefore the training course will be conducted continuously over one week (36h).

During the training course, the students will be divided into groups of 6-8 persons (number of students per year:40-50), then they will be conducted by the experienced instructors according to the simulator training programs.

The simulator training course for the marine engineering students is constructed on the basic of IMO Model Course 2.07, the experiences of some training institutions around the world and the E.R.S maker's guidance. The detailed training course of the first and second period can be seen in Tables 6.3 and 6.4.

Table 6.3 The First Period of The Simulator Training Course /36h/.

Week 1: General description of the engine room simulator /4h/

- E.R.S configuration, working principle, dynamic model...
- Alarm system
- Methods of communication system use
- Familiarization with systems
- Discussion

Week 2: Description of the simulator dynamic plant system model /3h/

- Explanation of symbols meaning in system models and propulsion plant parameter checking
- Demonstration of starting procedures for some systems / sea water system, fuel oil system.../

Week 3: Description of the simulator dynamic plant system model (continue) /3h/

- Demonstration of starting procedures for some systems.

Week 4: Preparation for getting underway /4h/

- Starting procedures from "dead ship"
- Demonstration on starting from "dead ship"
  + Lining up of auxiliary systems
  + Starting up pumps, compressor and fans
  + Starting of diesel engine generators
  + Synchronizing and connecting alternators to main switchboard
  + Procedures for making main engine ready for start

Week 5: Preparation for getting underway (continue) /4h/

-Demonstration on starting of some systems

Week 6: Operation of auxiliary boiler, cargo pumps and turbo-generators (3h)

- Starting procedures of auxiliary boiler, cargo pumps and turbo-generator
- Demonstration on the auxiliary machinery

Week 7: Operation of auxiliary boiler, cargo pumps and turbo-generators (continue) /3h/

- Starting procedures of auxiliary boiler, cargo pumps and turbo-generator (continue)

Week 8: Manoeuvring exercises /3h/

- Manoeuvring to open sea
  + Manoeuvring of main engine
  + Change from diesel oil to heavy fuel oil
  + Putting exhaust gas boiler into operation
- Manoeuvring into harbour
- Shutting down the engine room

Week 9: Manouevring exercises (continue) /3h/

-Manoeuvring procedures to open sea and into habour

-Shutting down of the engine room (continue)

Week 10: Regular watch routines exercises /4h/

Week 11: Test and evaluation /3h/

Table 6.4 The Second Period of The Simulator Training Course /1 week or 36h/.

1- **Watch keeping routines (6h)**
- Checking before duty handling
- Some routines during watchkeeping

2- **Main engine remote control (6h)**
- Automatic remote control system
- Alarm and monitoring systems

3- **Automatic subsystems (6h)**
- Seawater cooling system
- Fresh water cooling system
- Lub. oil system
- Compressed air system

4- **Tuning and adjustments of governor and controllers (8h)**
- Main engine governor (Woodward)
- Generator engine governor
- PID controllers

5- **Process of diagnosis and fault finding (6h)**

6- **Combustion performance and influenced factors (4h)**

7- **Test and evaluation**

As the aim of this course is to prepare the students in the future for employment as engineer assistants according to the country's regulations. Therefore, all the exercises are constructed on the basic of the international and national requirements for the duty engineer officers. All the exercises are concerned with the following specific items:

- Watch keeping routines
- Main and auxiliary machinery
  + Preparation of main engine and auxiliary machinery for operation
  + Method of checking machinery parameters during operation
  + Location of common faults of machinery and plant and action necessary to prevent damage

- Pumping systems:procedure pumping operations

- Generating plant: preparing, starting, coupling and changing over alternators or generators

- Safety and emergency procedures
  + Safety precautions to be observed during a watch and immediate actions to be taken in the event of a fire or accident
  + Safe isolation of electrical and other types of plant and equipment before personnel are permitted to work on such plants and equipment

Evaluation of the trained students is also based on such requirements including theoretical knowledge and practical skills which are carried out on the engine room simulator.

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CHAPTER VII

CONCLUSION AND RECOMMENDATIONS

VII- CONCLUSION AND RECOMMENDATIONS

A-Conclusion

1- During the last 10-15 years, due to the rapid development of modern engine room technology i.e

- Electronic monitoring and controlling equipment
- Reduced manning as much as possible
- The international competition leading to "high standards" for the major merchant fleets in the world, there is an increased demand for well

educated and experienced seafarers. Therefore, one of the best methods in the MET system is an increase in operational training ashore including an application of the computerized engine room simulator and good instructors which has become a popular method in the world.

The Vietnam Maritime University has also recognized that by only using the E.R.S it can train the VN marine engineer officers to meet the international requirements of "safe and efficient operating of the engine room machinery and systems".

2- The typical engine room simulator consists of three main parts: The Engine Control Room, the Engine Room Machinery and Equipment including the Mimic Panels, the Consols and the Bridge. The engine room simulator is built up from basic models, system models and the plant model which are set up as mathematical functions describing the relevant laws of physics.

3- The use of the E.R.S gives opportunities in educating and training seafarers as follows:

- Turning the classroom into an engine room
- Proving training in situations the marine engineers will be paid for to avoid later.
- Allowing to performed realistic emergency procedures
- Showing the results of incorrect engine room operations without damaging the equipment
- Showing all the effects of continuous engine room operations without using a drop of oil
- By only pressing a few buttons, can introduce unlimited faults, replace or repair components, freeze a specific process situation for later study, and give endless lists of other operations.

Furthermore, the E.R.S can be used partly as facility to examine and then issue the certificates of competency for marine engineer officers.

4- The engine room simulator is very flexible for training purposes from the low level needs of marine engineering students to the high level needs of chief engineers onboard ships of unlimited engine power. It is based on the following training courses:

- Basic
- Advanced
- Process studies including the fuel economy study, planned maintenance, heat balance and heat recovery, effects of environmental conditions and so on
- Future training problems.

5- However, the engine room simulator cannot replace reality, therefore in the maritime education and training for marine engineers there is a need to compromise when using the E.R.S and the real engine room on board ships for training purposes.

6- There should be international requirements and standards on using the E.R.S for training marine engineer cadets and officers.

2-Recommendations

1- Successfully training the marine engineers by using E.R.S is dependent mostly on the training course syllabus. It should be constructed on the basic of the IMO Model Course 2.07, the E.R.S maker's recommendation and experiences from maritime colleges around the world.

2- The instructors who will conduct the training courses should have the highest professional certificates of competency and should have specialized course training on simulator by the E.R.S manufacturer.

3- There needs to be funds available for the instructors to attend and participate the in " International Engine Room Simulator" conference so that they can exchange information regarding the E.R.S training and improve themselves in conducting the training course on the simulator.

4- The instructors and technician should be trained so that they can be competent to maintain, correct and carry out minor repairs during the simulator training course. For this purpose, they should be sent to the simulator manufacturer for a special training course.

5- The engine room simulator should be utilized not only for training purposes, but also for for research purposes.

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APPENDIX
I

APPENDIX I

I- The Particular Courses in Brief of The Marine Engineering Department.

The specific information of the courses at the Marine Engineering Department are given in detail in Table 1.1; 1.2; 1.3.

For all these courses ,the examinations are conducted by the Special Committee that is appointed by the Personnel Department of the Ministry of Transport and Communications of Vietnam.

The Certificates are issued by the Ministry of Transport and Communications.

The training programmes of all the courses were designed in a way that the programme of the higher-level course succeeds the lower-level course in a logical way.

Table 1.1 Course for Marine Engineer Certificate of Competency / First Class/

MARINE ENGINEER TRAINING COURSE AT VMU	
COURSE TITLE	First Class Chief Engineer
CERTIFICATE/Degree obtained /	Chief Engineer Certificate of Competency /First class/
QUAFILICATION	Ship's Propul.Power>3000 KW
COURSE DURATION	5 months
MAX No.OF PARTICIPANTS	No Restraction
STARTING DATE /FREQUENCY/	Once a year
COURSE LANGUEGE	Vietnamese

OBJECTIVE : To prepare candidates for the exams for the award of certificate of competency as First Class Chief Engineer.

MINIMUM ENTRY REQUIREMENTS :
1-Chief Engineer Certificate of Competency /Second Class/ or First Engineer on board of ship of a propul. power >3000 KW
2- Sea-going experence required by appropriate regulations.

COURSE CONTENT :
- Marine diesel engine
- Marine power plants
- Refrigeration and air-conditioning equipment
- Electrical facilities
- Ship automation
- Technical management
- Marine environment protection
- Ship fire protection
- Legal and insurance aspects
- Technigue of diagnostic faults
- Advanced English

REMARK : The programme is established in accordance with the requirements of the STCW covention and Vietnam regulations.

Table 1.2 Course for Marine Engineer Certificate of Competency /Second Class/.

MARINE ENGINEER TRAINING COURSE AT THE VMU	
COURSE TITLE	Second Class Chief Engineer
CERTIFICATE /Degree obtained/	Chief Engineer Certificate of Competency /Second Class/
QUALIFICATION	Ship's Propul.Power from 1000 Kw to less than 3000 Kw
COURSE DURATION	5 months
MAX No OF PARTICIPANTS	No restriction
STARTING DATE/friquency/	Once a year
COURSE LANGUEGE	Vietnamese

OBJECTIVE : To prepare candidates for the exams for the awardi of Certificate of Competency as Second Class Chief Engineer.

MINIMUM ENTRY REQUIREMENTS :
1-Chief Engineer Certificate of Competency /Third Class/ or First Engineer on board ships of a propul.power 1000-3000 Kw.
2-Sea-going experence required by appropriate mondatory regulations.

COURSE CONTENT:
- Marine diesel engine
- Ship auxilaries
- Technical operation of ship propul.plant
- Steam turbine
- Electronic and electrotechnic
- Ship automation
- Technical chemistry
- Maintenance and repair procedures
- Shipboard fire-fighting
- Marine environment protection
- Aspects of ship's register
- Advanced English

REMARK : The programme is established in accordance with the requirements of STCW convention and Vietnamese regulations.

Table 1.3 Course for Marine Engineer Certificate of Competency /Third Class/.

MARINE ENGINEER TRAINING COURSE AT VMU	
COURSE TITLE	Third Class Chief Engineer
CERTIFICATE /Dgree obtained/	Chief Engineer Certificate of Competency /Third Class/
QUALIFICATION	Ship's Propulsion Power from 400 to less than 1000 Kw
COURSE DURATION	4 months
MAX No.of PARTICIPANTS	No restriction
STARTING DATE /Frequency/	Once a year
COURSE LANGUEGE	Vietnamese

OBJECTIVE : To prepare candidates for the exams for the award of Certificate of Competency as Third Class Chief Engineer.

MINIMUM ENTRY REQUAREMENTS :
1- Chief Engineer Cerrtificate of Competency /Fouth Class / or First Engineer on board a ship of a propul.power less than 400Kw.
2- Sea-going experence required by appropriate regulations.

COURSE CONTENTS :
- Theory of heat engines
- Steam boiler
- Ship construction and naval architecture
- Ship auxilaries
- Marine propulsion plants
- Ventilation
- Water,fuel and lub.oil on board of ship
- Ship electrical facilities
- Maintenance and repair procedures
- Legal and insurance problems
- Shipboard fire-fighting
- Marine environment protection
- Advanced English

REMARK : The programme is established in accordance with the requirements of the STCW convention and Vietnamese regulations.

APPENDIX II

The structure of a simulation program of a turbocharged diesel engine constructed by T. Ruxton and Dr KS Hoong in their paper "Application and expert system to performance of marine diesel engine" is shown in block diagram form in Figure 3.9.

The mathematical model which describes the performance of the internal combustion engine contains the following basic models:

- Cylinder
- Exhaust manifold
- Inlet manifold
- Turbocharger
- The system of one or more valves per cylinder
- The air scavenging cooler.

a- Cylinder

To simulate the diesel engine cylinders, the following system of differential equations should be applied.

For the energy balance:

$$\frac{d(mu)}{d\alpha} = \frac{dQf}{d\alpha} + \frac{dmi}{d\alpha}hi - \frac{dmo}{d\alpha}ho - \frac{dQo}{d\alpha} + \frac{dv}{d\alpha}p \qquad (1)$$

For the mass balance:

$$\frac{dm}{d\alpha} = \frac{dmi}{d\alpha} - \frac{dmo}{d\alpha} + \frac{dmu}{d\alpha} \tag{2}$$

and:

$$\frac{dT}{d\alpha} = \frac{1}{mdu/dT} * \frac{dQf}{d\alpha} + \frac{dmi}{d\alpha}(hi-u) - \frac{dme}{d\alpha}(he-u) - \frac{dmu}{d\alpha}u - \frac{dQo}{d\alpha} -$$

$$- p* \frac{dv}{d\alpha} - m\frac{du}{d\alpha} * \frac{dl}{d\alpha} \tag{3}$$

Where: m - Mass

u - Internal energy

Qf- Heat transfer of fuel

mi- Mass of injected fuel

hi- Stagration enthalpy of injected fuel

mo-Output mass

ho-Stagration enthalpy of output mass

Qo-Heat transfer of output mass

v -Volume

p -Pressure

α -Crank angle

mu-Mass of unberned fuel

l -Air fuel ratio

According to the Whitehouse Model, the heat release rate consists of two rates:

- The combustion rate:

$$R = kPo - acf[\ T \int (P-R)\ dt]N\ sqr(T) \qquad (4)$$

- The preparation rate:

$$P = Kmi * mu\ Po \qquad (5)$$

The heat release rate defines the form:

$$\text{if} \quad \int R d\alpha \ > \ P d\alpha \qquad HR = P \qquad dQf/d\alpha = HR \qquad (6)$$

$$\text{if} \quad \int R d\alpha \ < \ P d\alpha \qquad HR = R \qquad (7)$$

Where: R - Combustion rate

k - Combustion rate constant

Po - Oxygen partial pressure

e - Effectiveness of air cooler

act- Activation energy constant in reaction rate

P - Pressure

N -

T - Temperature

k - Preparation rate

HR - Heat release rate

The output and input mass rate is determined in accordance with the isentropic flow through the ports or valves depending on the engine because:

$$mi,e = Aeg * Y\ sqr(2RT) \qquad (8)$$

and, for subsonic flow:

$$Y = sqr\{[k/(k-1)]\ [(po/pi) - (po/pi)]\} \qquad (9)$$

$$\text{if:} \quad \frac{po}{pi} > [2/(k+1)]^{k/(k+1)} \qquad (10)$$

or, for supersonic flow:

$$Y = [2/(k+1)]^{1/(k+1)} \operatorname{sqr}[2k/(k+1)] \qquad (11)$$

Where: Aeq- Equivalent discharge area

Y - Flow function

R - Gas constant

For the heat transfer model we can use Annad's model:

$$\frac{dQ}{dt} = aKh\,(Re)^{b}\,[Tc-Tw]/D - c[Tc^{4} - Tw^{4}] \qquad (12)$$

Where: a,b - Constants of Annad's heat transfer model

Kh - Thermal conductivity

Re - Reynolds number

Tc - Mean temperature of cylinder contents

Tw - Cylinder wall temperature

D - Cylinder bore

from the geometry of the kinematic mechanism we have:

$$V(t) = Vc + (\pi * S * D^{2}/8)\ \{ 1 + 11 - [11 - \sin^{2}\alpha]^{1/2} - \cos\alpha \} \qquad (13)$$

Where: Vc - Clearance volume

S - Stroke

D - Cylinder bore

α - Crank angle

Where the mixing-displacement short circuiting scavenging model, is used.

b- Modelling of Exhaust and Inlet Manifolds

Due to the exhaust and inlet manifolds connected directly to the cylinders of the diesel engine, the equation for energy and mass balance are similar to those for the cylinder. So, for energy balance:

$$\frac{d(mu)}{d\alpha} = \frac{dmi}{d\alpha} hi - \frac{dmo}{d\alpha} ho \qquad (14)$$

for the mass balance:

$$\frac{dm}{d\alpha} = \frac{dmi}{d\alpha} - \frac{dmo}{d\alpha} \qquad (15)$$

from the equation of state, Pm Vm = m RTm
we can get:

$$\frac{dT}{d\alpha} = \frac{1}{mdu/dT} \left[\frac{dmi}{d\alpha}(hi-u) - \frac{dmo}{d\alpha}(ho-u) - \frac{du}{d\alpha} * \frac{dl}{d\alpha} m \right] \qquad (16)$$

if we solve equation (14), (15), and (16) simultaneously, temperature and pressure of the exhaust manifold can be found as a function of the crank angle.

If the inlet manifold includes an additional compression stage underneath each piston, or utilizes scavenging pistons the volume of the inlet manifold is a function of the crank angle Vm= Vim (α).

c- **Mathematical Model of Turbocharger**

To simulate the turbocharger, K.Zinner suggested a method that is based on the following equations:

$$Mi,e = Aeg * Y * rsqr\ (2RT) \qquad (17)$$

for the subsonic flow:

$$Y = sqr[k/(k-1)]*[(Pe/Pi)^{(2/k)} - (Pe/pi)^{(k+1)/k}] \qquad (18)$$

The turbocharger efficiency can be calculated by following the formula:

$$\eta_{T.CH} = \frac{ma * \ his\ comp}{(ma+mf)\ \ his\ turb} \qquad (19)$$

Where:

$$\Delta his\ comp = Tc*[kc/(kc-1)][\ c^{(kc-1)/kc} \ -1\ ] \qquad (20)$$

$$\Delta his\ turb = Tt[kt/(kt-1)][1- \ t^{(kt-1)/kt}\ ] \qquad (21)$$

and $$\eta_c = \frac{Patm + Pcool + Psc}{Patm - Pfilter}$$

$$t = \frac{Patm + Pres}{Patm - Pafter\ turb}$$

Where: Patm - Barometric pressure

Pcool- Pressure difference of cooler

Psc - Boost pressure

Pfilt- Pressure difference of air filter

Pres - Pressure difference of exhaust manifold

Paft turb- Pressure difference after turbine

The mathematical model of the turbocharger has the ability to evaluate the fouling condition of the diffusers and the disadvantage of being unable to predict the surge line of the compressor.

d- Mathematical Model of The Air Cooler

The effectiveness of the cooler that is a function of mass flow rate and is expressed as a polynomial, is used to model the cooler.

$$To = (Ti - T\ col)(1-e) + Tcol*e \qquad (22)$$

Where: To - Output temperature ;

Ti -Input temperature

Tcol-Cooling temperature;

e -Effectiveness of air cooler

To make a simulation of a diesel engine to be more accurate and match of the sub-systems, some additional requirements are required:

- In terms of the cylinder, the working gas thermodynamic parameters must be the same at the start and end of the cycle.
- The inlet and exhaust manifold have to show the known mean pressure and exhaust gas temperature

which are determined from experimental results.

- From the given inlet and outlet conditions, the thermodynamic parameters in the cylinder at any crank angle must be calculated and the predicted indicator diagram must have the same characteristic values as determined by the experimental results, i.e compressed pressure and max. pressure etc.
- The turbocharger's efficiency and air cooler's effectiveness must be determined in a way that allows the best fit between predicted and measured values.

APPENDIX III

DIESELSIM TRAINING COURSE
FOR CHIEF ENGINEERS

GENERAL PROGRAM

EXERCISE No1- 1 hour

DIESELSIM GENERAL DESCRIPTION

1- Dieselsim configuration, working principles, dynamic models and real scale elements.

2- Operating principles of the alarm system.

3- Methods of communication system use.

4- Dieselsim plant technical and operation data.

EXERCISE No2- 4 hours

DIESELSIM PLANT STARTING PROCEDURE FROM "DEAD SHIP" TO SEA PASSAGE CONDITIONS- St.By

EXERCISE No3- 4 hours

DATA CHIEF III - Computurized Engine Room Automation System. Description and Sybsystem Demonstration.

1."Data trend" - Main Engine Condition Monitoring and Maintenence Pridiction System.

2."Data Safe" - Watch keeping, Monitoring and Logging System. Automation System of Pumps, Purifiers, Compressors, etc.

3."Data Power" - Automation Systems of Auxiliary Engines and Generators. Electrical Power Supply and Required Power Control.

4."Auto-Chief" - M.E Bridge Control System and Engine Overload Protection Arrangements.

EXERCISE MODULE No4- 3 hours

M.E REMOTE CONTROL-AUTO CHIEF II SUBSYSTEM-DESIGN ADJUSTMENTS AND ON BOARD MAINTENANCE

EXERCISE MODULE No5 - 6 hours

M.E CONDITION MONITORING AND DIAGNOSIS.

1. Taking Cylinder Indicator Diagrams.

2. Piston Ring Monitoring.

3. Metal Temperature Monitoring of Cylinder Liners and Head Covers.

4. Cylinder Faults Detection Through Indicator Diagrams Analysis.

5. Engine Condition Analysis.

6. Trend Condition Prediction of Engine Wear Based on Partial Analysis.

EXERCISE MODULE No6- 4 hours

SIMULATED ENGINE ROOM PLANT PERFORMANCE WITH INTRODUCED FAULTS. DEMONSTRATION AND INTERPRETATION FOR SHIP'S ENGINE ROOM PLANTS.

EXERCISE MODULE No7 - 6 hours

PID-CONTROLLERS- Influence of PID Controllers Setting on Their Proper Performance. Demonstration of Such Effects on So-Called Hardware Regulator.

DIESELSIM TRAINING COURSE
FOR ENGINEERS ON WATCH

GERERAL PROGRAM

EXERCISE MODULE No1- 4 hours
DIESELSIM GENERAL DESCRIPTION.

1. Dieselsim Configuration, Working Principles, Dynamic Models and Real Scale Element.
2. Operating Principles of The Aiarm System.
3. Methods of Communication System Use.
4. Dieselsim Plant Description.

EXERCISE MODULE No2- 6 hours
DESCRIPTION OF THE SIMULATORS DYNAMIC PLANT SYSTEM MODELS.

1. Explanation of Symbols Moaning on System Models and Dieselsim Plant Parameters Checking.
2. Demonstration of Starting Procedures for Some Selected Dieselsim Systems / Sea Water System, Piston Cooling System, Fuel Systems, etc/.

EXERCISE MODULE No3- 6 hours
DIESELSIM PLANT STEAM-UP PROCEDURES.

1. Dieselsim Plant Operating Conditions:"Dead Ship", Harbour Operation, Maneuvring, Sea Passage.
2. Dieselsim Plant Starting Procedure From "Dead Ship" to St.By Readiness for Sea Passage.

EXERCISE MODULE No4 - 4 hours

DIESELSIM PLANT FAULT FINDING AND CONDUCTIVE ACTION OF PREVIOUSLY SET "FAULTS".

EXERCISE MODULE No5 - 6 hours

DATA CHIEF III- COMPUTERIZED ENGINE ROOM AUTOMATION SYSTEM.

DESCRIPTION AND SUBSYSTEM DEMMONSTRATION

1."Data Trend"- M.E Condition Monitoring and Maintenance Prediction System.

2."Data Safe" - Watch Keeping, Monitoring and Logging System, Automation System of Pumps, Purifiers, Compressors etc.

3."Data Power"- Automation System of Auxiliary Engines and Generators, EL.Power Supply and Required Power Control.

4."Auto Chief"- M.E. Bridge Control System and Engine Overload Systems.

EXERCISE MODULE No6- 3 hours

SOME SIMULATED PROBLEMS OF AUTO CHIEF II SUBSYSTEM PERFORMANCE.

EXERCISE MODULE No 7 - 6 hours

M.E DIAGNOSIS- INTRODUCTION AND EXPLANATION OF SOME PHENOMENA CONCERNING M.E. WORKING PROCEDURES: COMBUSTION, INJECTION, PISTON RINGS CONDITION ANALYSIS.

The Training Program

at The Training Centre (TNO)

The Netherlands

Training course programme

Day	Time	Subject
Monday	08.30-09.30	Introduction Simulator and simulator course to be introduced.
	09.30-12.15	Orientation exercises Familiarization with systems.
	13.15-13.45	Forum Discussion of operational problems.
	13.45-14.45	Steam and feed system Discussion
	14.45-17.00	Steam raising exercise (from cold)
Tuesday	08.30-10.30	Steam raising exercise (continuation)
	10.30-12.15	Manoeuvring mode exercises Leaving port manoeuvres, introduction of malfunctions.
	13.15-16.00	Manoeuvring mode exercises Continuation of manoeuvring mode fault exercises.
	16.00-17.00	Forum Discussion of results. Preview of Wednesday's programme.
Wednesday	08.30-12.15	Energy balance and Performance monitoring Use of "Mollier" diagramme. Discussion on sources of plant losses. Assess and quantify value of losses. Quantify total performance of plant. Maximise plant efficiency.
	13.15-16.30	Sea state mode exercises Fault finding exercises. Recovery of plant from black-out conditions.
	16.30-17.00	Forum Discussion of results. Preview of Thursday's programme.
Thursday	08.30-12.15	Control Theory and control tuning General discussion on control theory. Description of control loop tuning method. Exercises.
	13.15-15.45	Control loop tuning (continuation)
	15.45-17.00	Sea state mode exercises Various fault condition exercises.
Friday	08.30-10.00	Automatic versus manual control Comparison of quality of control between automatic and manual operation of critical plant parameters.
	10.00-12.15	Slowdown operation Operate power plant at optimum conditions during extended periods of reduced power operation.
	13.15-15.15	Slowdown operation (continuation)
	15.15-17.00	Free form and course evaluation Exercises as trainees request. Evaluation of training course.

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