COURSE MANUAL

MARINE ENGINEERING AND ELECTRICAL, ELECTRONIC AND CONTROL ENGINEERING

OPERATIONAL LEVEL

PROJECT: COMPETING
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PREFACE

To assist education and training entities to meet the requirements of the Standards of competence for inland navigation personnel, required by Directive (EU) 2017/2397 on the recognition of professional qualifications in inland navigation, and Delegated Directive (EU) 2020/12 supplementing Directive (EU) 2017/2397 as regards the standards of competences and corresponding knowledge and skills, for the practical examinations, for the approval of simulators and for medical fitness, the transnational Course Manual on Marine engineering and electrical, electronic and control engineering at Operational Level was developed.

This Course Manual will be a useful transnational training tool for conducting the 'Train the Trainer' session and is intended to assist education and training providers and their teaching staff in organising and introducing new education & training programmes, or in enhancing, updating and supplementing existing didactical materials with the ultimate end results of raising quality and effectiveness of the education & training programmes.

Since education & training systems as well as the cultural background of inland navigation topics differ considerably from one country to another, the Course Manual on Marine engineering and electrical, electronic and control engineering at Operational Level has been designed so as to support the preparation, organisation and planning of effective teaching and training and to be used as a part of the quality assurance of the education and training institutes.

Technical content and levels of knowledge and abilities are in line with the applicable Delegated Directive (EU) 2020/12 supplementing Directive (EU) 2017/2397 as regards the standards of competences and corresponding knowledge and skills, for the practical examinations, for the approval of simulators and for medical fitness, being an essential tool for crew members at Operational Level, to be able to assist the management of the craft in and to perform maintenance work on marine, electrical, electronic, and control engineering to ensure general technical safety.

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1. GENERAL INFORMATION

1	**Aim**	Provide training to meet the requirements of Directive (EU) 2017/2397 on the recognition of professional qualifications in inland navigation and ES-QIN-Standards of competence – Marine engineering and electrical, electronic and control engineering at Operational Level.
2	**Objective**	Provide training and practical guidance for trainees in order to be able to perform human resource management, be socially responsible and take care of organisation of workflow and training on board the craft.
3	**Entry standards**	See Directive (EU) 2017/2397 - Annex 1.
4	**Course certificate**	On successful completion of the course, a document may be issued, stating that the holder graduated this learning module.
5	**Course intake limitation**	Admittance may be limited by the capacity of the educational infrastructure used for this learning module.
6	**Staff requirements**	The trainer should meet the requirements of Directive (EU) 2017/2397, Art. 18.
7	**Training facilities, equipment and teaching aids**	The theoretical part of the course requires a classroom with video presentation equipment, teaching aids, etc. The practical part of the course requires a laboratory equipped with specific simulators or a school ship. It could be useful to use different inland vessels which are in a repair programme or engaged in transportation activities.
8	**Learning outcomes**	The Boatmaster shall be able to perform human resource management, be socially responsible, and take care of organisation of workflow and training on board the craft. At the end of the course the trainee shall be able to: • Assist in monitoring the engines and propulsion system; • Prepare main engines and auxiliary equipment for operation; • React adequately to malfunctions of engines; • Operate machinery including pumps, piping systems, bilge and ballast systems • Assist in monitoring electronic and electrical devices; • Prepare, start, connect and change generators, and control their systems and shore supply; • Define malfunctions and common faults, and describe the actions to prevent damage; • Use required tools to ensure general technical safety; • Perform the daily maintenance work on the main engines, auxiliary machinery and control systems; • Perform the daily maintenance work on machinery including pumps, piping systems, bilge and ballast systems; • Use required tools to ensure general technical safety; • Follow procedures of maintenance and repair; • Use technical information and document technical procedures.
9	**Assessment & evaluation**	Minimum requirements for assessment & evaluation of the trainees to graduate from the learning module (i.e. minimum score for theoretical evaluation, for practical evaluation, etc.). I.e. Online training record book as a pathway for the course.

2. INSTRUCTOR MANUAL

2.1 Introduction

This instructor manual provides guidance on the material that is to be presented during the training course for Marine engineering and electrical, electronic and control engineering at Operational Level, and has been arranged under the nine Learning Outcomes (competences) identified in the course outline. The reference material indicated may be supplemented by additional texts or material at the discretion of the teacher/trainer.

The course outline and provisional timetable also provide guidance on the time allocation for the course, because the time actually taken for each subject area may vary, especially in respect of time allocated to practical activities. The detailed teaching syllabus must be carefully studied and appropriate lesson plans or lecture notes compiled. A template of a lesson plan is presented under 2.2.

Each lesson should commence with a statement of the learning outcomes it is intended to achieve. At the end of each lesson, the participants should be told which associated portions of the reference material they should read and any activity they should undertake. Questions arising from such readings and activities must be given priority at an appropriate time.

The presentation of the various subject areas should be done in such a way that those taking part in the course are involved in an interactive participation during the lessons and learning process. Questions from the course participants should be encouraged, as should answers to such questions from other course participants.

The lessons should aim at conveying as much practical instruction and practice as possible to the participants, in order to develop their knowledge of and their skills in the tasks they will be expected to carry out.

Course materials for additional study must be prepared and distributed if required.

2.2 Lesson plan

This lesson plan is just a template to give the teachers/trainers a general idea on how to create their lessons for the various competences. This template can be used for every competence and adjusted as suitable for the institute to use.

Competence 4.1.1. Assist in monitoring the engines and propulsion system			
Learning objective			
Learning outcomes			
Required equipment			
Lesson structure			
Learning activity	Didactical method (ABC method)	Materials	Time

2.3 Background materials

Bibliographical materials, reference documents, and other didactical materials are presented in Annexes of this Course Manual.

2.4 Practical training

This practical training links the theoretical content of the lessons to their practical use.

Case studies
Theoretical subjects are elaborated by the candidates autonomously in case studies. The candidate should expand his or her knowledge in defined theoretical subjects by elaborating on a variety of facts and figures about this topic and present them in front of his or her classmates afterwards.

Discussions and reflection, interactive learning
Possible solutions to theoretical and practical subjects can be discussed within (parts of) the learning group. Different views and opinions on a defined subject are exchanged and discussed by the participants in order to broaden the view of the individual on this problem and show different possible solutions and their respective advantages and disadvantages. A discussion should be monitored and steered (stimulated or consolidated) if necessary, in order to secure that every participant actively participates.

Team work
Assignments can be individual as well as group assignments, depending on the objective. An individual assignment should stimulate and show the competences of the individual. In teamwork assignments the participants will have exposure to a wide range of experiences from quick problem-solving involving synergy to experiences which may relate to such items as interpersonal difficulties in a group setting. Depending on the purpose of the assignment, the team should be defined in advance and the assignment and the rules of the working process, if there are any, should be communicated to the group in a very clear and formal manner.

Annex 2 of this Course Manual presents a few practical scenarios that are useful for practical training and examination of inland navigation personnel.

The **ETRB** is the tool on which the students can be tested.

2.5 Class room facilities and educational tools

The theoretical part of the course requires a classroom with video presentation equipment, teaching aids, etc. The practical part of the course requires a school ship or laboratory equipped with specific devices.

2.6 Examination & assessment

According to Directive (EU) 2017/2397, Article 17, assessment of competences:
The Commission shall adopt delegated acts in accordance with Article 31 to supplement this Directive by laying down the standards for competences and corresponding knowledge and skills in compliance with the essential requirements set out in Annex II.2.
Member States shall ensure that persons who apply for the documents referred to in Articles 4, 5 and 6 demonstrate, where applicable, that they meet the standards of competence referred to in paragraph 1 of this Article by passing an examination that was organised:
(a) under the responsibility of an administrative authority in accordance with Article 18 or;
(b) as part of a training programme approved in accordance with Article 19.

The essential competence requirements set out in Annex II of Directive (EU) 2017/2397 for Marine engineering and electrical, electronic and control engineering at Operational Level are:

The Boatmaster shall be able to:
- assist the management of the craft in marine, electrical, electronic, and control engineering to ensure general technical safety;
- perform maintenance work on marine, electrical, electronic, and control engineering equipment to ensure general technical safety.

To assess the progress and level of understanding of the students it is necessary to test the students in a formative way. The main goal of these tests is to give feedback to the student. A standard for practical examination for Boatman is developed in CESNI QP.

The Illias platform provides examples of assessments for the separated competences for 'Marine Engineering' at Operational Level.

3. REGULATION AND CERTIFICATION

According to Chapter 2, Union Certificates of Qualification, Article 4, Obligation to carry a Union certificate of qualification as a deck crew member of Directive (EU) 2017/2397:

1. Member States shall ensure that deck crew members who navigate on Union inland waterways carry either a Union certificate of qualification as a deck crew member issued in accordance with Article 11 or a certificate recognised in accordance with Article 10(2) or (3).
2. For deck crew members other than boatmasters, the Union certificate of qualification and the service record book as referred to in Article 22 shall be presented in a single document.
3. By way of derogation from paragraph 1 of this Article, certificates held by persons involved in the operation of a craft, other than boatmasters, issued or recognised in accordance with Directive 2008/106/EC, and therefore in accordance with the STCW Convention, shall be valid on sea-going ships operating on inland waterways.

In Directive (EU) 2017/2397 in Annex I, the minimum requirements for certification as a boatman are as follows:

Every applicant for a Union certificate of qualification shall:

(a)
- be at least 17 years of age;
- have completed an approved training programme, as referred to in article 19, which was of a duration of at least two years, and which covered the standards of competence for the operational level set out in annex ii;
- have accumulated navigation time of at least 90 days as part of this approved training programme.

or

(b)
- be at least 18 years of age;
- have passed an assessment of competence by an administrative authority as referred to in article 18, to verify that the standards of competence for the operational level set out in annex ii are met;
- have accumulated navigation time of at least 360 days, or have accumulated navigation time of at least 180 days if the applicant can also provide proof of work experience of at least 250 days that the applicant acquired on a sea-going ship as a member of the deck crew.

or

(c)
- have a minimum of five years' work experience prior to the enrolment in an approved training programme, or have at least 500 days' work experience on a sea-going ship as a member of the deck crew prior to the enrolment in an approved training programme, or have completed any vocational training programme of at least three years' duration prior to the enrolment in an approved training programme;
- have completed an approved training programme as referred to in article 19, which was of a duration of at least nine months, and which covered the standards of competence for the operational level set out in annex ii;
- have accumulated navigation time of at least 90 days as part of that approved training programme.

4. LESSON MATERIALS

The lesson materials referred to in this Course Manual are for inspiration and are free to use for the teachers of the educational institutes. The lesson materials will be available on the Edinna website (https://www.edinna.eu/).

As already mentioned in Chapter 2, background materials and practical activities can be found in Annex 1 and Annex 2 of this Course Manual. The background materials referenced can be used as additional documentation for the teachers to create their lessons and/or add more details. Annex 2 consists of suggestions and examples of exercises, case studies and/or practical scenarios.

Thematic content of the Course Manual for MARINE ENGINEERING AND ELECTRICAL, ELECTRONIC AND CONTROL ENGINEERING – OL is presented in Annex 4 of this document, which is linked to the European Standard for Qualifications in Inland Navigation (ES-QIN), Part I, Chapter 1, Point 4 Marine engineering and electrical, electronic and control engineering[1].

The numbering of the chapters is in accordance with the Standards for competences for the Operational level - 4. MARINE ENGINEERING AND ELECTRICAL, ELECTRONIC AND CONTROL ENGINEERING.

OL 4 - Marine engineering and electrical, electronic and control engineering

4.1 The boatman shall be able to assist the management of the craft in marine, electrical, electronic, and control engineering to ensure general technical safety

Competence	Knowledge and skills
1. Assist in monitoring the engines and propulsion system;	1. Knowledge of principles of propulsion system. 2. Knowledge of different types of engines and their construction, performance and terminology. 3. Knowledge of the function and operation of air delivery, fuel delivery, lubrication, cooling and engine exhaust system. 4. Knowledge of main and auxiliary engines. 5. Ability to carry out basic checks and ensure regular functioning of engines.
2. Prepare main engines and auxiliary equipment for operation;	1. Knowledge of starting systems of main engines, auxiliary equipment and hydraulic and pneumatic systems according to instructions. 2. Knowledge of principles of reversing systems. 3. Ability to prepare the machinery in the engine room according to checklist for departure. 4. Ability to use the starting system and auxiliary equipment according to instructions, e.g. steering equipment. 5. Ability to start the main engines following starting procedures. 6. Ability to use hydraulic and pneumatic systems.
3. React adequately to malfunctions of engines;	1. Knowledge of control equipment in the engine room and of reporting procedures for malfunctions. 2. Ability to recognise malfunctions and to take appropriate measures in the case of malfunction including reporting to the craft's management.

1 https://www.cesni.eu/en/standards-and-explanatory-notices/#02

Competence	Knowledge and skills
4. Operate machinery including pumps, piping systems, bilge and ballast systems;	1. Knowledge of safe operation and of control of the machinery in the engine room, ballast compartments and bilge following procedures. 2. Ability to control the safe function, operation of machinery in the engine room and to maintain the bilge and ballast system including. reporting incidents associated with transfer operations and ability to correctly measure and report tank levels. 3. Ability to prepare and operate shut-off-operations of the engines after operation.
5. Assist in monitoring electronic and electrical devices	1. Knowledge of electronic and electrical systems and components. 2. Knowledge of AC and DC current. 3. Ability to monitor and evaluate control instruments. 4. Knowledge of magnetism and the difference between natural and artificial magnets. 5. Knowledge of electro hydraulic system.
6. Prepare, start, connect and change generators, and control their systems and shore supply;	1. Knowledge of the power installation. 2. Ability to use switchboard. 3. Ability to use shore supply.
7. Define malfunctions and common faults, and describe the actions to prevent damage;	1. Knowledge of malfunctions outside the engine room and of procedures to follow to prevent damage and procedures to follow if malfunctions occur. 2. Ability to identify common faults and take action to prevent damage to mechanical, electrical, electronic, hydraulic and pneumatic systems.
8. Use required tools to ensure general technical safety;	1. Knowledge of characteristics and limitations of processes and materials used for maintenance and repair of engines and equipment. 2. Ability to apply safe working practices when maintaining or repairing engines and equipment.

4.2 The boatman shall be able to perform maintenance work on marine, electrical, electronic, and control engineering equipment to ensure general technical safety

Competence	Knowledge and skills
1. Perform the daily maintenance work on the main engines, auxiliary machinery and control systems;	1. Knowledge of procedures to follow for maintenance and good care of the engine room, main engine, main machinery, auxiliary equipment and control systems. 2. Ability to maintain main engines, auxiliary equipment and control systems.
2. Perform the daily maintenance work on machinery including pumps, piping systems, bilge and ballast systems;	1. Knowledge of daily maintenance procedures. 2. Ability to maintain and to take care of pumps, piping systems, bilge and ballast systems.
3. Use required tools to ensure general technical safety;	1. Knowledge of use of maintenance material and repair equipment on board, including their qualities and limitations. 2. Ability to choose and use maintenance material and repair equipment on board.
4. follow procedures of maintenance and repair;	1. Knowledge of manuals and instructions for maintenance and repair. 2. Ability to conduct maintenance and repair procedures according to applicable manuals and instructions.
5. Use technical information and document technical procedures;	1. Knowledge of technical documentation and manuals. 2. Ability to document maintenance work.

5. EFFECT ON THE HUMAN ELEMENT ON SUSTAINABLE SHIPPING

The human activities of deck crew members on board of vessels have a direct relation with sustainability in Inland Shipping. Due to the uniformization of training and conformity with Directive (EU) 2017/2397 on the recognition of professional qualifications in inland navigation, there will be an increase of navigational safety.

Different factors affect the development of sustainability in shipping, from regulatory to socio-economic factors, market related aspects and human factors, which all together contribute in different ways to the development of these three pillars. Since many different stakeholders are involved in the process, it follows that one of the main factors in supporting Sustainable Shipping is the understanding of all parties' concerns, needs and expectations.

The shipping industry is run by people, for people. People design ships, build them, own them, crew them, maintain them, repair them and salvage them. People regulate them, survey them, underwrite them and investigate them when things go wrong. While these people vary in all sorts of ways, they are all, nevertheless, people – with the same basic set of capabilities and vulnerabilities.

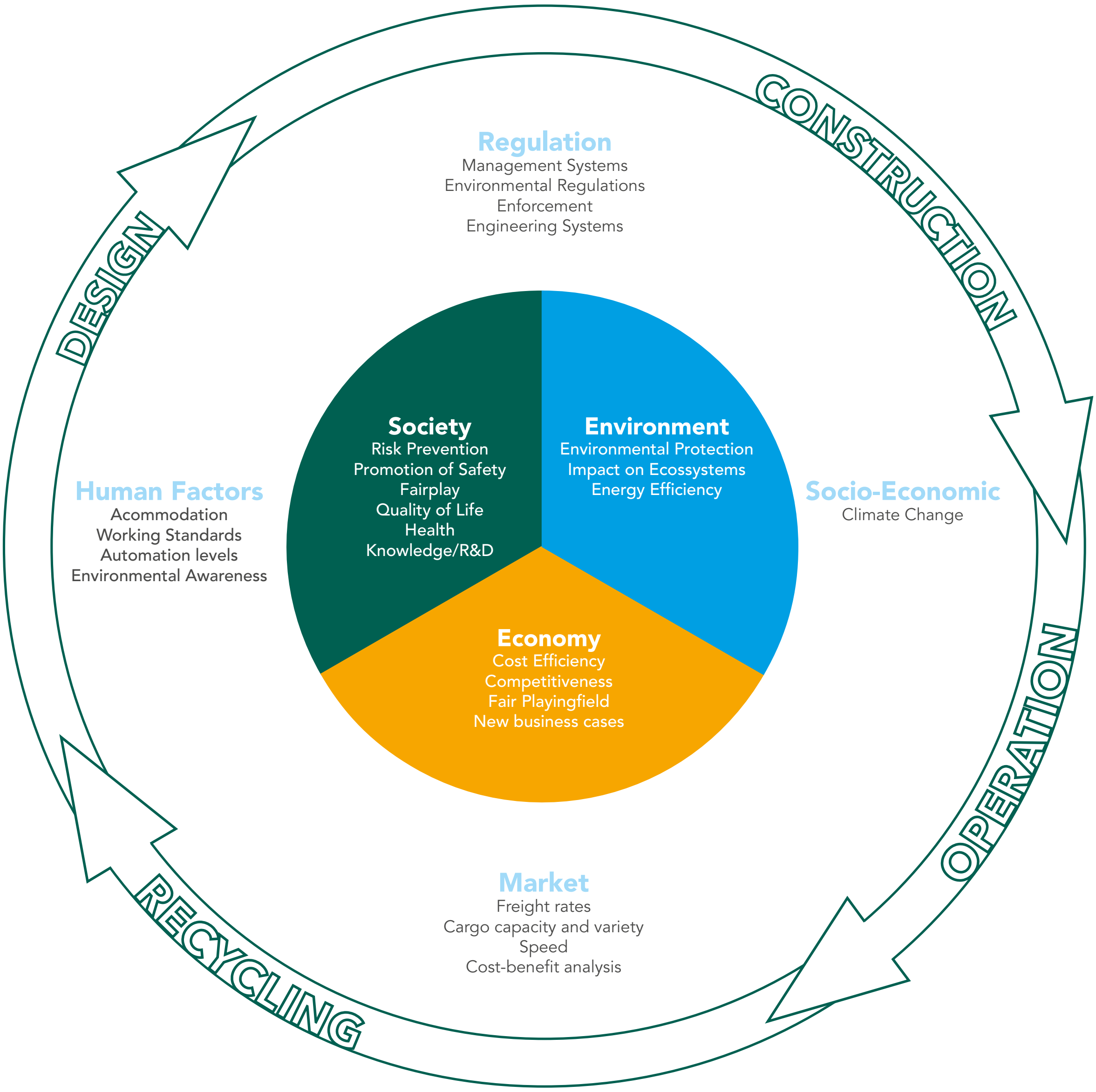

Figure 1 https://www.emsa.europa.eu/implementation-tasks/environment/sustainable-toolbox.html?start=10

Humans are not simply an element like the weather. They are at the very centre of the shipping enterprise. They are the secret of its successes and the victims of its failures. It is human nature that drives what happens every day at work – from the routine tasks of a ship's rating, right through to policy decisions.

The eight aspects of human nature are:

1. **People actively make sense of things** What's obvious to you may be far from apparent to somebody else. We explain how it is that most of what you see and understand is down to you and your expectations, rather than a response to 'what's out there'. The key problem is ensuring that the sense you make of things is enough for you to deal effectively with the reality of a continuously unfolding situation – a situation that you must also share with your colleagues.

2. **People take risks**
   Everybody takes risks all the time. In a world that is essentially uncertain, this is not only normal but inescapable. We explain how the human perception of risk is quite different from the probability with which events actually occur. The key problem is in ensuring that your own perception of risk maps well onto the world with which you are interacting.

3. **People make decisions**
   We explain the difference between how people think they make decisions and how they actually do it – and how the decision making of experts is quite different from the way they did it when they were learning. We also explain why experience does not always lead to expertise, but that expertise always requires experience – and lots of it. The key problem is to understand what the components of a good decision are, and how to recognise when you are about to make a bad one.

4. **People make mistakes**
   A fundamental human strength depends directly on the ability to make, and then recover from, mistakes. Without error there can be no learning or development. And without these, organisations cannot achieve their goals. The important aspect is in ensuring that potentially harmful or expensive mistakes are prevented, caught or minimised before they have a chance to get far enough to matter. We explain how this depends as much on organisational culture as on individual competence.

5. **People get tired and stressed**
   We explain the causes and consequences of fatigue and stress, and explain what you can do to avoid them or lessen their impact. We also explain why workload turns out to be as much to do with your own experience, as the actual demands placed on you by the job.

6. **People learn and develop**
   People learn all the time. They can't help themselves. The main problem is in ensuring that they learn the right things at the right time. People also have aspirations which can be managed by an organisation to further its own safety and profitability. However, in the absence of good management, people's aspirations will either be ignored or permitted to dominate – with potentially disastrous consequences either way. We explain the enormous power that effective, well-timed training can give to an organisation.

7. **People work with each other**
   Working with each other sometimes requires us to work as individuals in pursuit of our own goals, and at other times as members of a team with a common purpose. The key problem is in ensuring that we have effective 'people' skills, as well as technical task skills. We explain what these other skills are, why they are important and what can go wrong when they are absent.

8. **People communicate with each other**
   Successful communication involves the clear transmission of a message. We explain what has to happen for communication to be successful. We explain the responsibilities of both listener and messenger.

These are eight things we do that help to make us human. They are inescapable and will not go away. Understanding a little more about their nature, and how you can deal with them more effectively, will change your behaviour – and, maybe, that of those around you.

6. REFERENCE TO NQF, EQF, ECTS

Nowadays, the European Union (EU) consists of 27 member states, and each state has a different education system. The European Commission (EC) therefore prepared the European Qualifications Framework (EQF) because it wanted to:

- make national qualifications more readable across Europe;
- harmonise national qualification systems of different countries in a common European reference framework;
- promote workers' and learners' mobility between the countries of the EU and to facilitate their lifelong learning.

The EQF system has got eight reference levels (figure 2), each level describes what a learner has to know, understand and be able to do.[1]

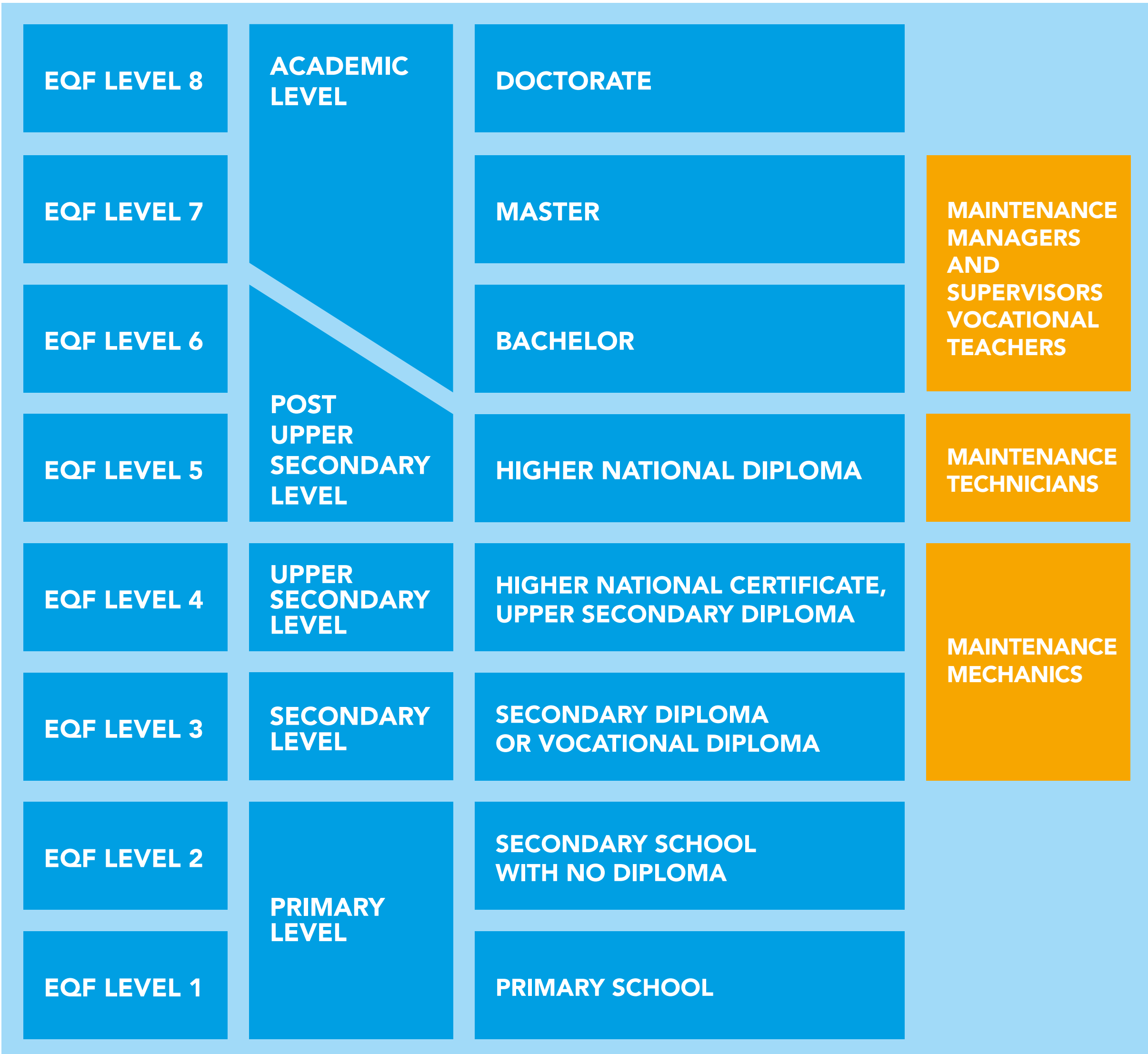

Figure 2 EQF levels compared with achieved education and maintenance personnel positions

1 http://www.maintworld.com/R-D/Application-of-European-Qualification-Framework-EQF-in-Maintenance, 1 December 2016

Germany	DQR Deutscher Qualifikationsrahmen für lebenslanges Lernen	www.dqr.de
The Netherlands	NLQF Nationaal Coördinatiepunt	www.nlqf.nl
Romania	anc Autoritatea Naţională pentru Calificări	www.anc.edu.ro
Slovakia	TREXIMA PEOPLE . PROFESSION . PROSPERITY	www.trexima.sk/new

Table 1 Overview of national organisations in the EQF context

Inland waterway transport (IWT) plays an important role in the EU in cargo exchange, especially at the international level on the network of the European waterways. On the one hand the transport is still more economical than any other mode of transport for many types of cargo, particularly such as bulk, general, liquid cargo and containers. On the other hand, it is the friendliest mode to the environment.

The IWTCOMP project outlined the fact that regarding international sectoral qualifications there is (still) not an agreement on the approach and international process of comparing the EQF levels via the National QFs (NQFs). Some member states do not want to adjust their procedures and this means all member states all still have their own NQF procedure.

Slovakia used to have two vocational schools which prepared students for jobs in IWT, but they were closed because of low interest of young people to work in this field. Nowadays, the Transport Authority examines the candidates for lower job positions in IWT such as skipper, captains, boatman (EQF 2 and 4). Before the exams, it organises the courses for applicants. The exam has oral and written forms and consists of various areas of IWT. The Department of Water Transport at the University of Zilina educates students for higher job positions (EQF 6, 7, 8) in IWT. The curricula are approved by the Ministry of Education, Science, Research and Sport of the Slovak Republic and its control body (Accreditation Commission). They are prepared according to the requirements of practice and standards of higher education in Slovakia.

In Germany there is a combined system of education at school and in a shipping company ending in centralised exams held by the chamber of commerce. Both schools and companies have to follow the curricula, but they are not responsible for the exams. The exams consist of two parts, one focussing on knowledge and one focussing on skills. Therefore both school and shipping company contribute to the education of the students, enabling them to pass the centralised exams.

In Romania there are dedicated programmes for IWT boatman (EQF 2). There are vocational schools for boatmen in Galati and Orsova, offering courses for boatmen qualification.

In the Netherlands there are qualifications set for the different levels of education within the IWT sector. For each educational level there is a set of qualifications given by the national contact point in cooperation with the work field and educational institutes. The Netherlands government decided to place the Captain/Manager IWT qualification in NQF level 5 (EQF5), but at a later stage it was withdrawn and placed in NQF level 4 (EQF4).

In conclusion, although the EQF system in the field of inland water transport has been accepted in all EU countries, this EQF system is not used by all countries. This is due to the fact that some institutes have to focus on the professional competences based on national and international legislation. The curricula at schools, universities and training centres are prepared according to the international or national standards in the cooperation with the international or national authorities (the Rhine Commission, the Danube Commission, the Ministries of Education), shipping companies and other authorities that work in the field of IWT in the Rhine or Danube Regions. It depends on the level of general education (higher or lower) per country.

ANNEX 1

Reference Documents

- TRAINING COURSE BOOK - Marine Engine Captain's Class CATERPILLAR;
- Directive (EU) 2017/2397 on the recognition of professional qualifications in inland navigation;
- Delegated Directive (EU) 2020/12 supplementing Directive (EU) 2017/2397 as regards the standards for competences and corresponding knowledge and skills, for the practical examinations, for the approval of simulators and for medical fitness;
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- N. Calder, "Boatowner's Mechanical and Electrical Manual", 2015.

ANNEX 2

Practical scenarios

Case Study 1

Fire due to improper maintenance and operation of the uncalibrated electrical safety installation, unverified term insulation resistance, accumulation of combustible / non-combustible materials in the compartments.

Actions needed to prevent:

- measuring the insulation resistance and obtaining the measurement certificate within the deadlines established by the rules;
- replacing contactors, worn fuses;
- for the prevention of work accidents, the electric shock protection inventory is used;
- the activity is monitored at ml level and the operations are performed according to the rules / manuals by the specialised implementing personnel.

Lessons learned:
Surveillance activity and up-to-date maintenance works of the installations eliminate accidents.

Case Study 2

Stranding of a ship because of a collision with a rock wall.

Collision due to the loss of steering capacity because of the malfunction of the hydraulic steering system:

Actions needed to prevent such an accident:

- replacement of used hydraulic pressure hoses;
- filling the hydraulic oil in the tank if needed;
- checking the operation of the steering system in "navigation" mode and in "manoeuvre" mode.

Lessons learned:
Surveillance activity and up-to-date maintenance work of the installations eliminates accidents.

Case Study 3

Rock wall collision due to shutdown of the propulsion engine.

Actions needed to prevent such an accident:

- proper maintenance of the propulsion system;
- proper maintenance of the main engines;
- supervision of the operation in time and carrying out the maintenance and repairs according to the programme given by the manufacturer, execution activity carried out under the supervision of the captain.

Lesson learned:
Surveillance activity and up-to-date maintenance work of the installations eliminates accidents.

Case Study 4

Installation failure during operation, in general.

Necessary actions:

- the realisation of the inspection schedule of the mechanical installations in accordance with the user manuals delivered together with the installations that are mounted on board the ship. The organisation of the work programme is established by the captain (ML), its execution by the execution staff (OL);
- carrying out the inspection schedule of the main and auxiliary engines in accordance with the user manuals delivered together with the installation on board the ship;
- carrying out the inspection schedule of the electrical installations and motors in accordance with the user manuals delivered together with the installation on board the ship.

Lessons learned:
Surveillance activity and up-to-date maintenance work of the installations eliminates accidents.

ANNEX 3

Draft model examination at operational level – marine engineering (annex to cesni (21)25)

The draft standard for the practical examination OL sets the framework for practical examinations on OL. To provide guidance to authorities on how to conduct an exam in this regard, the CESNI/QP working group has decided to develop a model examination in accordance with ES-QIN.

In these draft standards practical examination for OL, knowledge and skills elements that will be tested during the practical examination are specified. Listed are all elements described in the tables of competence standards on OL as "ability". Skills are usually tested during a practical examination. However, some abilities have knowledge elements. In this model examination, the term "examination element" is used to indicate both skills and knowledge.

The model examination is carried out on the assumption that the applicant has passed the knowledge elements (theoretical examination) of the standards for competence at OL as well as the assessment of the skills that for practical reasons were not assessed on board the craft during this practical part prior to the model examination.

For practical reasons, the exam is divided into four parts:

Part 1: Navigation
- Part 1a steering the craft (including applicable regulations)
- Part 1b assisting with anchor operations
- Part 1c mooring, unmooring and docking operations for pushed convoys / coupled convoys from deck, including operation and maintenance
- Part 1d loading and unloading

Part 2: Sailing the craft
- Skills shall be demonstrated on an approved simulator or a craft. Experts recommend the use of a craft of more than 38 meters length.

Part 3: Security and communication
- Part 3a safety and environment
- Part 3b communication

Part 4: Technology and maintenance
- Part 4a propulsion engine / machines
- Part 4b marine engineering, electricity, electronics, measurement and control technology
- Part 4c maintenance and repair.

For this Course Manual, Part 4 has to be taken into account.

The examination elements are listed in the table below:

All examination elements set out below may be tested prior to or during a practical examination or in a written assignment.

No.	Competence	Examination elements	Part	Cat.
40.	4.2.3 (2)	Use required tools to ensure general technical safety;	3c	II
41.	4.2.4 (2)	Follow procedures of maintenance and repair.	3c	II

Other examination elements that will be tested during a practical exam which do not belong to any of the aforementioned groups:

No.	Competence	Examination elements	Part	Cat.
30.	4.1.1 (5)	Assist in monitoring the engines and propulsion system;	4a	I
31.	4.1.2 (3+4+5+6)	Prepare main engines and auxiliary equipment for operation;	4a	I
32.	4.1.3 (2)	React adequately to malfunctions of engines;	4a	II
33.	4.1.4 (2+3+4)	Operate machinery including pumps, piping systems, bilge and ballast systems;	4a	I
34.	4.1.5 (3)	Assist in monitoring electronic and electrical devices;	4a	I
35.	4.1.6 (2+3)	Prepare, start, connect and change generators, and control their systems and shore supply;	4b	I
36.	4.1.7 (2)	Define malfunctions and common faults, and describe the actions to prevent damage;	4a	II
37.	4.1.8 (2)	Use required tools to ensure general technical safety;	3a	II
38.	4.2.1 (2)	Perform the daily maintenance work on the main engines, auxiliary machinery and control systems;	3c	I
39.	4.2.2 (2)	Perform the daily maintenance work on machinery including pumps, piping systems, bilge and ballast systems;	3c	I
42.	4.2.5 (2)	Use technical information and document technical procedures.	4c	II

ANNEX 4

Thematic content

This annex contains the thematic content of the competences of Marine Engineering at operational level as indicated in Chapter 4, if necessary.

COMPETENCES OF MARINE ENGINEERING AND ELECTRICAL, ELECTRONIC AND CONTROL ENGINEERING - OL

The numbering of the chapters is in accordance with the Standards of competence for the Operation Level 4.
MARINE ENGINEERING AND ELECTRICAL, ELECTRONIC AND CONTROL ENGINEERING

OL 4 - Marine engineering and electrical, electronic and control engineering

4.1 Monitoring the engines and propulsion system

Competences:
The boatman shall be able to:
1. Assist the management of the craft in marine, electrical, electronic, and control engineering to ensure general technical safety;
2. Perform maintenance work on marine, electrical, electronic, and control engineering equipment to ensure general technical safety.

4.1.1 Assist in monitoring the engines and propulsion system

Knowledge and skills

4.1.1.1 Knowledge of principles of propulsion system

Principles of shipboard propulsion system
Propulsion systems on board of the river ships are made of thermal or electric motors of different types, axial line and propellers. Taking into account the number and type of the thruster, there are:
- one main propulsion engine with an axial line and a free propeller or one with two rudders;
- two or more (up to 4 motors) motors with axial lines and propellers.

The thrusters can be:
- with fixed orientation, the steering gear being made by rudders or azimuth type;
- with governance assured by the main propeller which is oriented horizontally on 3600;
- with bow thruster, helpful when manoeuvring in tight spaces or when navigating in curves with small radius. These can be:
- with a propeller mounted in a transverse tube; or
- with a propeller mounted in a suction chamber, with adjustable discharge through flaps or azimuth.

Definition of propulsion, types of propellers
Naval thrusters are installations that create the propulsion force (thrust) necessary for the movement of the ship. The thrusters convert the mechanical energy produced by the engine into the kinetic energy of the ship's motion. The propulsion force developed by the propeller serves to overcome the resistance of the water as the ship advances.

From the point of view of the operating principle, the following types of naval thrusters are distinguished: reactive and active.

Reactive propellers are in turn divided into direct reaction and indirect reaction propellants.
Direct reaction thrusters develop propulsive force as a result of the reaction that occurs when throwing water sideways with the help of their working organs (blades).

In indirect jet engines, the propulsive force develops as a result of the reaction applied to the hull to the discharge of water or gas.
From the point of view of the transmission of the propulsive force, the propellers are divided into propellers with blades, and with jet.
Blade thrusters are an indirect reactions. These engines include the propeller, the wing propeller, the paddle propeller and the ordinary paddle.
The group of jet propellers includes pump, cone, hydro-reactive and autoreactive propellers.
Among the propellers is the sail, which is an active propeller. The sail develops propulsive force due to the energy of the wind, so it does not require an engine.
The wing propeller (Voith-Schneider) consists of a series of hydrodynamic profile fins, arranged vertically and evenly at the periphery of a rotating disk (Fig. 1.1).

Figure 1.1 Voth-Schneider propeller

The fins can be rotated around their axis by a special mechanism. The power train is mounted on the outer side of the stern of the ship. The axis of rotation of the wing thruster is arranged vertically.
The jet engine imparts to the ship the propulsive force by the lateral throwing reaction of water or gas through the system of pipes, channels or orifices.

The propeller

The propeller is the most common type of naval engine. The use of the propeller dates back to 1836. The construction of the propellers gradually improved. The axis of rotation of the propeller is arranged along the ship. From a constructive point of view, there are three main types of propellers, namely: one-piece propellers, propellers with removable blades and propellers with rotating blades (or variable pitch).

For one-piece propellers, the blades and the hub are a single piece, which can be cast, welded or stamped. Removable propeller blades are characterised by the fact that the blades are built separately and fastened to the hub by mounting with screws.

In the case of adjustable pitch propellers, the turning of the blades is performed with the help of special transmissions, located inside the propeller shaft, as well as with the help of a connecting rod-crank mechanism located in the propeller hub. The disadvantage of variable pitch propellers is their complicated construction and low operational safety, which is why they are used on small vessels operating in alternative modes (tugs, fishing boats, etc.).

Depending on the direction of rotation of the helical absorption surface, there are different helices with a right direction of rotation and a direction of left rotation. For the clockwise direction, the observer looking from the stern to the bow sees the propeller rotating clockwise.

The direction of rotation of the propeller can be determined by placing the propeller in a horizontal plane, so that the axis of the propeller is oriented vertically towards the positive ordinates.

4.1.1.2 Knowledge of different types of engines and their construction, performance and terminology

The operation of the internal combustion motors. Comparison between internal combustion piston engines and other types of heat engines.

Reciprocating internal combustion piston engines have the following advantages compared to other types of heat engines:

- short time required to prepare the engine for starting;
- ensures a great autonomy of the ships;
- high safety in operation regarding the occurrence of fires and explosions;
- the overall and weight indices are smaller;
- the main disadvantages of m.A.I. With reciprocating piston are:
- the high complexity of the construction and the need for highly qualified operating personnel;
- difficulties in reducing the operating speed;
- noise level, relatively high, especially at m.A.C. Semi-fast and fast.

Internal combustion engines have the following refinement directions and development:

  - improving the characteristic parameters of the engine cycle by improving the processes of mixture formation and fuel combustion;

- raising the compression pressure;
- increase of the average speed of the piston to the reduction of the average angular speed;
- reducing the overall and weight indices by increasing the speed, by applying supercharging;
- reduction of losses by friction, by the use of new anti-friction materials and by the improvement of lubrication installations and the addition of oils:
- increasing the reliability (durability) of the engines;
- decrease of the level of noise, vibrations and pollutant emissions produced by m.A.I.

Classification of internal combustion engines

1. Thermal machine refers to a mechanism, a set of fixed and moving parts, each using heat to produce mechanical work;
2. Internal combustion engine refers to a thermal machine where the combustion of fuel takes place inside the cylinder.

The classification of engines is done according to a series of factors:

a) According to the way the mechanical energy functions;
b) After the way the work process is carried out;
c) According to the way of forming the fuel mixture;
d) According to the purpose of feeding the cylinders with fresh load;
e) According to the fuel used;
f) According to the way of igniting the fuel mixture;
g) By the nature of the evolution cycle.

4.1.1.3 Knowledge of the function and operation of air delivery, fuel delivery, lubrication cooling and engine exhaust system

Air delivery

The management of the air destined for the consumption of the engines from the engine room is important for their correct operation and performance. In general, the following questions must be answered:

For proper operation and easy maintenance of ventilation system, the following questions must be answered:

1. Are ducts for ventilation air entering and leaving the engine room of adequate size and properly routed?
2. Is ventilation air flow in and out of the engine room adequate even when hatches and doors are secured for bad weather conditions?
3. If ventilating air fans and/or exhaust educators are used, are these of adequate size and properly designed and/or located?

For proper operation and easy maintenance of the combustion air system, the following questions must be answered:

1. Is combustion air ducted directly to the engine air cleaner(s) from outside the engine room? (Good practice)
2. Are combustion air ducts equipped with baffles to prevent water from reaching the engine air cleaner(s)?
3. If standard air cleaners are not used, is substitute cleaner of sufficient size?

Fuel delivery

Fuel-Diesel engines have the ability to burn a wide variety of fuels. These fuels are divided into two general groups. The two groups are called the preferred fuels and the permissible fuels.

Lubrication cooling

Naval engines are equipped with a lubrication system generally composed of a lubrication pump coupled to the engine, a lubrication pump that loads the lubrication circuits before starting the engine and serves the oil preheating circuit, piping, storage tank, oil filter or filters, preheating with piping and electric boiler or with hot water.
Proper operation of the lubrication system and maintaining the optimum engine cooling temperature during operating conditions extends the life of the engine.

Engine exhaust system

The exhaust system evacuates the flue gases outside the engine room through elastically mounted pipes to take over the vibrations caused by the operation of the engine. The system must be inspected at certain intervals to observe the tubing tightness and insulation integrity. On some state-of-the-art motors, we find a lambda probe installed to measure the noxious substances operation as well as for establishing the engine maintenance and repair program.

Cooling system

The water cooling system of the engine is composed of the open circuit in which the water from outside enters through the bottom sockets (pipes), pipes, circulation pump and coolers. The water cools through the cooler the coolant in the closed circuit. The closed circuit directly cools the engine, mainly the outer area of the shirts where the fuel burns, and consists of the closed circuit pump, piping, the engine circuit located in the cylinder head and the common cooler with the closed circuit. Generally this circuit uses pure antifreeze or a mix with water and/or other liquid substances.

4.1.1.4 Knowledge of main and auxiliary engines

The latest generation naval engines are equipped with Electronic Control Module (ECM) computers. These computers have software installed for use by shipboard personnel as well as informing the manufacturer of all operating parameters. All data retrieved by sensors are stored in a history. In general, the software is divided into two parts, one is used by the crew on board and the second part is accessed by the engine manufacturer. The crew does not have access to this area, it is used by the manufacturer to observe the engine operating regime, engine wear and failure and to organise repairs.

The navigation crew monitors the engine operating parameters and possible alarms on the display. In case an alarm goes off, simple repairs can be performed, after which the alarm can be cancelled. The malfunction is recorded and remains in the history for analysis by the engine manufacturer. A repeater of the displacement on the engine is also found in the wheelhouse, where it can be tracked during navigation by the captain.

4.1.1.5 Ability to carry out basic checks and ensure regular functioning of engines

The engine operating parameters have limit values that are not allowed to be exceeded. If they are exceeded, the warning alarm is triggered and when the values exceed certain limits, the computer, through the ECM, stops the engine.

The ideal operating values are significantly different from one engine to another and from one producer to another. The computer has an "event code" system which records the engine operating parameters taken from the sensors and signals the alarm to stop the engine. For example, the values measured for CAT 3500B as set out in the Caterpillar Troubleshooting Manual.

The navigation personnel is limited in interventions and the occurrence of any alarm is automatically recorded in the ECM. The reaction of the ECM is described in the "CAT - Troubleshooting Manual".

Event description	Meaning
High Aftercooler Temperature Derate	>1070 °C
High Aftercooler Temperature Shutdown	>10700 °C for more than 480 seconds
High Crankcase Pressure Derate	>6 kPa for more than 10 seconds
High Crankcase Pressure Shutdown	>3.5 kPa for more than 3 seconds
High Engine Coolant Temperature Derate	>1070 °C for more than 30 seconds
High Engine Coolant Temperature Shutdown	>1070 °C for more than 5 seconds
High Engine Coolant Temperature Warning	>1020 °C for more than 5 seconds
High Exhaust Temperature Derate	>7500 °C for more than 5 seconds
Air Filter Restriction Derate	Air inlet pressure for left and right turbocharger is > 7 kPa for more than 5 seconds
Low Engine Coolant Temperature Warning	< 800 °C for more than 5 seconds
Low Engine Oil Pressure Shutdown	< 89/200 kPa for at least 10/9 seconds - depends on the engine speed (RPM between 350 and 1250 RPM)
Low System Voltage Warning	The supply voltage is <20 VDC
Fuel Filter Restriction Warning	The fuel filter differential pressure is >105 kPa for more than 5 seconds
Engine Oil Filter Restriction Warning	The oil filter differential pressure is > 105 kPa more than 5 seconds
Low Engine Oil Pressure Warning	The engine runs 10 seconds with pressure <89/200 kPa described by the default trip line
High Crankcase Pressure Warning	>2 kPa for more than 3 seconds
High Exhaust Temperature Warning	>6000 °C for more than 5 seconds
Engine Overspeed Warning	The default value for overspeed depends on the application
Inlet Air Restriction Warning	Left/right turbocharger >7 kPa for more than 5 seconds
High Aftercooler Temperature Warning	>1020 °C for more than 5 seconds

4.1.2 Prepare main engines and auxiliary equipment for operation

Preparations for start-up of the auxiliary engine

On board of the classic-propelled ship there are two auxiliary engines and, less often, an auxiliary engine with lower power that is used when the ship is at anchor or under operations.

- generally, the start-up of the generator engines is simple. it checks;
- the oil level in the crankcase;
- the water cooling installation, more precisely the water level in the expansion tank for older engines;
- the general condition of the circulation pump and the piping;
- condition of the cooler in case there are two circuits (open and closed);
- the opening of the inlet valve from the bottom sockets.

In the case of the latest diesel generators, the operations are automated, assisted by sensors, simply pushing the start button triggers the operation of automatic control and starting the engine.

Preparations for start-up of the main engines

The boiler is supplied from the heating circuit of the main engines, which will only be started after achieving a temperature of 55-6000C. Some high power main engines have pre-heating installations, both for oil and water. The latest engines have start-up algorithms in the automated system, and it cannot reverse or skip any of steps from the start-up procedure because the sensors will keep the engine stopped. Before the start-up, the engine is verified by an external visit and it is possible to check for leaks/losses of oil or water by reading the indicators from the engine or tanks. The consumption tank is fully fed in time for any impurities or condensate water that has formed in the main tank to settle.

4.1.2.1 Knowledge of starting systems of main engines, auxiliary equipment and hydraulic and pneumatic systems according to instructions

The starting systems are electro motors or pneumatic starters. These have to be coupled through a hydraulic flywheel and powerfully rotate the engine with the angular speed achieved by the engine at idling speed, the minimum speed required for starting. After the start-up, the hydraulic head is automatically disengaged.

4.1.2.2 Knowledge of principles of reversing systems

Unlike the old engines, the classic reversing of the direction of rotation is done by means of the gearbox-inverter. This lowers the engine speed from 800 – 1700 RPM to 250 – 350 RPM in the shaft. The command is made from the wheelhouse and is available to the captain. This command integrates the back and forward coupling operations and packaging of the propulsion engine. The control lever transmits the movement by cable, pneumatic or electronic, to the terminals on the gearbox-inverter and to the rack of the engine injection pump.

The operation of the forward-reverse coupling is mechanical, electrical through electro-coils or hydraulic by hydraulic arm/piston (linear hydraulic motor), depending on the size of the engine. There are also mixed electro-pneumatic systems that transmit the coupling control backwards and the engine speed is created through a pneumatic piston actuation of the injection pump. The reversal occurs by moving the median rail to the bow or stern and coupling it to the rail forward or backwards. The three disks or pair of disks slide on the grooved axis of the inverter.

4.1.2.3 Prepare the machinery in the engine room according to checklist for departure

4.1.2.4 Use the starting system and auxiliary equipment according to instructions, e.g. steering equipment; to start the main engines following starting procedures; to use hydraulic and pneumatic systems

Preparation for starting, operating supervision and stopping naval engines

The observance of the operations performed by the service personnel, embarked on board of the ships, for starting of the naval engines in according with the operating instructions specific to each constructive and functional type of engine, is of great importance for the operation of the engine at optimal parameters, for a long period of time. The preparation of the engine for start-up is carried out according to the stationary period of the engine.

a) Preparation for starting up the engine after a long stay (leaving the site, completing larger repairs, etc.). The preparation measures in this situation are complex, carrying out preparation operations for both the main engine and its installations. They consist of:
   - ventilation and release of any tools, devices, spare parts, materials, etc. of the car compartment;
   - verification of the axial line;
   - decoupling the break of the shaft;
   - checking the technical status of the oil level and the gearbox-inverter (if available);
   - checking the tightness of the engine by controlling every tightening nut by striking it with a hammer;
   - checking the fastening of the fixed and movable parts of the engine;
   - checking the operation of the pressure lubrication system;
   - priming of the fuel injectors to remove the air from the high pressure installation;

- checking the related engine installations (lubrication, fuel and cooling);
- steering the engine (with the purge valves open);
- balancing of the launching and distribution valves;
- verification of the launch installation (operation of the levers and control joints, the existence of air in the launch cylinders);
- checking the technical status of the regulator and controlling the level at the regulator (only if the motor has indirect acting regulator);
- controlling the operation of the cooling system by means of ballast or fire pumps (if provided).

b) Preparing for start-up after a shorter period of time (such as porting). The steps to take before starting are simpler:
   - the external check of the motor and of the axis line is made;
   - check the oil level in the push and support bearings - grease the gland shaft gland;
   - check the oil level in the crankcase (or circulation tank);
   - check the fuel level in the consumption tanks and the water level in the expansion tank;
   - the engine heats up;
   - the launch is made on the air, checking the change of the direction of travel.

c) Starting the engine and monitoring immediately after starting.

The start of the classic main engine, without automated systems, is made to order received by telegraph. In the case of large, slow naval engines (with air start), the start is made with the help of a lever (launch levers), after the desired reversal direction has been achieved beforehand, allowing air to enter the cylinders whose pistons are in position. The starting must be done with a minimum consumption of launch air.

The increase of the speed must be done gradually, to allow uniform heating of the organs. As the load and its speed increase, it is forbidden to use the maximum engine speed at short distances soon after starting and during manoeuvres.

Surveillance during start-up and immediately after start-up is a very important step in the correct operation of the engine and the way in which the uniform increase of the cooling and functional parameters of the engine is achieved, depending on its good subsequent operation and even prolonging the engine life.

Check list for - Stopping the engine

The main engine is stopped at the command received by telegraph or directly from the wheelhouse in the case of automated systems. Stopping must not be done suddenly (from maximum speed to zero), but gradually by reducing the speed progressively and in time, in order to ensure a gradual cooling of the engine assemblies. Throughout this period, the cooling and lubrication parameters must be kept as constant as possible.

After stopping the engine and receiving the "free car" command, the following measures are taken:
- stop the fuel supply pump of the injection pumps;
- the cooling and lubrication installations are left in operation for a period of time which is stipulated in the engine manual;
- the launching system is closed, isolating the launching air cylinders;
- the fuel, launch and reversing levers are left in the stop position (zero);
- the bleed valves on the cylinder heads are opened, oil is introduced inside the cylinders;
- the viror is coupled, the motor shaft being rotated in both directions for about 1-2 hours to ensure a uniform cooling of the cylinder liners;
- the turntable remains engaged, because for every day the ship is parked, the crankshaft must be rotated, always leaving it in a different position than the initial one (in order not to strain the shaft).

In addition to stopping the engine under normal conditions, it may also happen that under certain force majeure conditions (engine malfunctions that can lead to serious damage) it may be necessary to stop the engine abruptly (sometimes not even short-term operation is possible) at low speeds.

4.1.2.5 React adequately to malfunctions of engines

Running of the engine in damaged condition

The slow start of the engine, the smooth running during operation as well as maintaining the operating parameters within permitted indicated limits confirm the correct operation of the engine.

The occurrence of unusual noises, vibrations, smoke and sparks in the exhaust gases, the variation of the operating parameters outside the admitted limits, as well as the occurrence of other irregularities in operation are indications of errors or faults.
The sooner a fault is detected and fixed, the less chance of engine failure or possible damage. When anomalies occur in the operation of internal combustion engines, it is recommended to stop operating immediately and fix the problem.

Under certain special conditions (bad weather, manoeuvres, narrow navigation passages, etc.), the main or auxiliary engine can operate in damaged condition. For example, supercharged engines can be kept in operation with the turbocharger switched off, having around 50% of the rated power; in the case of failure of the sweeping air cooling system, the engine can be operated under reduced load in order not to exceed the indicated parameters.

In all cases of continuing the operation of the damaged engines, it will be taken into account to reduce the extension of faults or to fix them while navigating if possible.

4.1.3.1 Knowledge of control equipment in the engine room and of reporting procedures for malfunctions

For marine engineers working on ships, troubleshooting problems related to engine room machinery is the most important task they have to deal with on a daily basis. Though marine engineering training inculcates the very basics of maritime concepts, it is only through hands-on experience that marine engineers understand the vital techniques of engine room operation and maintenance.

Troubleshooting Ship's Machinery

The process of troubleshooting ship's machinery involves three important factors which are as follows:

- Requirement - Though the art of troubleshooting cannot be learnt just from marine engineering books, book knowledge is equally important.
- Approach - Though it is mandatory for a person to have all the "requirements" stated above in order to work on ships, these are also not enough. Fulfilling the requirements is just the first step towards successful troubleshooting. The right approach to learning and understanding the machinery is one of the three important factors seafarers must consider for troubleshooting.
- Learning - Learning from the last problem tackled always adds to the experience which can be used for future troubleshooting situations. Once the problem is solved, it is better to discuss the same with your team to find other, simpler ways of tackling the same issue.

Personnel safety

The engine room is an area full of machinery equipment, electric instruments, turbochargers, generators, etc. However, this equipment is managed by crew members on board who are responsible for its operation; this is the reason why human error is the main cause of accidents related to engine room failures. It is therefore very important that relevant procedures, posters or caution signs and guidance concerning machinery equipment be strictly followed to enhance personnel safety on board and to minimise human errors.

Welding is very hot and risky work in the engine room. Many serious fatalities in relation to welders have been reported due to exposure to fumes and gases, excessive noise and electrical shock or due to the use of the ship's hull as earth return.

Best practices for personnel safety

a) To avoid electric shocks, ship's personnel should take the following precautions
b) An appropriate risk assessment should be carried out prior to commencement of work to determine the potential hazards.
c) Wet working conditions should be avoided.
d) The welders should be insulated from the work piece and return cable and stand on a dry insulated mat.
e) Never use the ship's hull as return conductor.

4.1.3.2 Recognise malfunctions and take appropriate measures in the case of malfunction including reporting to the craft's management

Many accidents have been reported in the ship's engine room due to engine failures or loss of power and substandard working procedure. Poor housekeeping and many other safety issues that can be resolved would help improve the overall safety culture of a ship.
One of the most important qualities that a marine engineer must have is to know and understand his/her machinery extremely well. Before breaking down completely, every machine will show a variety of signs and symptoms indicating the type and severity of the fault.

Along with knowing the right procedures to operate the ship's machinery, seamen must also know how to identify and troubleshoot any problem in the engine room.

a) Abnormal Sound - Sound is by far the most prominent factor which draws a seaman's attention to a troubled part or machinery.
b) Smell - Another powerful indication, which can be easily detected by human senses, is that of abnormal smell coming from machinery or systems. When you note a heavy/strong smell in the vicinity, it can be due to leakage of oil, fire, effects of high temperature, etc.
c) High Vibration - All machinery systems with moving parts generate vibration. One of the most neglected maintenance jobs for machinery on board ships is that of vibration analysis.
d) Leakages - Leakages are a result of faulty piping or machinery systems.
e) Smoke - Every machine with a combustion chamber can be judged for its performance by checking the exhaust smoke for its colour and density.
f) Abnormal Parameters - Abnormal or fluctuating parameters are mainly related to machine faults.
g) Alarms - Every alarm indicates a problem, major or minor, on board ships. They have been installed for the purpose of identifying faults. Never ignore an alarm related to any kind of machinery.
h) Observing Problems in Connected System - In the ship's engine room, most of the systems are connected to another system or machine. If a problem is observed in one system, make sure to check the other machinery connected to it.

i) Change in Amperage - More than 80% of the machinery on a cargo ship are electrically operated, i.e. from ship's generated power. Make sure to check the current of all the electrical operated machinery and pumping systems.
j) Knowing Your Machinery Inside-Out - Last but not the least, knowing your designated machinery inside-out will help you identify the minutest change in its performance.

Special attention must be paid to the following in the engine room:
1. Exhaust manifolds and ducts through the entire casing shall be free from leakages;
2. Steam pipes and other hot surfaces shall be properly lagged;
3. Insulation contaminated by oil or other flammable products shall be renewed;
4. No flammable material shall be left in buckets or open containers;
5. Short sounding pipes and automatic closing arrangements shall never be left open;
6. Bunker tank high level alarm shall be tested before each bunkering operation and at least monthly;
7. Leakages of fuel and lube oil shall be contained as soon as possible;
8. Thermometers and pressure gauges shall be tested and calibrated on a sequential basis allowing all to be tested annually;
9. Monthly Safety Inspections to be carried out

Engine rooms by their very design are hazard areas to the unwary or unfamiliar for all sorts of reasons - automatically starting machines, loud noises, loud alarms, poorly indicated or signposted escape routes, 'blind' areas with no exit, etc.

4.1.4 OPERATING MACHINERY INCLUDING PUMPS, PIPING SYSTEMS, BILGE AND BALLAST SYSTEMS

Competences

The boatman should be able to:
1. Recognise the safe operation and control of the machinery in the engine room, ballast compartments and bilge following procedures.
2. Control the safe function, operation of machinery in the engine room and to maintain the bilge and ballast system including: reporting incidents associated with transfer operations and ability to correctly measure and report tank levels.
3. Prepare and operate shut-off operations of the engines after operation and operate pumping bilge, ballast and cargo pumping systems.

Kingston waterway

Water is needed for the proper functioning of the on-board installations. The technical / sanitary water is taken from the outside through a "main" pipe provided with two "kingston" type valves in the domestic water piping. If the cooling pressure on the engines decreases and the temperatures increase due to navigation or manoeuvring in areas with low water levels, one of the first operations to be performed is to clean the coarse filter that clogs with sand and/or shore.

Water extinguishing system

The fire extinguishing system is also supplied from the main pipeline. This installation is composed of an extended network of pipes on the entire ship with fire sockets / mouths to which the fire hoses are connected. The installation comes under pressure when starting the fire pump, the pump three-phase electric power (see photo, pump body and electric motor painted in blue). The control panel includes the on-off switch and the optical on-off and overload indicators. The fire pump can also be switched on from the main deck of the ship, when an emergency or a fire in the engine room requires it.

A basic rule for the water extinguishing system is that the pump must be permanently supplied with both electricity and water from the bus control as well as remote control from the deck.
Fire extinguishing systems with fixed networks of pipes, fire-smoke sensors and sprinklers is an installation that starts automatically when the smoke-high temperature sensors do. The advantage is that the trigger is automatic, much faster and with high efficiency. This installation consists of a hydrophore tank that keeps water at working pressure, pipe network and sprinklers with sensors that trigger splashing when it detects smoke, heat or fire.

Bilge pump with two pistons

The piston bilge pump is an installation composed of the pump assembly and a network of pipes that are distributed in all the ship's bilges. The pump has the ability to extract all the bilge water from all compartments. It is a self-priming pump, with low flow but which "dries" the bilge.

This pump is used only when, for various reasons, water, hydrocarbons, etc. have collected in the ship's bilge. To prevent pollution of the aquatic environment, this pump has a valve on the discharge pipe on board the ship, closed and sealed. The bilge water is drawn by the piston pump and stored in the tank with bilge residues, also by the bilge pump with piston overboard, through the transfer installation overboard. The operation of pumping overboard and handing over the waste is mentioned in the "hydrocarbon log" of the ship.

Water pump for cooling and lubrication of the stern tube bushing with closed circuit drinking water

By means of water flow, this pump provides for the cooling of the bearings of the shaft line of the propulsion installation. Lack of water flow or a high temperature is detected by the sensors and transmitted to the ship's command on the central monitoring panel "miniguard", which will signal optically and audibly exceeding values and will display on the screen "Lack of water flow axial line Bb / Tb" or "High temperature Bb / Tb". The bearings of the shaft line left without cooling will overheat and grip the bearing shaft on the bearing.

An alarm started for this installation can be seen in the "miniguard" and involves fast and energetic intervention:

- emergency stop of the propulsion operation for the signalled shaft line;
- restart the pump if possible;
- cooling with a source of drinking water.

Hydraulic installation for steering the ship

The hydraulic system for steering consists of:

a) The rudder car they belong to:
   - the oil tank, the one in the photo has a capacity of 600 litres of hydraulic oil;
   - two main hydraulic pumps driven by two three-phase electric motors that can operate separately or in parallel for emergency situations or manoeuvring;
   - a hydraulic emergency pump;
   - three hydraulic distributors operated with electric coils supplied at 24 volts, one distributor for each hydraulic pump.

b) Two or four hydraulic pistons (hydraulic linear motors) that drive the rudders.

c) The electrical control panel of the hydraulic installation for steering the ship is mounted in the wheelhouse. The driver of the ship is the person who starts or stops the operation of the steering installation depending on the nativity.

For the safety of steering, the manufacturer also mounts a hydraulic pump for emergency steering on the main engine, which ensures steering in case the ship runs out of electricity.

4.1.5 Assist In Monitoring Electronic And Electrical Devices

Competences

The boatman should be able to:

1. Understand how the power is generated on ships and to tell the difference between the AC and DC current.
2. Describe the main characteristics of the synchronous generators.
3. Enumerate the components of the power distribution system.
4. Explain the use of the megger and the thermocouples on board the ship.

Electricity On Ships

Power Generation On Ships: A ship is equivalent to a floating city that enjoys almost all privileges available to any operational set-up on land. Just like any conventional city, the ship also requires the basic amenities to sustain life on board, the chief among them being power or electricity. Electricity on ships is generated by an alternator or generator.

AC and DC current

There are two types of current used in electrical applications: alternative current and direct current.

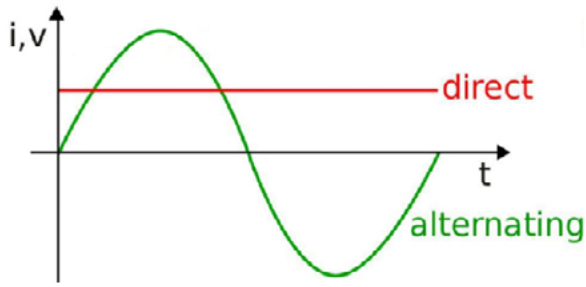

Figure 1.2 Axis of AC and DC current

Alternative Current (AC)

AC current flow changes between positive and negative because of electrons - electrical currents come from the flow of these electrons, which can move in either a positive (upward) or negative (downward) direction. This is known as the sinusoidal AC wave, and this wave is caused when alternators at power plants create AC power.

Direct Current (DC)

Direct current (DC) is a linear electrical current - it moves in a straight line. Direct current can come from multiple sources, including batteries, solar cells, fuel cells, and some modified alternators. DC power can also be "made" from AC power by using a rectifier that converts AC to DC.

AC motors

AC motors work with alternative current which reverses its direction with a frequency of 50 Hz (about 50 times/second). With a 50 Hz grid, the needle will make 50 revolutions per second, i.e. 50 times 60 = 3000 rpm (revolutions per minute). They are composed of a stator and a rotor.

Stator

The stator is the stationary component of the motor which houses the rotor inside it; it consists of a pile of laminations forming a cylindrical hollow that is held in place against a sturdy frame made of steel. The inner circumference of the cylindrical laminations is punched with slots that are spaced out at uniform distances from each other.

The stator is designed to produce a rotating magnetic field. This can be done by placing electromagnets arranged around the outside. The coils of the electromagnets are energised in pairs, in sequence, producing a rotating magnetic field.

Rotor

The rotor, the revolving component of the 3-phase motor, is made of laminations which are piled in a manner that leads to the creation of a number of rotor slots. These rotor slots, in turn, make room for the squirrel cage rotor winding.

The movement of the rotor inside the stator is based on Faraday's law. The rotor, suspended inside the magnetic field produced by the stator, is an electrical conductor. The magnetic field is constantly changing and induces an electric current inside the rotor. If the conductor is a ring or a wire, the current flows around in a loop.

Failures of electrical engines

The following failures of electrical engines are the most common:

- Electrical overload
- Low resistance
- Overheating
- Contamination
- Vibration
- Phase imbalance
- Bearing failure

Synchronous Generators

A Synchronous Generator (SC) is an electrical machine which converts the mechanical energy into electrical energy. The main characteristic of an SC is that the rotor speed is equal to the rotating magnetic field produced by the stator. The structure of an SC is in accordance with its application. For instance, in case of diesel generators installed on board of the ship, the SC is characterised by low speed and therefore it uses a salient pole rotor.

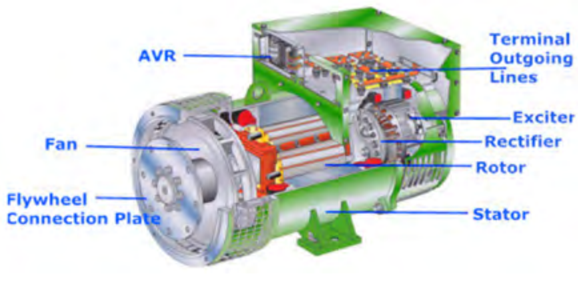

Figure 1.3 A model of a synchronous generator

In marine and inland ships, the SC is used for generating power for electrical devices on board of the ship. In most cases, each ship is equipped with 2 synchronous generators which work in parallel connection in order to provide enough energy. The parallel functioning of diesel generators will provide maximum output for peak requirement or the desired minimal output during other times. From an exploitation/maintenance point of view, there are several advantages offered by coupling in parallel two or more generators:

- reliability;
- expandability;
- flexibility;
- ease of maintenance and serviceability;
- cost-effectiveness and quality performance.

Ideally, any type of a generator can be paralleled together with another type as long as their frequencies and voltage are the same at the point of interconnection. In order to synchronise, two generators are required to fulfil the following conditions.

- phase sequence – the phase sequence of both generators should be identical
- voltage – the terminal voltage of both generators should be the same
- phase angle – the phase angle of both generators should be equal
- frequency – the frequency of both generators should be nearly the same

Shipboard power is generated when a prime mover and alternator work together. For this purpose, an alternating current generator is used on board. The generator works on the principle that as a magnetic field rotating around a conductor varies, a current is induced in the conductor. The generator consists of a stationary set of conductors, wound in coils of iron core also known as the stator.

Power Distribution on Ships

The ship's power distribution system consists of different components for distribution and safe operation of the system. The main components of this system are:

- ship's generator - consists of prime mover and alternator;
- main switchboard - a metal enclosure taking power from the diesel generator and supplying it to different machinery systems;
- bus bars - act as power carrier and allow transfer of load from one point to another;
- circuit breakers - act as a switch, and in unsafe conditions can be tripped to avoid breakdown and accidents;
- fuses - safety devices for machinery;
- transformers - to step up or step down the voltage.

In a power distribution system, the voltage at which the ship's electrical system works is usually 440v. However, there are some large installations in which the voltage is as high as 6600v.

Emergency Power Supply

In case of failure of the ship's main power generation system, an emergency power system or a standby system is used. The emergency power supply ensures that the essential machinery systems continue to operate the ship. Batteries or an emergency generator or even both can supply emergency power on ships. High Voltage Systems On Ships: As the ship's size and capacity increase, bigger machinery/equipment are installed to ensure its operational efficiency; however high voltage is used only for a few important machinery systems.

Usually a 3 phase, 60Hz, 440 Volts supply is generated and distributed on board ships. As the ship size increases, there is a need to install more powerful engines and other machinery systems. This increase in size of equipment demands more electrical power and higher voltages.

Electrical Propulsion System

The conventional propulsion system of ships is efficient but requires high operating costs and increases marine pollution. Among all prospective alternate power sources for ships, electrical propulsion system is one of the most promising alternatives today.
The electric propulsion system consists of a prime mover, which can be of two types:

- diesel driven;
- turbine or steam driven.

Both these systems produce less pollution as compared to a conventional marine propulsion system, which involves burning heavy oil.
Advantages of an electrical propulsion system:

- a large amount of power is generated by the system and the excess power can be utilised by supplying it to cargo pumps, fire pumps and other important auxiliary machinery;
- there is more flexibility in installation of machinery;
- it provides improved manoeuvrability and high redundancy;
- environmental benefits from lower fuel consumption and emissions;
- high performance in tough ice conditions due to maximum torque at zero speed;
- reduces lifecycle costs by less fuel consumption and maintenance costs.

Disadvantages of this system:

- the efficiency of an electrical plant is less than that of a conventional system;
- the installation cost of an electrical propulsion plant is much higher;
- improvised training for ship's crew is required as the system is completely different from a mechanical system and involves major automation.

Other Ship Electronics Used On Board

Autopilot and/or self-steering systems

These systems must coordinate data from many devices on the ship and interface with control and propulsion systems to keep the vessel on a predetermined course.

Chartplotter

Compass

Sonar (or Fishfinder)

Acoustic devices using electronically emitted and detected pulses of sound to locate underwater objects. These include transmitters, receivers, and equipment used to analyse acoustic information.

GPS

Global Positioning Systems are space-based radio-navigation systems that broadcast highly accurate navigation pulses to users on or near the Earth.

Fuel monitoring and management

The rising prices of marine fuel and heightened emissions regulations have led to advances in the technology used to measure, monitor, and report fuel use. Electronic MFM devices can reduce fuel costs and increase operational efficiency.

Marine VHF radio

Radar

Radar is an object detection system that emits electromagnetic waves and analyses their interaction with objects. Radar systems are able to identify the range, altitude and velocity of moving and stationary objects such as aircraft, ships, ground vehicles and meteorological formations.

Electrical Instruments

Megger or Ohmmeter

The most important routine maintenance for electrical machinery involves checking of insulation resistance, which is done by an instrument called a "Megger" or "ohmmeter".
A Megger is a portable instrument used to measure insulation resistance of electrical machinery or systems. It is battery operated or mechanically operated (hand crank dc generator) and gives direct reading in ohms. Megger is used to measure voltage ratings in the range of 100V to 5000V.

A Megger consists of the following parts:

1. control and deflecting coils;
2. permanent magnet;
3. pointer and scale;
4. d.c generator or battery connection;
5. pressure coil and current coil.

Permanent Magnet Moving Coil Instrument (PMMC)
A variety of instruments are used on board for measuring parameters of electrical machinery and systems. A permanent magnet moving coil (PMMC) is one such instrument which is popularly used on board for several applications.

The PMMC has a variety of uses on board ship such as:
1. Ammeter
2. Voltmeter
3. Galvanometer
4. Ohm Meter

Thermocouples
Thermocouple is a device widely used as a pyrometer on board ships for continuous measurement of temperature for machinery systems such as main engine, auxiliary engine, gas turbines, etc.

It is absolutely important to choose the correct thermocouple material for different temperature range operations, depending on the machinery and thermocouple location where the parameter has to be measured.

Rectifier and Rectifier Circuits
Since most ships generate A.C. current from their alternators, it becomes essential to use a device, along with the transformer, that can convert this A.C. current into D.C. current for using equipment or circuits running on direct current. A rectifier is a circuit which utilises one or more semiconductor diodes to convert an alternating current into a pulsating direct current.

Types of rectifiers:
- Half wave rectifier:
- Full wave rectifier:
- Bridge rectifier:
  Some of the uses of rectifiers on board ships are:
  - used in marine electronic devices and circuits;
  - used for onboard battery charging from the ship supply;
  - used in electroplating process;
  - used in operation of D.C. motor;
  - used in field excitation of three-phase alternator.

Amplifier and Amplifier Circuits
An Amplifier or an operational amplifier (op-amp) circuit is commonly used in the automation, control and other electronic circuits of marine applications. The applied input signal is normally a voltage or a current signal. The purpose of an amplifier is to produce an output signal larger than that of the input signal.

The purpose of an amplifier or an op amp is to amplify or increase the input signal to produce an output signal, which is much larger than that of the input, with a similar waveform as that of the input. The main change in the output signal will be the increase in the power level. This additional power is supplied by a D.C. voltage, which is externally provided. The output signal is controlled by the input signal in an amplifier.

An amplifier circuit is popularly used in marine electrical/electronic circuits and applications such as:
- it is used to amplify audio signal (loudspeaker, VHF);
- it is used as voltage and current regulator;
- it is used as analogue to digital converter and vice versa;
- the output signal from amplifier is supplied to a relay in a circuit.

4.1.6 Prepare, start, connect and change generators, and control their systems and shore supply

Competences
The boatman should be able to:
1. Describe how a generator works, and what are the main components of an electric generator.
2. Define the role of cooling and exhaust systems for the protection of the generators.
3. Present at choice a method of synchronization of the generators on a ship.

Ship power plant
The power plant of a ship normally consists of three diesel generators driven by diesel engines. One generator is normally used when the ship is at sea while more sets of diesel generators are employed during entering or leaving port and during loading or unloading. The diesel generators can also be set as automatic starting stand-by generators.

A generator on a ship is known as the heart of the ship. It is that life-line which supports each and every function of the ship. The ship's generator requires special care, attention and maintenance for its effective and economic running. Generators are useful appliances that supply electrical power during a power outage and prevent discontinuity of daily activities or disruption of business operations.

How does a generator work?
It is important to understand that a generator does not actually 'create' electrical energy. Instead, it uses the mechanical energy supplied to it to force the movement of electric charges present in the wire of its windings through an external electric circuit. This flow of electric charges constitutes the output electric current supplied by the generator. This mechanism can be understood by considering the generator to be analogous to a water pump, which causes the flow of water but does not actually 'create' the water flowing through it.

The modern-day generator works on the principle of electromagnetic induction discovered by Michael Faraday in 1831-32. Faraday discovered that the above flow of electric charges could be induced by moving an electrical conductor, such as a wire that contains electric charges, in a magnetic field.

The main components of an electric generator can be broadly classified as follows:

- Engine
- Alternator
- Fuel System
- Voltage Regulator
- Cooling and Exhaust Systems
- Lubrication System
- Battery Charger
- Control Panel
- Main Assembly / Frame

A description of the main components of a generator is set out below.

Engine

The engine is the source of the input mechanical energy to the generator. The size of the engine is directly proportional to the maximum power output the generator can supply. There are several factors that you need to keep in mind while assessing the engine of your generator. The manufacturer of the engine should be consulted to obtain full engine operation specifications and maintenance schedules.

(a) Type of Fuel Used – Generator engines operate on a variety of fuels such as diesel, gasoline, propane (in liquefied or gaseous form), or natural gas.

(b) Overhead Valve (OHV) Engines versus non-OHV Engines – OHV engines differ from other engines in that the intake and exhaust valves of the engine are located in the head of the engine's cylinder as opposed to being mounted on the engine block.

(c) Cast Iron Sleeve (CIS) in Engine Cylinder – The CIS is a lining in the cylinder of the engine. It reduces wear and tear, and ensures durability of the engine. Most OHV engines are equipped with CIS but it is essential to check for this feature in the engine of a generator.

Alternator

The alternator, also known as the 'genhead', is the part of the generator that produces the electrical output from the mechanical input supplied by the engine. It contains an assembly of stationary and moving parts encased in a housing. The components work together to cause relative movement between the magnetic and electric fields, which in turn generates electricity.

The following are the factors that you need to keep in mind while assessing the alternator of a generator:

a) Metal versus Plastic Housing – An all-metal design ensures durability of the alternator. Plastic housings get deformed with time and cause the moving parts of the alternator to be exposed. This increases wear and tear and more importantly, is hazardous to the user.

b) Ball Bearings versus Needle Bearings – Ball bearings are preferred and last longer.

c) Brushless Design – An alternator that does not use brushes requires less maintenance and also produces cleaner power.

Fuel System

The fuel tank usually has sufficient capacity to keep the generator operational for 6 to 8 hours on average. In the case of small generator units, the fuel tank is a part of the generator's skid base or is mounted on top of the generator frame. For commercial applications, it may be necessary to erect and install an external fuel tank. All such installations are subject to the approval of the City Planning Division.

Common features of the fuel system include the following:

1. Pipe connection from fuel tank to engine – The supply line directs fuel from the tank to the engine and the return line directs fuel from the engine to the tank.
2. Fuel pump – This transfers fuel from the main storage tank to the day tank. The fuel pump is typically electrically operated.
3. Fuel Injector – This atomises the liquid fuel and sprays the required amount of fuel into the combustion chamber of the engine.

Voltage Regulator

As the name implies, this component regulates the output voltage of the generator. The mechanism is described below against each component that plays a part in the cyclical process of voltage regulation.
When you add a load to a generator, its output voltage dips a little. This prompts the voltage regulator into action and the above cycle begins. The cycle continues till the generator output ramps up to its original full operating capacity.

Cooling & Exhaust System

Cooling System

Continuous usage of the generator causes its various components to get heated up. It is essential to have a cooling and ventilation system to withdraw heat produced in the process.
Raw/fresh water is sometimes used as a coolant for generators, but these are mostly limited to specific situations like small generators in city applications or very large units over 2250 kW and above. Hydrogen is sometimes used as a coolant for the stator windings of large generator units since it is more efficient at absorbing heat than other coolants.
It is essential to check the coolant levels of the generator on a daily basis. The cooling system and raw water pump should be flushed after every 600 hours and the heat exchanger should be cleaned after every 2,400 hours of generator operation.

Exhaust System

Exhaust fumes emitted by a generator are just like exhaust from any other diesel or gasoline engine and contain highly toxic chemicals that need to be properly managed. Hence, it is essential to install an adequate exhaust system to dispose of the exhaust gases.
Exhaust pipes are usually made of cast iron, wrought iron, or steel. These need to be freestanding and should not be supported by the engine of the generator. Exhaust pipes are usually attached to the engine using flexible connectors to minimise vibrations and prevent damage to the generator's exhaust system. The exhaust pipe terminates outdoors and leads away from doors, windows and other openings to the house or building. It must be ensured that the exhaust system of the generator is not connected to that of any other equipment.

Lubricating System

Since the generator comprises moving parts in its engine, it requires lubrication to ensure durability and smooth operations for a long period of time. The generator's engine is lubricated by oil stored in a pump. The level of lubricating oil should be checked every 8 hours of generator operation. The crew should also check for any leakages of lubricant and change the lubricating oil every 500 hours of generator operation.

Battery Charger

The start function of a generator is battery-operated. The battery charger keeps the generator battery charged by supplying it with a precise 'float' voltage. If the float voltage is very low, the battery will remain undercharged. If the float voltage is very high, it will shorten the life of the battery.
Battery chargers are usually made of stainless steel to prevent corrosion. They are also fully automatic and do not require any adjustments to be made or any settings to be changed.

Control Panel

This is the user interface of the generator and contains provisions for electrical outlets and controls. Different manufacturers have varied features to offer in the control panels of their units. Some of these are mentioned below.

- electric start and shut-down – Auto-start control panels automatically start your generator during a power outage, monitor the generator while in operation, and automatically shut down the unit when no longer required;
- generator gauges – The control panel also has meters for the measurement of output current and voltage, and operating frequency;
- other controls – Phase selector switch, frequency switch, and engine control switch (manual mode, auto mode) among others.

Main Assembly/Frame

All generators, portable or stationary, have customised housings that provide a structural base support. The frame also allows for the generator to be earthed for safety.

Important checks before starting generators on ships
The starting procedure of engines on ships requires several points to be taken into consideration. While it is important that none of these points should be missed, there are a few extremely important things that should be done without fail while starting these ship engines.

1. Lubrication of Main Engine;
2. Check All Important Parameters;
3. Open Indicator Cocks and Blow Through;
4. Rotate the Crankshaft;
5. Manually Check Turning Gear;
6. Check Jacket Cooling Water Temperature;
7. Warm up the Engine;
8. Put Load Sharing Switch to Manual;
9. Avoid Excessive Opening of Exhaust Valve;
10. Examine the Engine.

Starting procedure of a generator:

- check fuel tank level is normal and fuel line valve open;
- check engine radiator water level is normal;
- check engine lubricating oil sump level is normal;
- check trip reset switch on engine in reset position;
- select "Auto - manual mode" switch to manual mode (manual starting);
- press start button on engine control panel and engine starts on air;
- check engine and alternator parameters are normal once started.

How to Synchronize Generators on a Ship?

Synchronizing of an incoming generator or alternator is very important before paralleling it with another generator. The synchronizing of the generator is done with the help of synchroscope or with the three bulb method in case of emergency. It is of utmost importance that before paralleling the generators the frequency and voltage of the generators need to be matched.

A. Synchroscope method

The synchroscope consists of a small motor with coils on the two poles connected across two phases. Let's say it is connected in red and yellow phases of the incoming machine and armature windings supplied from red and yellow phases from the switchboard bus bars.

B. Emergency synchronizing lamps or three bulb method

This method is generally used when there is a failure of synchroscope. In case of failure a standby method should be available to synchronize the alternator, and thus the emergency lamp method is used.

Three lamps should be connected between three phases of the bus bar and the incoming generator should be connected as shown in the photo.

Figure 1.4 The connection of the three lamps

Shore Supply Connection of ship electrical system

When a ship docks, it no longer needs energy for propulsion. However, ships may still be large consumers of energy when stationary as several of the ship functions are still operating. This includes ventilation/heating/cooling, pumps, control systems and cargo handling systems. Consequently, the generators are running when in port, resulting in local noise and air emissions as well as global climate driving emission. Rather than letting the generators on board make the electricity, this can come from shore power.

Shore power can be installed for all types of vessel and for all ages with need for power in harbour, and has been used for years especially for smaller vessels, but also some larger passenger vessels.
Shore power may potentially eliminate the local noise and air pollution related to ship activity in a port. Depending on the energy source, it may also contribute positively to the climate driving effects of ship operation, but as an isolated initiative, it is generally not considered to be among the most cost effective climate initiatives.

4.1.7 Knowledge of malfunctions and common faults, and describe the actions to prevent damage (see annex 1)

Competences

The boatman should be able to:
1. Describe at choice the causes and remedies of a malfunction that can appear in small ship engines.
2. Enumerate the remedies in case the engine ejects excessive black smoke.

4.1.7.1.Knowledge of malfunctions outside the engine room and of procedures to follow to prevent damage and procedures to follow if malfunctions occur.

4.1.7.2 Ability to identify common faults and take action to prevent damage to mechanical, electrical, electronic, hydraulic and pneumatic systems.

4.1.8.Use required tools to ensure general technical safety

Competences

The boatman should be able to:
1. Understand the use of maintenance material and repair equipment on board, including their qualities and limitations.
2. Choose and operate maintenance material and repair equipment on board.

Technical safety on board the ship

Respecting the rules of labour protection in the activities of operation, maintenance and repair is very important to protect the health of the navigation personnel. Within the activities, the navigation personnel work with tools dedicated to the interventions on different types of machines and installations in conditions of noise, vibrations, closed/poor ventilated environment or loaded with toxic vapours from the substances that are transported in the warehouses of the chemical tanks. Individual protection equipment is provided for all working or intervention conditions. These must be stored on board of the ships and must be accompanied by instructions on how to use them and what kind of risk are covered. Thus we have:

- different types of protection equipment for head, ears and eyes;
- general protection, equipment type overalls, which can be specialised for wearing in hostile environments-dangerous chemicals;
- equipment for the protection of hands and feet for the work with the ship's ropes, with mechanical tools, in the electrical installation and with dangerous chemical substances;
- respiratory protection equipment intended for working in unventilated enclosed spaces.
- the given examples present the diversity of the protection equipment. Thus, before beginning a maintenance/repair activity it is necessary to be equipped with appropriate protection means.

4.1.8.1 Knowledge of characteristics and limitations of processes and materials used for maintenance and repair of engines and equipment.

Apply safe working practices when maintaining or repairing engines and equipment.
The boatman shall be able to perform maintenance work on marine, electrical, electronic, and control engineering equipment to ensure general technical safety.
The boatman shall be able to examine the students through theoretical exams.

4.2.1 Perform the daily maintenance work on the main engines, auxiliary machinery and control systems

Competences

The boatman should be able to:

1. Understand the procedures to follow for maintenance and good care of the engine room, main engine, main machinery, auxiliary equipment and control systems.
2. Keep main engines, auxiliary equipment and control systems safe.

Maintenance Interval Schedule

Before performing any operation or maintenance procedures, ensure that the Safety Information, warnings, and instructions are read and understood.
To determine the maintenance intervals, use fuel consumption, service hours or calendar time, whichever occurs first. Experience has shown that maintenance intervals are most accurately scheduled on the basis of fuel consumption.
Before each consecutive interval is performed, all of the maintenance requirements from the previous interval must be performed.

The operating and maintenance conditions are factors that condition the service life of the engines. During operation, the initial characteristics of the engine bodies undergo modifications that lead to the reduction of the functional qualities, finally reaching the need for their replacement.

In order to maintain the engine in perfect working condition and at all times ready to be started, it is necessary to apply and observe the maintenance rules. These indicate the intervals at which the personnel of the machinery need to intervene to disassemble the component parts exposed to dirt or wear, to carry out the control, cleaning, overhaul and repair, if necessary. The time intervals between various revisions depend on the average load of the engine, the number of hours of operation, fuel and lubricants quality, etc.
The maintenance works are divided into: daily revision works and periodic revision works. Within the current (short-term) daily operations that can be performed during the operation of the engines or during short-term stationary, without affecting the possibility to start the engine at an eventual order.

As examples of current works there are: cleaning of filters, purging of tanks, cleaning of cooling water, filling service tanks with oils and lubricants, checking the lubrication of movable elements (connecting rod). The periodic current revisions are made at a certain number of operating hours and include: partial or total decarbonisation, which require shutting down the engines for a certain period of time.

Decarbonisations, as the name shows, are those works whose main purpose is to remove the deposits of carbonic residues resulting from the combustion process, from the walls of combustion chambers, pistons, cylinders, segments, injectors heads, etc. During partial decarbonisation only the cylinder heads and their external reinforcements are dismantled. Total decarbonisation also requires dismantling of the piston-crank mechanism, control and measurement of the axial line of the engine and all other aggregates mounted on the engine (i.e. turbo-chargers, blower pumps, valves, injection pumps, speed regulator, etc.). The precise deadlines for the execution of the works for each type of engine are shown in the documentation and instructions sent by the manufacturer, in addition to the internal instructions of the shipowner's technical service.

4.2.2 Perform the daily maintenance work on machinery including pumps, piping systems, bilge and ballast systems Competences

The boatman should be able to:

1. Remember the daily maintenance procedures - see 2.1.
2. Maintain and take care of pumps, piping systems, bilge and ballast systems.

Daily procedures

The daily procedures for monitoring the operation and intervention are specific to each installation of bilge, ballast and pumping systems. Generally, these installations have maintenance instructions that must be learned by the designated navigation personnel and applied daily or whenever necessary. For example, tightening the stuffing boxes, filling the lubricants with consistent grease, checking and eliminating, when necessary, leaks, keeping the bilges clean, pumping the ballast by manoeuvring the valves and pumps according to the provisions received.

The main aim of any maintenance plan on ship is to get the maintenance and repair work done in the shortest possible time with minimum costs.
A maintenance plan is therefore followed by every shipping company to ensure that the ship's machinery maintains a particular standard of operation and safety.

While making a maintenance plan, several aspects are taken into consideration, starting from the International Safety Management code (ISM) to the guidelines provided by the machine manufacturers.

What should be the main objectives of a maintenance plan?

As mentioned before, the main objective of a maintenance plan is to make sure that the work is done in the least possible time with utmost efficiency and at optimum cost.

How is the maintenance plan made and implemented?

In order to carry out a successful maintenance plan, the following steps are considered in order to form a strategic approach:

1. Identifying the problem.
2. Establishing the cause.
3. Proposing a solution.
4. Evaluating the solution.
5. Implementing the solution.
6. Evaluating effectiveness.
7. Solving.

Considering the above mentioned points, a systematic and planned maintenance procedure is made which also forms an integral part of the ship's planned maintenance system.

For inspection purposes, checklists are often used to ensure that the inspection, test and maintenance are performed according to the guidelines of manufacturers, shipping company and the ISM code.

Ship's piping system - maintenance guideline

Unless they are made of non-corrosive material, are galvanised or plastic-coated, the external surfaces of pipes should be painted. Generally, the maintenance of pipes should concentrate on identifying and replacing those that have weakened.
It is important to identify failing pipes before leakage occurs; maintenance of piping is as much about procedural checks and pressure tests to locate weak points as it is about actual repair.

DOs AND DON'Ts:

ALWAYS DO:

- replace pipes that have significant corrosion, i.e. wen the corrosion allowance has been used up, and check all similar pipes, replacing as necessary.
- as a pipe ages, check its wall thickness regularly, concentrating on bends, elbows, deck, bulkhead or shell penetrations;
- keep pipes leak-free; paint them to prevent corrosion;
- fit spray shields around fuel and other pipes carrying flammable substances close to hot surfaces;
- ensure that insulation is maintained in good condition and is free from oil contamination.

NEVER:

- fit wet lagging around mild steel pipes;
- wait until a suspect pipe begins to leak before arranging repair;
- repair with a mis-match of materials, or with material of different thickness in the same piping run;
- leave material, equipment or clothing inside a pipe after repair;
- force pipes into alignment;
- use welding to repair an 'in-situ' fuel or lubricating oil pipe.

Pipeline Identification, Valves

Pipelines used for common services such as water, fuel, lubricating oil, steam and compressed air are to be colour coded in accordance with Class or Flag requirements. Where no specific requirements exist, pipelines must be coded in accordance with the standards of ISO14726.

Care should be taken when replacing or repainting pipelines that the correct colour is used. Colour coding of pipelines may vary from ship to ship, therefore new members of the crew should check with a competent officer as to what the colours mean.

A standard information board with the colour coding is to be placed at the main Engine Room Entrance. All valves must be properly identified and labelled in order to minimise the risk of incorrect operation and relevant staff briefed in their correct function, where appropriate. Fuel supply piping must be double-sheathed and regularly inspected for integrity.

Bilge and Ballast Systems for Ships Machinery Spaces

The bilge system is used to remove small quantities of fluid that have leaked or condensed into a dry space. The system serves the machinery spaces, cargo holds, cofferdams, voids, stores, tunnels and pump rooms. Each space has its own piping but the pump is likely to be shared.
The bilge main is arranged to drain any watertight

compartment other than ballast, oil or water tanks and to discharge the contents overboard. The number of pumps and their capacity depend upon the size, type and service of the vessel.

Bilge and ballast systems are interconnected so that each can perform the other's function in an emergency, i.e. a ballast pump could be used to pump out a flooded engine room. They are connected by means of a crossover valve.

The capacity of a bilge system is defined by the diameter of the bilge main and pump capacity for the volume of the enclosed space. In passenger and cargo ships, where the engine room provides bilge pumping, the whole ship is the 'enclosed space'.

The diameter of the bilge main is:
d = 25+1.68vL(B+D)
where,
d = internal diameter of bilge main, in millimetres
L = length between the ship's perpendiculars, in metres
B = extreme breadth, in metres
D = moulded depth, in metres

The pumping system in a passenger ship must be able to drain water from any dry space when one or more of the ship's other compartments are flooded. However, the system is not required to empty the flooded space. A flooded passenger ship is required to have at least one bilge pump, with its own power supply, available for pumping. Bilge suctions must have remotely operated suction valves. The minimum number of pumps required is three or four, depending on the ship's design.

The ballast system

The ballast system is arranged to ensure that water can be drawn from any tank or the sea and discharged to any other tank or the sea as required to trim the vessel. Combined or separate mains for suction and discharge may be provided. The system must therefore be arranged so that only the appropriate pipeline is in service; the other must be securely blanked or closed off.

Ballast Tank Monitoring

Level Monitoring: The water ballast tank on the ship is installed with the level sensors to control the valves and ballast pumps for safe ballasting operation.
Multiple ballast pumps are provided in the engine room which takes the suction from the main seawater line (from sea chest) and during the deballasting operation, they discharge the water from ballast overboard line and valve. The CCR is provided with the ballast tank level monitoring system, and the pump cut-off is controlled once the water level reaches the sensor level to activate the trip.

In oil tanker ships, the ballast tank is provided with gas measuring sensors at various levels - usually, upper and bottom levels.

When the ship is the ballast/partial ballast condition, it will be turned to activate the top sampling point. This is done to avoid the entrance of water into the analysing unit through the sampling points.

The volume monitoring of the ballast tank is done to achieve the ballast/deballast rate of the pumping system. This is done by the loadicator software installed on the ship, and the ship's officer will manipulate the results displayed by the loadicator to operate the fill/discharge valve of the ballast tank.

4.2.3. Follow procedures of maintenance and repair

Competences

The boatman should be able to:
1. Be aware of the information from manuals and the instructions for maintenance and repair.
2. Conduct maintenance and repair procedures according to applicable manuals and instructions.

Procedure lists

The use of procedures lists (check lists) elaborated by the engines or installations is necessary. These instructions have a table form written for older motors/installations or one which is included in the software that supervises the function and displays on the screen, based on the alarms given by sensors, or eventually an abnormality and the way of intervention (reducing working rpms, stopping the installations/motors, reporting and resetting alarms, summary intervention in the installation to eliminate leaks, cleaning, replacing some used parts, etc. and finally reporting the abnormality to the service that keeps maintenance for a more evolved reparation). Below are some checklists for small and large naval engines.

Malfunctions, causes and remedies in small ship engines (annex 1)

Causes	Remedies
Engine does not start	
It's not diesel. The tap of the decanter is closed. One or more of the diesel pipelines are clogged. Diesel oil is too viscous due to low temperatures. The injection pump parts are very worn out. The feed pump piston spring is broken. The piston of the feed pump is stuck. The supply pump valves are no longer closing.	Fill the fuel tank with diesel and prime the fuel system. The tap is opened and the supply system is primed. The supply system is primed and in case the defection is maintained, the connecting pipe tightens and the condition of the sealings is checked.
The engine does not develop nominal power	
There is air in the supply circuit. Injection pump clamps are very worn out. Injection pump discharge valves are worn out. Sprayers are worn or their needles are stuck* The injection advance adjustment has been changed.	The supply system is primed and in case the defection is maintained, the connecting pipe tightens and the condition of the sealings is checked. Replace the injection pump. Replace the seat-relief valve assembly.
The engine ejects excessive black smoke	
The diesel fuel flow is too high, which is why the burning is incomplete. The discharge valves are worn or broken. The discharge valve spring is broken. The injection pressure is very low. Diesel fuel is not of proper quality. The air filter is blocked.	The injection pump is adjusted. They are replaced. It is being replaced. The injection pressure adjustment is restored. Replacing diesel. Wash the filter.
The engine speed oscillates	
The adjusting rod moves slowly and the regulator is malfunctioning. The joints of the regulator mechanism have friction or clearance.	Remove the causes that produce this displacement (bumps, deformations, etc.). Remove the causes that would produce this friction (dirt, deformation or incorrect installation).
Electrical installation does not work	
The key switch has failed. The regulator relay 3 has been disturbed. The regulator relay 3 has been disturbed or has been switched off (the generator and the battery are switched off). The generator went off. Broken pipes, dirty contacts or short circuits.	It is being replaced. The relay is adjusted or replaced; charge the battery or replace and repair the generator. The generator is rewound. Charge the battery. The broken pipes are replaced; short circuits are removed; the contacts are cleaned.

Malfunctions, causes and remedies to large naval engines

Causes	Remedies
At the launching operation, the motor masts do not move or do not fully spin	
The valves for opening the air from the cylinders are closed. The air pressure in the cylinder is too low. The cylinder control valves are opened. The start valve is stuck. The air dispenser drawers get stuck. The ship's propeller is blocked.	Check the opening of the valves. Load the cylinder using the air compressor. Load the cylinder, using the air compressor, close the valves. Check the closure of the valves. Press the start valve with compressed air and check the valve opening. Check, bilge and blow with air, then reassemble. It is verified and if so, the propeller is disturbed.
The engine stops during operation	
Interrupting the supply of fuel pumps. Too much water in the consumption tank. Leakiness of the fuel pump and supply line. The combustion chamber is burnt.	The existence of the fuel in the fuel tank is verified. The condition of the filters is checked. Water is drained from the piping, pump and consumption tank, after being filled with clean fuel. The connections of the pump and the supply piping are tightened.
The exhaust gases have a dark colour	
Too much fuel mixture. The needle of the injector is blocked or the nozzle holes are closed. Cracks in needle holder and injector nozzles. The fuel pump discharge valves do not close. At the pumps with a drawer, the height of the inlet opening is not well adjusted. The compression pressure in the cylinders is insufficient. The fuel comes late.	The fuel pump flow is reduced to the respective cylinder. Try the injector needle; if it does not move freely or stops, the needle must be slightly tightened or weakened. Remove the injector, repair the malfunctions or replace it. Dissemble and grind the valve or replace the needle if it is broken. Check the pump installation.
The exhaust gas has a white colour	
Combustion of fuel is incomplete; the temperature in the combustion chamber is too low. The fuel contains too much water or the water enters the cylinders through the cylinder head. The air admitted to the combustion chamber of the cylinder is too humid.	Increases compression to normal value. The water will be separated from the fuels in the feed tank, into the filters, and the cracked heads will be replaced. The water from the air cylinders will be evacuated.
Gas explosion at the safety valves	
The fuel abounds at the injectors due to too high pump flow. The explosion pressure is higher than normal or the safety valve spring is too low. Cylinder overloading or water entering the combustion chamber during intake. The tip of the injector needle is burnt.	Pass the fuel adjustment lever to the minimum, checking that the pump supply is in position 0. The intake advance is reduced and the safety valve spring is adjusted. The fuel flow is reduced, the cylinder head is examined. The burnt needle of the injector is replaced.
Heating parts in motion	
The piston body heats up. Warming of the cross head's gliders. Heating the bearings of the connecting rod or thrust bearings.	• the engine speed is reduced, the supply of the respective cylinder is switched off and an abundant lubrication is made with fresh oil; • the lubrication tube of the cylinder is dissolved and the respective cylinder is put into operation after reaching the normal temperature; • if the piston has deformations or cracks * it is replaced. Check the lubrication, the functioning of the cooling system, the correct installation and the lack of de-oiling. The quality of the oil used will be examined.

The main and the safest means of operating and maintaining in good condition the shaft line of the ship, is the knowledge and observance of the operating parameters and of the assembly clearance within the permissible limits, the realisation of the instructions of the construction site and the basic technical rules. During navigation, the shaft line malfunctions or parameter disturbances may occur, the immediate detection and repair of those will make the installation to continue to operate under normal conditions.

4.2.4 Use technical information and document technical procedures.

Competences

The boatman should be able to:

1. Understand the content of technical documentation and manuals.
2. Document maintenance work.

The Most Important Engine Room Documents a Ship Cannot Sail Without

A vessel can only travel from one foreign port to another with valid certificates and up to date recorded documents. All documents in the engine room and bridge should be duly filled, checked and signed by the operating officer and countersigned by a managerial level officer for the smooth and lawful operation of the ship.

Engine Room Log Book

- the engine room log book is used to record all the parameters of running machines which includes main propulsion plant, power generation system, boiler, purifier, refrigeration plant, air conditioning plant, etc., with the signature of the duty officer;
- any abnormal finding is noted by the duty engineer during his/her watch;
- any major maintenance for machines is recorded with the date and remarks by the officer in charge of the work;
- voyage number and "from" and "to" ports is written in the log book.

Oil record book

It is one of the most important documents on board with a written record for compliance with Annex I of MARPOL.

- bunkering operation to be recorded including date, time, bunkering grade, quantity bunkered, port of bunkering and retention of tank used in bunkered operation;
- any maintenance on ows is recorded and acknowledged by the engineer officer carrying out the operation.

Engine Room Tank Sounding Log

- it is used to keep a written record of soundings of all the engine room tanks including waste water tank, fuel oil and diesel oil service settling and bunker tanks.
- frequency of sounding is normally twice a day – once in the morning and once in the evening.
- record of sounding is acknowledged by the engineer officer taking the sounding.

Sewage Management Log

- the sewage management log consists of ISPP certificate, operating procedure of sewage plant, and maintenance procedure of the sewage plant;
- any maintenance in sewage plant (chlorine tablet dosing, etc) is recorded and acknowledged by the engineer officer carrying out the maintenance;
- oil to Sea Interface Log;
- it is used to record the working of those systems which have direct interface of oil with sea water;
- the chief engineer is responsible for maintaining this log.

Seal log

- all the seals placed onboard have an individual number, which is logged in the seal log;
- the date when the seal is removed, the purpose of removal is also logged in the seal log;
- Saturday/Monday Routine Log;
- it includes emergency generator, emergency fire pump, emergency compressor, life boat engine, emergency stops of pumps and ventilation fans, fire dampers and other equipment and systems as per company requirement.

Chief Engineer Night Order Book

- only the chief engineer is responsible for maintaining this log;
- chief engineer's instructions are written for night watch officers in this book.

Maintenance availability planning tools

The following is a listing and description of some of the many instruments available to the Commanding Officer, department heads, division officers and work centre supervisors aboard ship to be used for effective organisation and management of maintenance related activities. These tools are designed to result in a higher level of equipment and system reliability and improved productivity.

1. Maintenance Data System (MDS).

MDS is the basic system for maintenance and repair planning and documentation. The following parts are essential to repair planning:

a. Current Ships Maintenance Project (CSMP).
b. Planned Maintenance System (PMS).
c. Master Job Catalogue (MJC) and Standard Work Request Items.
d. Zone Inspections.

2. Standard Repair/Overhaul Classes.

Work requests or job orders frequently contain requirements using terms such as "class B overhaul" or "class C repairs ". These terms are often misused and the scope of work to be performed misunderstood. According to the CNSP Maintenance Manual, correct definitions are:

a. Class A.

Work requiring overhaul or repairs, modifications, field changes, ORDALT's or SHIPALT's to sustain or improve the operating and performance characteristics of the system, subsystem or component being repaired or altered to meet the most recent design and technical specifications for that item are defined as class A.

b. Class B.

Work requiring overhaul or repairs to restore the operation and performance of a system, subsystem or component to original design and technical specifications is defined as class B.

c. Class C.

Repair work on a system, subsystem or component specified by work request, or work required to correct particular deficiencies or malfunctions specified by the customer is called class C.

d. Class D.

Class D work is defined as work associated with Open, Inspect and Report work requests in which the customer cannot specifically identify the problem.

e. Class E.

Class E work is defined as work required to incorporate all alterations and modifications specified for a designated system, or component.

3. Standard Work Items

Standard work items and repair standards have been established by NAVSEA to improve the quality and methods of work performed in repairing or overhauling various equipment. Under this system most routine repairs will be covered.

a . NAVSEA Standard Work Items.

NAVSEA Standard Work Items (SWI) establish a Navy-wide standard for methods and quality control measures used in disassembly, inspection, repair, reassembly and testing of equipment covered by SWI's. SWI's are developed for private sector availabilities.

b. Technical Repair Standards (TJRS) .

Technical repair standards are similar to SWIs but apply to Naval shipyards and repair activities.

c. Reliability Centred Maintenance Influence on Use of Standard Work Items.

NAVSEA SWI and TRS are written to include all elements of work required for complete class B overhaul.

d. Quality Assurance (QA).

No maintenance work and planning efforts are complete if QA is lacking.

COMPETING

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