Improvement of Marine Engineering Curriculum Using the Engine Room Simulator

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ABSTRACT

The Engine Room Simulator (ERS) course design is initially established as a parallel to the updated version of IMO Model Course 2.07. IMO Model Course is so general that needs to be modified with available functions and systems of the ERS as well as according to the use of the ERS for the purpose of the course. For example, Model Course 2.07 subjects are not clearly defined for management level of training.

With the cooperation of Japanese International Cooperation Agency (JICA) and Istanbul Technical University Maritime Faculty (ITUMF), ERS of ITUMF was installed in June 2001 and ERS based courses were integrated into the marine engineering curricula. Current ITUMF ERS courses aim to develop knowledge and skills of senior level ITUMF students on the regular operation, watchkeeping, and malfunction detection of engine room machinery and systems. In order to achieve an integrated education and training process; classroom briefings, workstation guided exercises with checklists concept, and full-mission ERS are utilized. An important element of simulator use in the curricula has been focus on the compliance with STCW-95 competency evaluation requirements. This highly integrated simulator-based education and training system has been ramping-up to full operation to provide integrated individual and team training in the marine engineering professional courses.

This paper outlines the specifications of ITUMF simulator and provides a progress report on the recent improvements in the marine engineering education curricula, which includes lessons learned from the early development stages and integration into the marine engineering curricula. The authors also discuss the feasibility of the use of ERS to establish higher-level skills, such as risk management, teamworking, and internal and external communication. The final part of the paper includes the use of ERS for the initial research studies at ITUMF for safety management.

1. Introduction

Japanese International Cooperation Agency (JICA) and ITUMF started a project at ITUMF for the improvement of Maritime Education and Training in 1999. The project duration is scheduled for five years. Since the start of the projects, the following are some of the achievements completed:

- Installation of a full-mission ERS,
- Installation of a Ship Handling Simulator (SHS),
- Training of instructors,
- Start of education and training of ITUMF students using ERS,
- Initiation of Research Projects on Safety Management,
- Study on Curricular activities,
- Realization of International conferences and seminars on related fields,
- Establishment of new short-term Maritime Safety Training & Certification (MSTC) training courses, such as ARPA-RADAR, Medical First Aid & Medical Care, Tanker Familiarization, Advanced Tanker Course, English/SMCP, Advanced Fire Fighting,, etc.

JICA-ITUMF projects are now in a stage that all available tools such as SHS and ERS could be used both for training and education of ITUMF students and for the training and certification of seafarers serving onboard. With long and successful efforts, the simulator building of ITUMF is completed to serve to the plan for the utilization, which is that the simulator building is a ship . Having ERS installed in 2001, ERS based courses were already introduced into ITUMF marine engineering curricula.

This paper focuses on the effective utilization of ERS in four-year marine engineering program along with other training methods; namely: utilization of labs and workshops, training on a Training Ship and Merchant Ship training.

2. Training & Education Using ERS

Maritime training institutions all over the world started recognizing the value of simulation systems as training as well as evaluation of competence level tool. The International Maritime Organization (IMO), the highest international maritime body, has now officially promoted the use of simulators[1]. Its endorsement is embodied in the international convention on Standards of Training, Certification, and Watchkeeping for Seafarers 1978, as amended in 1995 (STCW Convention & Code). The convention makes ARPA-RADAR training mandatory and recommends the use of simulators for training as well as for the assessment of competence[2].

The ERSs are designed to simulate various machinery and equipment as used in the engine room of a ship using generally a diesel engine as propulsion system. The development of computer technology has had a dramatic influence on simulators and most now run on highly structured PC-based programs. ERSs could be a PC based self-training software or could include panels and interface equipments. Kluj (2001) proposed the following convention for the classification of simulators:

- **B (like Basic) Class simulators -** include CBT Software and/or Basic Machinery Simulators like Main Engine, Auxiliary Boiler, Separator, etc. which has a software to be run on a single PC/workstation.
- **P (like Personal) Class simulators** — usually simulate a model of an engine room and main engine type, which has a software runs on a single PC or on the set of several networked PCs co-operating.
- **F (like Full) class simulators** — simulates all of the engine room environment, machinery, and systems with physical appearance and sound effects.
- **S (like Special) class simulators** — specialized simulators, usually programs running on a single PC.

The above-defined convention for classification of ERSs will be used throughout this paper. The main purpose of all simulators is to simulate the systems as much similar as possible for a good utilization in education and training. The advantages of the utilization of ERS in MET are summarized by Cicek *et al.* (2002) as follows:

- The operations of the machinery are simulated as close as possible to their actual conditions,
- Training for both normal and abnormal condition repeatedly is possible,
- It is cost-effective,
- It is time effective,
- It offers a flexible and controlled schedule of the training curricula,
- It makes controlled evaluation of the students possible,
- It make standardization of a marine engineering education & training curricula possible,

The biggest advantage of using ERS as a training tool is the possibility of creating malfunctions repeatedly to train students for increasing their troubleshooting skills. However, even though ERS simulates the real engine room environment and systems, still ERS is not the actual working place of trainees. Therefore, effective utilization of ERS along with laboratories and workshops, training on a merchant ship, and training using a training ship would be most effective. Cicek *et. al.* (2002) studied comparatively the effective training methods and made some recommendations for IAMU Universities to utilize all available training methods efficiently and effectively to come up with a high-level training curricula. And now this paper utilizes the tables and conclusions that they made to initiate a study on baseline for an effective utilization of ERSs in marine engineering undergraduate program.

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[1] IMO: Engine Room Simulator, IMO Model Course 2.07, IMO Publication, 1989.

[2] IMO: STCW95, International Maritime Organization (IMO), 1996, 92-801-1412-3.

3. Specifications of ITUMF ERS

ERS (Engine Room Simulator) system was installed into ITUMF in June 2001 as a part of the JICA-ITUMF Project. The ERS System is Norcontrol made, which is a full-mission type of simulator for a container type of ship. The ERS of ITUMF is consisted of two types of simulator, namely full mission simulator and PC based simulator. Both of them were produced by KMSS (Kongsberg Maritime Ship Systems). ITUMF ERS consist of the following secions:

- Engine Room: interactive mimic panels that simulates all machinery and systems in an engine room. M/E local control stand is used for local control with telegraph. Two workstations are utilized for control of details of systems. Sound system simulates the noise produced by Main Engine, DGs, compressors, boiler, drains, etc.
- Engine Control Room: includes engine remote control console (ECC) with telegraph order, AutoChief, PowerChief, power-distributing panels (DG power panels, TG, power consumers, full electrical switchboard synchronization, emergency generator switchboard and shore connection), and two workstations.
- Instructor s room: from where all ERS system can be controlled, malfunctions can be created, and scenarios can be arranged.
- Exercise room: 6 workstations, used for self-training.
- Classroom — for briefing/debriefing sessions with the networked utilization ofsnapshots of training.

The general specifications of the Engine Room Simulator are summarized in Table 1.

Table 1. Specifications of ITUMF Engine Room Simulator.

Type	ERS-L11 SULZER 12RTA 84-Container, KMSS
Vessel	4,200TEU Container Ship LOA : 295m, Breadth oulded : 32m, Draught : 12.6m, Dead-weight : 55,000tons
Main Engine (ME)	SULZER 12RTA 84 Bore: 840 mm, Stroke: 2,400mm, MCR: 48,600 kW ME Speed: 102 rpm, Number of Cylinders: 12, ME Indicated Pressure: 17.0 bar, Scavenge Air Pressure: 2.4 bar, Number of Air Coolers: 3, Number of TG s: 3 Specific Fuel Consumption: 165 g/kwh.
Electric Power Plant	Diesel G.: 1,810kW x 2sets, Turbo G.: 2,250kW x 1set, Emergency G.: 1set
Steam Generation Plant	Oil fired boiler, Exhaust gas boiler: 0.75MPa, 12.0tonf/h

The ERS execution can be frozen at arbitrary situation, and the condition can be stored and reloaded as an initial condition. Instructor can make various scenarios using with actions and malfunctions menu based on both time and event. Since both two types of simulators, workstations (P) and full-mission (F), are completely same system except for hardware such as levers, buttons, etc, it is very easy and effective to develop application from self training to full mission with a team training. The snapshot ability of the software makes briefings and debriefing sessions more active with the inclusion of recorded snapshots of the training. Also, evaluation editor module of the software can be used for the assessment of actions of students during an exam or training.

4. Improvements in Marine Engineering Curricula with ERS

The major role of the marine engineering department of IAMU member universities/faculties is to provide their undergraduate students with effective and high-level education and training to allow them to be highly competent marine engineers. ERS based courses have recently begun to attract notice as a new training method because of the several advantages over the traditional methods as mentioned earlier. Based on these advantageous, Cicek *et al.* (2002) proposed the following additional competences for being a qualified engineering officer:

- Teamwork among engineer officers (how to be a part of the team)
- Leadership (how to organize the team)

- Safety culture and management of the risk in the machinery space (how to predict and prepare for an accident)
- Aspect of the human error (the causes, behaviors and results, human-machine interface, etc.)
- Communication aspects (how to communicate in multicultural environment with standard use of English)

Cicek *et. al.* (2002) pointed out that education and training curriculum to demonstrate these additional competences should be provided to undergraduate students of IAMU member universities. ERS training could be used to give marine engineer candidates higher-level qualifications discussed and proposed above. For example, the use of ERS for team-management and for communication skills could very efficiently be arranged because of the opportunity of preparing the scenarios based on the type of the training and education. Furthermore, by providing a scenario of simulated severe accidents in the machinery space, marine engineer candidates will be able to experience the situation without any damage to training equipments. Through this type of training, marine engineer candidates can learn the safety culture for the management of the risk (i.e. the aspect of human error). Simultaneously, the behaviors of the trainees during this type of training recorded on ERS will provide the academic staff of the department of marine engineering with opportunities to do research on human factor issues for safety management. Therefore, authors proposal is that IAMU institutions should introduce and use the state-of-the art ERSs in the undergraduate curricula. Proposed utilization of ERS in marine engineering curricula has two main parts. These are:

- ERS as laboratory tool in marine engineering courses, and
- Utilization of ERS as a training tool.

4.1. ERS as a Laboratory Tool:

The simulators can be used not only for training of candidates but also for other educational purposes and even for investigating engineering problems (Hikima, 2001), i.e. in courses such as Marine Diesel Engines, Operations & Troubleshooting, Auxiliary Marine Engines, Marine Electrical Systems, Refrigeration & HVAC Systems, Thermodynamics, Automatic Control Systems. Last few decades, some qualitative techniques such as automation of both navigation and engineering systems in shipping industry have contributed to productivity and saving of manpower on board, resulting a tendency of crew reduction. Nowadays having 3-4 engineers onboard is common. Therefore, skills and experience for a qualified marine engineer have been changing last decades due to the technological innovation such as remarkable improvements of computerized control systems. Therefore, the training of students in state-of-the-art simulators is beneficial. For example, Hikima *et. al.* (2001) showed how students as well as experienced engine room personnel were able to adjust PID controllers with the use of an engine room simulator, which is a very difficult experience to gain onboard a ship.

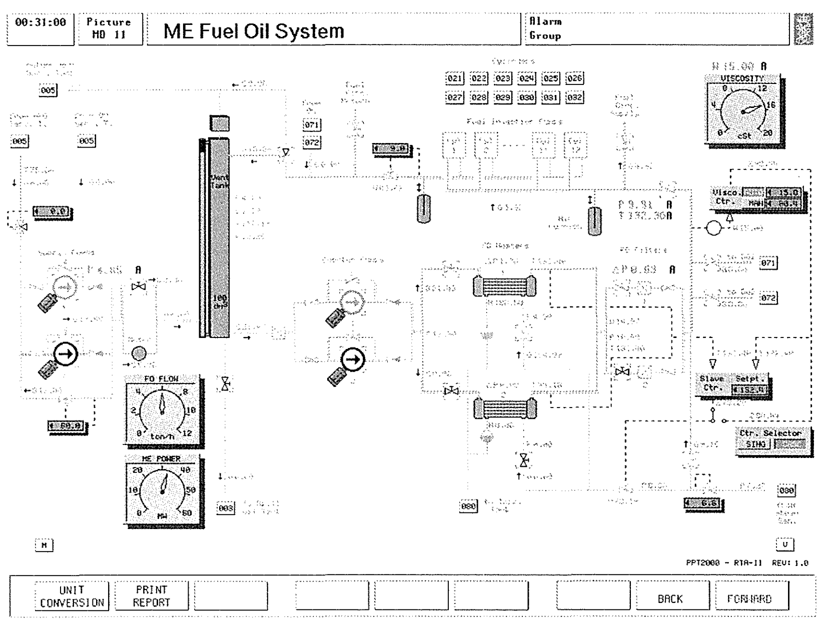

Figure 1. Adjusting PID Values of Viscosity Controller in ME Fuel Oil System.

At ITUMF, until now, ERS was used as a laboratory tool in Automatic Control Systems and Marine Diesel Engines Courses. For example, learning to familiarize with controllers in engine room systems and fine tuning of PID controllers is possible with the utilization of ERS as a laboratory tool. Figure 1 shows a viscosity control system in ITUMF ERS. On the other hand, authors of this paper believe that utilization of ERS in the above mentioned courses make students grasp of subject easier and also the cumbersome number of credit hours of ITUMF engineering courses, which is a total of 3192 hours of Undergraduate Engine program of ITUMF due to the IMO and Turkish Higher Education requirements (Sag and Cicek, 2000), may noticeably be decreased.

4.2. ERS as a Training Tool:

In ERS training courses, aim is to develop knowledge and skills of students on the regular operation, watchkeeping, and malfunction detection of engine room machinery and systems. On successful completion of this course, marine engineering candidates should be able to:

- Handle comfortably the *start-up procedures* of the individual engine room machinery and associated systems.
- Learn and practice the *regular watch keeping operations* in the engine room.
- Do practices to obtain skills for detecting *malfunctions for troubleshooting* to manage the possible breakdowns - bringing the engine room systems from abnormal condition to normal one.
- Develop *higher level skills* such as *risk management*, *team working* understanding in the engine room, and improvement of *internal and external communication skills* in the engine room.

The first three qualifications are mainly to meet STCW95 convention requirements. The last two of the above qualifications are more advanced training which was called Type B training (Nakazawa et al., 2001). Nakazawa et al. (2001) describe the Type B Training criteria as training for recovering the abnormal condition to normal one based on the knowledge and experience. For this purpose, training in ERS for recovering process repeatedly, for controlling the panic, is needed. To achieve completion of these qualifications, three new ERS based courses were proposed and described in Table 4.1. An effective utilization of these ERS-based courses in a 4-year marine engineering undergraduate program is shown in Table 3.

Table 2. Proposed ERS Courses.

Proposed ERS Courses	Lect.	Ex.	Total (Cr.)	Total (Hrs.)
ERS Course Operation Level (5th Sem.)	1	3	4	56
ERS Course Management Level (7th Sem.)	0.5	2.5	3	42
ERS Course Advanced Skills (8th Sem.) (Team Manag. Comm Skills. Risk Manag.)	0.5	2.5	3	42

Table 3. Proposed Utilization of ERS-based Courses in Marine Engineering Programs.

<table>
<tr><th></th><th>Fall (1st) Semester</th><th>Spring (2nd) Semester</th><th>Summer</th></tr>
<tr><td>1st Year</td><td>Intr. Marine Engineering Courses</td><td>Intr. Marine Engineering Courses
(ERS as lab tool (C, B): Int. to Marine Engines)</td><td rowspan="2">Training Ship
+
ERS (P, B)
(2 months)</td></tr>
<tr><td>2nd Year</td><td>Marine Engineering Courses
(ERS as lab. Tool (C, P): Marine Electrical Systems)</td><td>Marine Engineering Courses
(ERS as lab. Tool (C, P): Marine Diesel Engines, Aux. Marine Eng. I.)</td></tr>
<tr><td>3rd Year</td><td>Marine Engineering Courses
(ERS as Lab. Tool (C, P): Automatic Control Systems)
+
(ERS Course (P, F): Operation Level)</td><td colspan="2">In Service Training
(Merchant Ship)
(min. 4 months)</td></tr>
<tr><td>4th Year</td><td>Marine Engineering Courses
(ERS as Lab. Tool (P, S): Aux. Mar. Eng. II)
+
(ERS Course (P, F, S): Management Level)</td><td>Marine Engineering Courses
(ERS as Lab. Tool: Refrigeration & HVAC Systems)
+
ERS Course (F)
(Advanced Skills)</td><td>Graduation</td></tr>
</table>

B: Basic Type ERS, **C**: CBT, **P**: PC or Workstation Type ERS, **F**: Full mission ERS, **S**: Specialized ERS.

The major roles of engine officers onboard ship are mainly operation and management. Therefore, firstly, the training should focus into these two types of training. Table 4 shows the contents of ERS Courses proposed. Notice that these contents may construct a baseline for a future study among members of IAMU and may dynamically be changed based on the type and availability of the ERS. The contents of the courses described in the first two columns were selected to comply with STCW Code, Table A-III/1 and Table A-III/2 respectively. The topics in the third column, which is ERS Course Advanced Skills: Team Management, Communication Skills, and Risk Management, are for higher-level education of students. The concept explanation of each of these courses is made in the following sub-sections.

Table 4. Contents of Proposed ERS Courses.

ERS Course Operation Level (5th Semester) (Type A Training)	ERS Course Management Level (7th Semester) (Type A + Type B Training)	ERS Course Advanced Skills Team Management, Communication, Risk Management (8th Semester) (Type B Training)
- Familiarize with the Engine Room - Start and Shut down individual engine room machinery and associated systems. - Observation of response parameters - Prep. Main Engine - Manoeuvring - regular watch keeping operations - Operate, evaluate and monitor engine and system performance.	- Plan and schedule the operations-Operate, evaluate and monitor engine performance. - Do practices to obtain skills for detecting malfunctions for troubleshooting to manage the possible problems for bringing the engine room systems from abnormal condition to normal one (scenarios — Type B Training). - Manage fuel and ballast operation - Utilize resources, equipment, and information effectively.	- Develop higher level skills such as; - risk management, - team working understanding in the engine room and leadership practices - Internal and external communication skills development in the engine room. - Scenarios for simulating situation where management of panic condition is needed at most. Emergency procedures. - Case studies to reflect the real situation where team management is evaluated. - Utilize recourses and personnel effectively.

4.2.1. ERS Course Operational Level (5th Semester):
Operational level of STCW95 training is aimed in this course. This course is particularly important to be offered in 5th semester since students must do in-service training during 6th semester. Mainly workstations were used in this training. When students come to a certain level, students practice the regular watchkeeping and observation of readings. Traditional checklists are used in this training. The checklists are formed with a plain technical English. In later part of this course, utilizing ERS, students practice startup of individual systems, maneuvering, filling the logbook, watchkeeping, and observation of parameters. Notice that the operation level based ERS course is completed before the long-term training.

4.2.2. ERS Course Management Level (7th Semester):
Management level of STCW95 training is aimed in this course. Having this course studied in 7th semester after the long-term training, students will have the opportunity of having training on the development of troubleshooting skills, evaluation of system performance, management of ballast operations, etc. Type B training explained in previous section is focus in this course (Nakazawa *et al*, 2001).

4.2.3. ERS Course Advanced Skills (8th Semester):
Risk Management: The engine room is designed so that, even if the initiating even is an operating error, serious risks may not occur as long as the safety system is working properly. However, if operation errors and troubles with the safety mechanisms occur simultaneously, a great number of risks are estimated to occur in the engine room system (Nakamura, *et al.*, 1999). There may be an argument that a marine engineer does not always need theoretical knowledge if he has adequate experience. However, if he/she meets an incident for the first time and which he/she has inadequate knowledge about, he/she may fall into panic easily. Human factors become an issue in these cases (Nakazawa, 2000). The United States National Transportation Safety Board and several international organizations site that statistically %70-%80 of all investigated commercial marine accidents are due to human errors[3]. To reduce the human errors, training for troubleshooting repeatedly with a good communication and team working is needed

[3] National Transportation Safety Board Report, Washington D.C., PB98-916401, NTSB/MAR-98/01.

and therefore, utilization of ERS for this purpose is proposed. For this purpose, this part of the course is about to increase the ability of student s over the control of risk. The training for having the knowledge and experience of what situations creates and leads to make human errors may create qualifications to control panic, stress, and fatigue and to focus on what to do correctly under these difficult circumstances. This case is currently under investigation at ITUMF and the details were explained in Section 5 of this paper.

Communications Skills: In order to benefit from the advantageous fully, the simulators are started being also used for Maritime English education & training of students (Bas *et al.*, 2002). Although most of the chief engineers and engineering officers are not the native speakers on a worldwide basis, they are trying to carry out the most of their engineering activities in English. Although Standard Communication Phrases (SMCP) is in force, there is no any clear identification for the marine engineering terminology yet. IMO Model Course 3.17 Maritime English defines only the basic engine room preparations and the planning of activities in cooperation with the deck department. However, communication in the engine room is so important in terms of eradicating of marine accidents which are considered to be based on communication failures. In this respect, it is authors wish to have a study on the standardization of internal and external engine room communications and use ERS for this purpose as well. One part of this study is using a standard technical English during lectures. For example, experience has shown that the application of the checklist concept in engine room training and operation are found to be very useful. (Kluj, 1999).

Engine Room Team Management (ERTM): Team working understanding in the engine room and practices. Knowing the fact that human communication is not only through a language, teamwork scenarios are also being prepared to train students for both internal and external communications and for English improvements. The development of standard communication phrases should be studied by related colleagues of IAMU for the engine room training and education of students with navigation and maneuvering scenarios.

The examination and assessment methods for these courses are presented in Table 5. The student however must be present for the entire course and participated in all of the exercises and activities.

Table 5. ERS Examination and Assessment Methods of ERS Courses.

ERS Course Operation Level (5th Semester)	ERS Course Management Level (7th Semester)	ERS Course Advanced Skills Team Management, Communication, Risk Management (8th Semester)
- Duration of study using Workstations, following the Checklists - Startup procedures in workstations, - Operation in the Full-Mission ERS - Short Exams from Checklists - Instructors Oral Ex. (and/or instructor s opinion)	- Exams for Troubleshooting using the Full mission ERS - Homework Projects and Exams for the Evaluation of Engine Performance and Associated Systems	-Oral Exams, -Performance evaluation with team in F Type ERS

5. Research Studies at ITUMF Using ERS

Some research studies were also started along with education and training using Engine Room Simulator. Uchida *et. al.* (2002) performed experiments on the feasibility of research on safety management using the ERS. For this purpose, experiments in ERS on human behavior were carried out. For performing these experiments, besides of ERS, an Eye Mark Recorder (EMR) was used. The EMR can detect the movement of examinee s viewpoint and record viewpoint coordinate data on PC and/or VTR continuously together with viewing images. EMR system is compounded from head cap unit, controller, PC and VTR as shown in Figure 2. Examinee puts the head cap unit on during a measurement, so that examinee can move his head freely. If examinee carries portable battery, controller and portable VTR stored in a knapsack on his back, there are no restrictions of his movement. ERS scenario was made as a typical case of watch keeping at an engine control console that is change over the control responsibility from bridge to ECC, stand by engine and half slow down. The flowchart of this scenario is shown in Fig. 3. It takes about 10 minutes from the experiment beginning to the end.

The contribution to the improvement of maritime safety has been set to an ultimate target and the measurement of one of human behavior that is eye movement in ERS has been carried in this research. It is expected that one can approach to the goal by execution of following processes based on the obtained results.

- Individual teaching based on grasp of personal characteristics

- Use a replay of various example of typical case as education and training material
- Conduct of measures beforehand by grasp of potential dangerous factors of miss-operation and oversight of profitable information, etc.

Experimental results obtained from the research study in ERS until now are summarized as follows:
- One of human behavior, eye movement, was measured during watch keeping in ERS by using EMR.
- There are definite differences in the human behavior between skilled engineers and beginners even under the quite simple scenario.

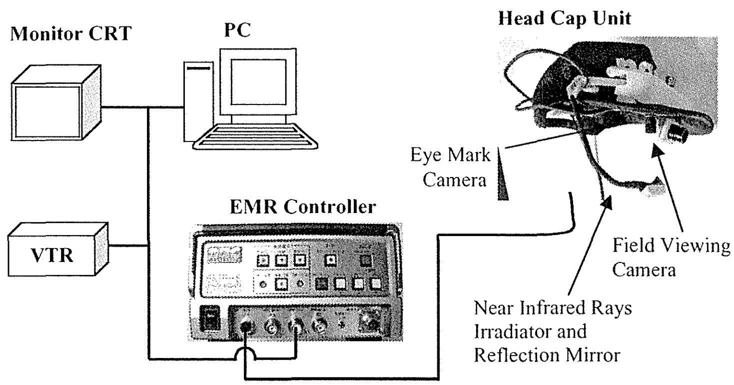

Figure 2. General arrangement of EMR

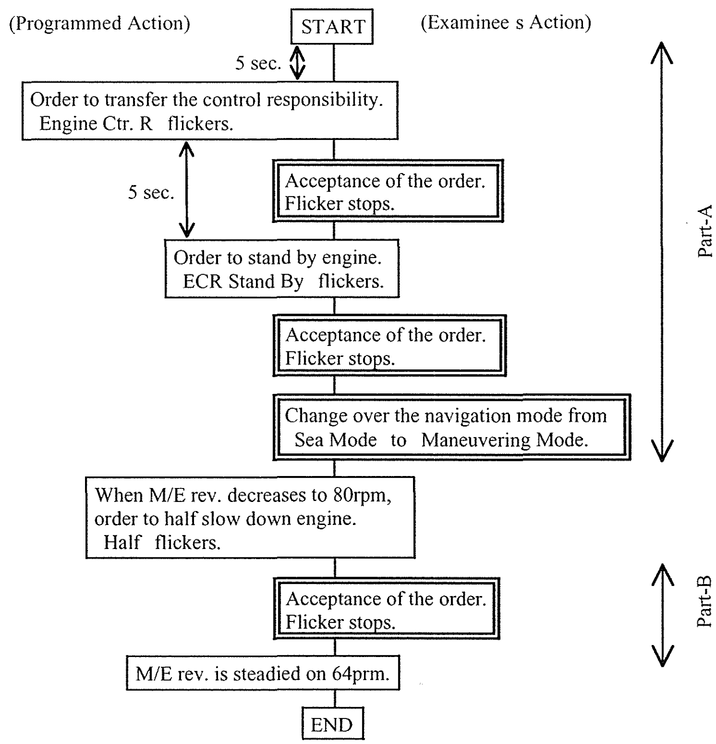

Figure 3. Flowchart of ERS experimental scenario

The following items are the subjects for a future study utilizing ERS at ITUMF:
- Data accumulation and the examinations of data processing

- Development of experimental scenario for more complex operations
- Development of experimental scenario for malfunction managements
- Concrete proposal for maritime safety

6. Conclusions

Based on the results of the previous sections, it is concluded that ERS training could be used to give marine engineering candidates higher-level qualifications discussed. For example, the use of ERS for team-management and for communication skills could very efficiently be arranged because of the opportunity of preparing the scenarios based on the type of the training and education. Through this type of training, marine engineer candidates can easily learn the safety culture, how to manage the risk and the aspect of the human error. Simultaneously, the behaviors of the trainees during this type of training recorded on ERS will provide the academic staff of the department of marine engineering with opportunities to develop research topics in order to prevent mistakes by human errors. The concrete findings and outcomes of the research currently under investigation will be presented at later stages.

ERSs could be used both as a laboratory tool for fundamental marine engineering courses and as a training tool based on operation and management level training, and fro advanced skills. In this paper, an example of utilization of ERS in a marine engineering program is presented. It is authors wish that the presentation of this paper initiates a study among Marine Engineering Departments of IAMU member universities for the establishment of a standard but flexible and dynamic four-year marine engineering program.

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