Diesel Simulator Training in the Marine Engineering Technology Curriculum

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Abstract

Diesel simulator training to Marine Engineering Technology students is critical to close the gap between theory and application. The instructor can utilize the simulators to provide high quality of training on auxiliary systems and overall running of the diesel propulsion power plant operation with the creation of multitude of interactive exercises. Diesel simulators also offers the feasibility of isolating or freezing various sub-systems to develop understanding and knowledge to students in situations that will demand complex decision making. The two different simulation environments that are available at California State University Maritime Academy include Full Mission and Part Task trainers. The Full Mission simulators consist of engine control room, emergency diesel generator room, instructor operating room, and engine room. The Part Task Trainers are individual computer workstations, running the same plant model as the Full Mission Simulator, to assess individual students' knowledge. The discussion of the paper will include the design of the simulators to provide training on casualty procedures, critical thinking, problem solving under stressful environments that are commonly encountered in real-world startup and shutdown procedures. The diesel simulator training is a path forward to build competence and provide students with relevant real-world experience to be effective engineers.

1. Introduction

Engineering licensed graduates of California State University Maritime Academy (CSUM), both Marine Engineering Technology (MET) students and Mechanical Engineering License Track (ME-L) students, enter the workplace with a United States Coast Guard, 3rd Assistant Engineer, Steam, Diesel, Gas Turbine, Unlimited Horsepower license. This credential allows them to sail on any vessel in the US shipping fleet as a 3rd assistant engineer. Currently, the US fleet has approximately 180 privately held self-propelled vessels over 1000 gross tons [1], and 56 ships in the National Defense Reserve Fleet [2]. These vessels are container ships, dry bulk carriers, general cargo ships, Ro-Ro's and vehicle carriers that range from 300'-1000' in length. This is not the full extent of vessels that the graduates are licensed to operate but represents vessels that have large propulsion plants similar to what the students are exposed to in the simulators at CSUM.

At CSUM, diesel simulator training has become an important teaching aid in the MET curriculum. Diesel simulator training is based on the concept of specific skill transfer that is required for a mariner. Diesel simulators tend to create a realistic environment that will allow students to experiment with multiple approaches to solve a wide variety of problems. Students can try different solutions and benefit from a safe environment and receive feedback from experienced instructors. To provide detailed feedback, the instructors may monitor student performance through a variety of technological capabilities, which are then used for briefing and debriefing of simulator exercises. The exercises introduced in the simulator facilities provide considerable amount of ingenuity for the engineers produced at CSUM.

The diesel simulator at CSUM is controlled by digital computer system that consists of marine propulsion plant models. The diesel simulator has adequate devices that are set up to simulate various operating conditions of ship power plants.

2. Diesel Plant Simulators

The diesel plant simulator in use is manufactured by Kongsberg Digital. This simulator system is capable of different types of propulsion plants, but CSUM is using the K-Sim MC90-V. This is a 188,000 dead weight ton tanker with a MAN B&W 5L90MC mechanically fuel-injected, five-cylinder main engine generating 23,000 HP. This engine, operating at a maximum of about 90 revolutions per minute, is considered a “slow-speed.” Power generation is from five different power sources including main diesel generators, steam turbine generator, shaft generator and an emergency diesel generator.

In the diesel simulator, the students are exposed to both “Part Task” (PT) and “Full Mission” (FM) environments. The PT is simply an individual computer workstation while the FM is a multi- station immersive environment. The simulator is set up with PT and FM adjacent to each other with the instructor station separating the two (Fig. *1*). There are two-way mirrors and cameras so that instructor can see both PT and FM at the same time. The FM and PT are operated simultaneously by one faculty member during a lab period.

Fig. 1. PTT with instructor station glass in background.

While the PT only has a single dual screen computer for operation of the engineering plant, the FM has multiple types of controls. There are four primary types of controls in the FM.

1. *Local Operating Stations (LOS)*: These are computer workstations that can be assigned to specific tasks (Fig. *2*). The five LOS may be configured differently depending on the evolution. They can be configured for monitoring only or monitoring and control.

Fig. 2. LOS in foreground, big view in background.

2. *Switchboards*: These are physical representations of the power control system on the ship. These are simply large circuit breaker panels for main power and emergency power (Fig. *3*).

Fig. 3. Student operating emergency switchboard.

3. *Control Consoles*: These are similar to LOS but are representative of what would be physically on a ship in an engine control room (ECR). The control room panel includes main

propulsion engine monitoring, main engine remote control, engine order telegraph, generator power management, pump management, and phones to different areas of the simulator (Fig. *4*).

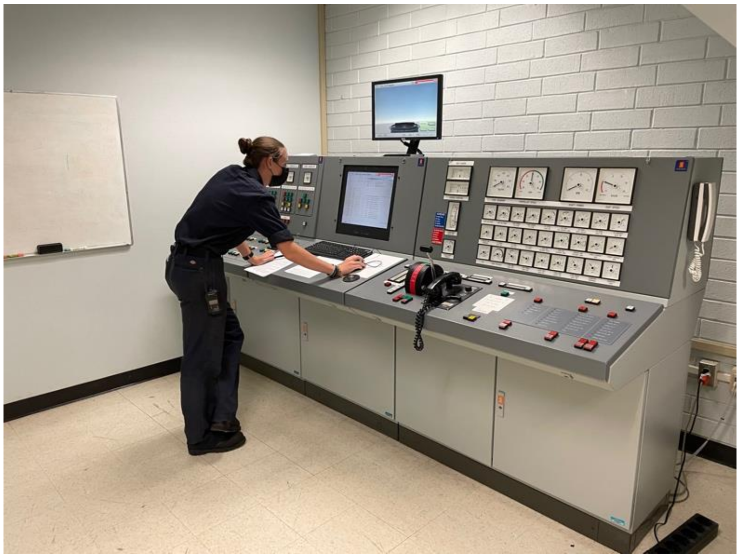


Fig. 4. Engine control room console.

4. *Big View (BV)*: There are four screens located in the engine room that display all piping systems in the engineering plant (Fig. *5*). The systems are intertwined to force students to trace out the systems as well as show interactions between systems. These are the primary controls while in FM. BV is not used in PT or online environments.

Fig. 5. Big view screens.

The FM is spread over two levels. The lower level is the main control room with remote engine controls, alarm monitoring/silencing, and main switchboard. The upper level is considered the engine room with five local operating stations, local engine control, big-view screens, and the emergency generator/switchboard. Ideally, the emergency generator/switchboard would be located in a different room, but there were physical constraints during the build process of the simulator. The steering gear controls and firefighting controls are located on the lower level but in the room with the PT computers.

3. Full Mission Simulator Design Considerations and Class Experience

Throughout the semester, students are presented five different simulation evolutions. These evolutions represent the various tasks it takes to prepare ship's machinery to get underway starting at a "Dark Ship" condition, defined by no stored energy, no operating power generation, no shore power, and the primary fuel is not hot. The final evolution of the semester involves taking "Departure," which is a condition that is met when the ship is underway, clear of all obstructions, concluded with maneuvering, and will be speeding up to full sea speed.

This class is broken into a weekly one-hour lecture and a two-hour lab. The lecture section is used to expand on knowledge of systems encountered in the lab as well as to provide a briefing on the next upcoming evolution in the lab.

Each lab section consists of eight students and one instructor. Four students will be utilizing FM, and four will be utilizing PT simultaneously. While students are in PT, preprogrammed prompts, known as "E-Coach" in the Kongsberg system, are used to guide students through the evolution. E-Coach allows the instructor to dedicate more attention to the FM evolution. E-Coach can be applied to FM as well, but it has been found that the instructor serving as the "coach" of the evolution is far more effective.

Two primary factors determine the number of students that can work in FM at one time. The first contributing factor to number of students that can be accommodated in FM is the number of controls that can be manipulated at one time and the number of operating stations. With a low number of available control stations, students tend to collect around one screen and evaluation of individual performance will be difficult. Evaluation of communication between students will also become impossible. Secondly, physical size of the simulator factors into the number of students that can be accommodated. At CSUM, the simulator that can accommodate six people has a two-level engine room, separate control room, and separate emergency diesel generator room. The simulator that can accommodate three people in one level, has one control station for the engine room, separate emergency diesel generator room, and all the three rooms are adjacent to each other.

The size of the simulator is critical because it ensures that students distribute work, work collaboratively, and communicate well. An actual engine room on a ship may span over five stories, well over 100 feet long, and over 70 feet wide. While we cannot duplicate something of this magnitude, we can train students in different physical locations by design of the evolution, prevent them from speaking directly to each other, and preventing them from seeing what each other is doing for all individual assessments. As an example, the student in charge of the FM evolution plays a role of "1st assistant engineer" (1AE). The other students play a role of "3rd assistant engineers" (3AE). The 1AE is responsible for ensuring that all aspects of the evolution are conducted safely, while the 3AE students are responsible for the operation of the plant. The 1AE is positioned in the engine control room (ECR), and the ECR must be manned continuously. The ECR LOS has the capability of viewing valve and machinery status but does not have the capability of operating valves and can only operate machinery that has been placed in remote control from the engine room. If the 1AE would like to enter the engine room, a 3AE must be pulled from their task and relocated to the ECR prior to the 1AE leaving ECR. The primary means of communication of the team is via radios. Alternately, phone systems are available.

Another feature of the simulator that helps maintain separation of the students while still in close proximity is the sound. Engine noises are duplicated via a sound system located throughout the simulator; alarm horns are actual engine room alarms. Maintaining relatively high engine room sound pressure level (SPL) prevents the 1AE from overhearing conversations in the engine room and forces all students to wear hearing protection while working in the engine room. While a typical engine room SPL of 104dB [3] is not employed, the simulator engine room is loud enough to provide a realistic communication challenge and sound stressors. The alarm horn, when activated, is loud enough that all conversations in the engine room must stop. To make it realistic, the only place that can silence the alarm is located in the ECR. This may lead to confusion or breakdowns in communication if the 1AE or engineer in the ECR is not managing alarms properly.

This class is predominately focused on changing the status of the machinery to get to a new condition that is closer to underway status. The simulator at CSUM has capabilities to cause predetermined engineering casualties, but given the time allotted to the class, we generally do not fail equipment on students. This is not to say that the students are not conducting casualty response; the students are usually the ones to cause the casualty when they are not operating equipment correctly. A prime example of this is in the first training evolution, they are tasked with placing a Ship's Service Diesel Generator (SSDG) online. Prior to placing the SSDG online, the Emergency Diesel Generator (EDG) must be placed in service to prepare the systems to support the SSDG. Ship's power is then transferred from the EDG to the SSDG, but a blackout occurs in the process resulting in all cooling pumps shutting down. The students have about 30 seconds to restart all the cooling pumps before "over-temperature" alarms start to ring, strobe lights activate, the generator shuts down, the lights go out, and they have to start over. Unfortunately, the students have just created more work for themselves, but fortunately they have made the mistakes in an environment where no damage has occurred.

4. Student Assessment

Students are assessed multiple ways while in PT and FM. In either case, students are assessed by the Kongsberg system automatically. They are evaluated by "Progress" and "Penalties" action lists that are pre-programmed by faculty. The progress assessment starts at 0% at the beginning of the evolution. As students' complete tasks, their grade increases until they have completed all assigned tasks.

Fig. *6* shows a student's performance mid exercise during a testing evolution. While all of the assessments add up to 100%, there are certain critical items that must be completed to pass. These items are notated with the green check marks. Even with a passing grade, if these certain items are not accomplished, the student will not pass the exercise. An example from this exercise is fully preparing an SSDG prior to starting.

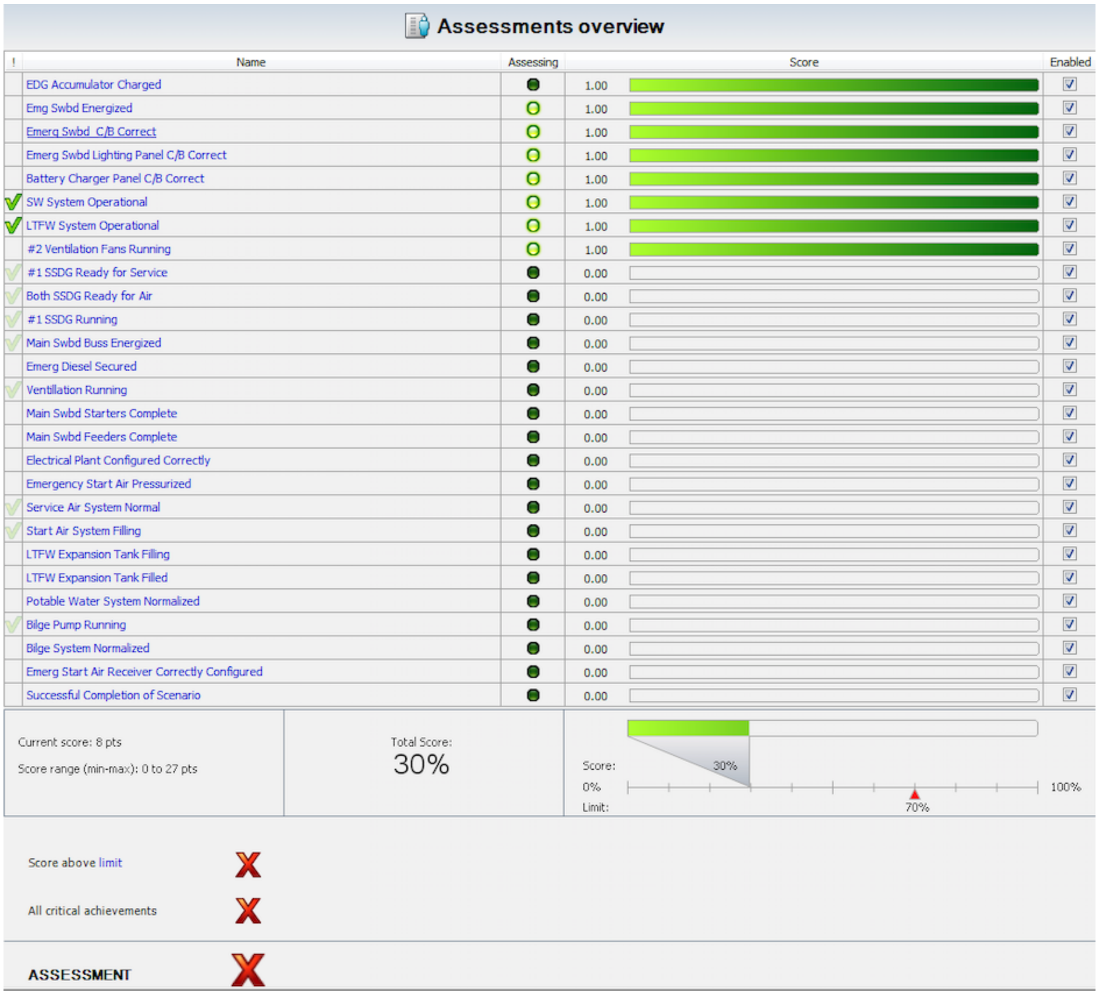


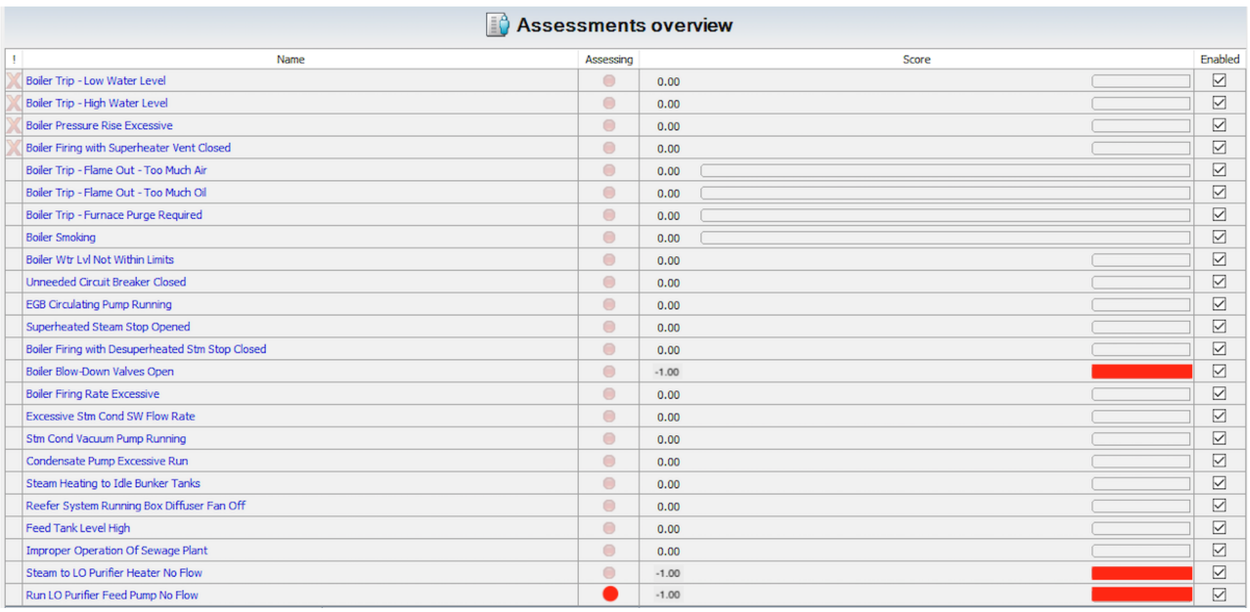
Fig. 6. Kongsberg Neptune instructor summary page for "Progress" in Lesson 1.

The penalty assessment starts at 100% and is reduced as mistakes are made. The penalties have been incrementally developed over years of assessment. When trends are found in mistakes made by students, additional penalties are added to the assessment. However, without fail, students can make mistakes that are not programmed as penalties in the system. These mistakes may not be caught in the PT assessment because there is no direct supervision during testing, but these are caught in FM. Fig. *7* is a penalty report given to a student who had completed an exercise focusing on '*lighting a boiler and raising steam pressure*'. From this report the instructor will be able to determine if a mistake was made and if it has been corrected. The "Assessing" column indicates if the mistake is active and the "Score" column indicates if a mistake is made at some point during the exercise. The program can be configured to track how many times a mistake is made if that type of tracking is desired. In the case of the example provided, we can see that the student made three mistakes.

1. Boiler blow-down valves were opened at some point, likely an incorrect valve was opened accidentally, or the boiler was overfilled prior to operation and the student corrected the mistake by draining water. The mistake has been corrected.

2. Steam was applied to a lube oil heater prior to oil flow.
3. The lube oil pump is currently not pumping oil due to a closed outlet valve.

While none of these mistakes will immediately cause damage or danger to life, there are actions that need to be corrected and discussed in post-action review. This student still received a 93% on this part of the exercise. Similar to the progress report, there are critical items in the penalty report. If students trigger any of these penalties, they will fail the assessment. These penalties are based on gross negligence, actions that could cause equipment damage or actions that could cause harm to people (if such a mistake is performed in an actual engine room). Examples in this lesson are boiler high and low water trips, heating the boiler at an excessive rate, or running the boiler without the superheater vent open.



Assessments overview

!	Name	Assessing	Score	Enabled
	Boiler Trip - Low Water Level		0.00	
	Boiler Trip - High Water Level		0.00	
	Boiler Pressure Rise Excessive		0.00	
	Boiler Firing with Superheater Vent Closed		0.00	
	Boiler Trip - Flame Out - Too Much Air		0.00	
	Boiler Trip - Flame Out - Too Much Oil		0.00	
	Boiler Trip - Furnace Purge Required		0.00	
	Boiler Smoking		0.00	
	Boiler Wtr Lvl Not Within Limits		0.00	
	Unneeded Circuit Breaker Closed		0.00	
	EGB Circulating Pump Running		0.00	
	Superheated Steam Stop Opened		0.00	
	Boiler Firing with Desuperheated Stm Stop Closed		0.00	
	Boiler Blow-Down Valves Open		-1.00	
	Boiler Firing Rate Excessive		0.00	
	Excessive Stm Cond SW Flow Rate		0.00	
	Stm Cond Vacuum Pump Running		0.00	
	Condensate Pump Excessive Run		0.00	
	Steam Heating to Idle Bunker Tanks		0.00	
	Reefer System Running Box Diffuser Fan Off		0.00	
	Feed Tank Level High		0.00	
	Improper Operation Of Sewage Plant		0.00	
	Steam to LO Purifier Heater No Flow		-1.00	
	Run LO Purifier Feed Pump No Flow		-1.00	

Fig. 7. Kongsberg Neptune instructor summary page for “Penalty” in Lesson 2, given to student.

While in FM there are criteria that are in addition to the “Progress” and “Penalties” assessed by the Kongsberg system. Students are rated on a scale of 0-4 in each of the categories as shown in Fig. *8*. This scoring rubric is blended with the Kongsberg assessment to create a grade for FM evolution. At the end of a FM exercise, the team will review their performance with the faculty member. The students have access to the Kongsberg reports and the team collectively discuss the scores of the evaluation criteria.

Watch Management/Situational Awareness Evaluation Criteria – 1AE	
Leadership	• 1AE clearly in charge of operations • 1AE makes all important decisions • Remain calm during difficult situations • 1AE clearly defines objectives for team members • 1AE Does not micro-manage • Team members follow instructions
Situational Awareness	• Clear knowledge of all ongoing operations • Mentally tracks progress of all team members • Understanding of engineering systems is sufficient to cope with casualties
Communications	• Communication between control room and engine room accomplished using sound powered phones or radios • Directions to team members is concise, easily understood, and pertinent • Uses proper procedures & terminology to communicate with team members

Plant Operations/Engineering Knowledge – 1AE	
Plant Operations	• Clearly understands the sequence of events required to successfully complete scenario • The ability to prioritize during emergencies • Has sufficient knowledge of plant systems to direct team members when plant casualties occur
Engineering Knowledge	• Understands machinery procedures for normal & emergency situations • Comprehends how each system interrelates with other systems

Plant Operations/Engineering Knowledge – 3AE	
Engineering Knowledge	• Understands instructions when assigned plant operation tasks from 1A/E • Team member able to carry-out duties assigned by 1A/E without supervision

Team Preparedness Evaluation Criteria – All Engineers	
Team Preparation	• Students have prepared for each scenario with fellow team members • Each student enters Full Mission with an understanding of both their own duties and also those of their team members
Individual Preparation	• Each team member successfully completes the PTT evaluation. If any team member fails to pass the scenario, the instructor will assume that the team as a whole has failed in its responsibility to help that individual prepare.

Fig. 8. FM evaluation criteria.

5. Conclusions

In this paper, the authors have presented how PT and FM diesel plant simulators are integrated into the Marine Engineering Technology curriculum at California State University Maritime Academy. The sample evolutions that are discussed in this paper as a part of simulator training demonstrates that students learn by performing the activities in a context that is similar to that in the real world. The training provides an opportunity for a student to build a mental model of a real-world scenario and correct mistakes in safety without fear of injury and damage to the equipment. In conjunction with the simulator training conducted at CSUM, students also understand the role of 1st assistant engineer and 3rd assistant engineer, which makes them better prepared for maritime industry. The assessment strategies that are embedded in simulators combined with in-house developed scoring rubrics will provide opportunities for students to discuss their performance as an individual and as a team.

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Biographies

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