Influence of Standards of Training, Certification and Watchkeeping (STCW) standards on Marine Engineering Technology Curriculum

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Abstract

Marine Engineering Technology (MET) and Mechanical Engineering License Track (ME-L) graduates at the California State University Maritime Academy (CSUM) are mandated to pass a United States Coast Guard (USCG) licensure exam to achieve a 3rd assistant engineering license in diesel, steam, and gas turbine, and earn a bachelor's degree. To qualify for the USCG 3rd Assistant Unlimited Engineer's license, the engineering programs must meet the international Standards of Training, Certification and Watchkeeping (STCW). The STCW standards ensure that graduates met the minimum standards of competence required for seagoing personnel. To obtain STCW compliant licenses and certificates, the graduates must meet knowledge, understanding and performance (KUP) based assessments and earn required sea service. The training that is offered to satisfy the STCW mandates bridges the gap between practical and academic knowledge, ensuring the cultivation of experiential learning. In this paper we look at various curricular activities conducted to address STCW requirements ranging from the freshman to the senior curriculum. These include but are not limited to an understanding of the basic construction and operating principles (BCOP) of automatic control systems, and BCOP of flash type evaporator water plants.

Introduction

California State University Maritime (CSUM), founded in 1929, is one of five state maritime academies in the country. The institution was founded for those unique and hearty individuals intending to work in the challenging and rewarding maritime profession, specifically aboard ocean-going vessels in either the deck department or engineering department. It was initially founded to teach the practical skills required aboard ship. Over the course of almost 100 years the curriculum at CSUM has evolved far beyond its initial blueprint of catering to the sea going profession. CSUM now includes many other fields and professions related but not limited to the maritime industry, such as mechanical engineering, facilities engineering technology, oceanography, business administration, and global studies and maritime affairs.

Preparing our cadets for the maritime profession, both practically and theoretically, continues to be a fundamental priority within our engineering curriculum. One of the primary advantages to attending CSUM over other institutions, besides obtaining an undergraduate degree in either marine engineering technology or mechanical engineering, is the procurement of a United States Coast Guard (USCG) third assistant engineers unlimited license for diesel, steam, and gas turbine propelled vessels. This is a legal requirement to be a member of the engine room department aboard a modern maritime vessel. The acquisition of this entry level officer's license, referred to as a "3rd's license" qualifies the grantee for employment aboard a maritime vessel propelled by either diesel engines, steam propulsion, or gas turbines. The vessel types and/or cargo can vary between a modern container ship transporting over 24,000 containers, a very large crude carrier (VLCC) transporting over 2 million barrels of crude oil, a tugboat, research vessel, cruise ship, or just about anything in between. Essentially any vessel employed in the commercial transport of cargo or passengers will require licensed officers aboard.

The engineering licensing curriculum at CSUM is designed to cultivate the necessary tools both theoretically and practically to design, install, operate, maintain, and troubleshoot a wide range of equipment aboard ship, which is essentially a small floating city. At CSUM we cultivate a comprehensive and expansive skillset inclusive of mechanical, pneumatic, hydraulic, and electrical systems to advanced concepts involving electrical engineering, fluid mechanics, thermodynamics, physics, automation, and engineering mechanics. Our curriculum prepares our graduates to operate and maintain a vast array of systems and auxiliaries including electrical generation, potable water generation, sewage treatment, food preparation and storage, and even propulsion systems capable of propelling a vessel at speeds of up to 50 knots. A marine engineers' inherently isolated work environment aboard ship, means they must not only be capable, but experienced in their multifaceted profession. Our graduates must have the experience and capacity to address operational issues that may arise during sailing, with no assistance from the outside world, as the nearest point of dry land or any external assistance could easily be over 1000 nautical miles away while transiting oceans.

Standards of Training, Certification, and Watch Standing

In addition to meeting accreditation standards set forth by ABET, we are also audited and certified by the USCG to ensure our engineering curriculum meets the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) requirements. Initially introduced in 1978 at the International Maritime Organization (IMO) conference held in London and amended in 1995 and 2010, STCW requirements were established by the IMO a specialized agency of the United Nations (UN) to ensure minimum international training standards for all officers and watch-going personnel on large yachts and merchant ships. Previously, all minimum training standards for sea-going personal including officer (licensed) ratings and non-licensed ratings, such as able body (AB) seaman and qualified members of the engineering department (QMED), were established by individual governments, often without any standardization or communication between countries. This often resulted in wildly different standards, competencies, and safety mindset among mariners. The STCW convention was implemented to prescribe minimum standards aimed at globally improving mariner competence to reduce accidents.

Our curriculum must meet all STCW mandates as set forth by the IMO, including meeting the minimum required standards of competency, which generally requires a minimum number of days at sea, known as "sea time," while also having their engineering knowledge, understanding, and proficiency (KUPs) assessed before they can apply for a third assistant engineers officers license. KUPs are assessments that are either practical or knowledge based. A practical KUP assessment requires that a candidate physically demonstrate proficiency in a particular application or assessment, while a knowledge-based KUP requires a candidate to have a prescribed level of knowledge. A knowledge based KUP assessment can generally be completed by completing a USCG administered examination and/or by completion of USCG approved training. Our curriculum has a very extensive list of assessments, in excess of 200, administered by the USCG that faculty must witness. The assessments must have a performance condition, a performance behavior, and a performance standard that will enable the cadet to show competence, knowledge, understanding, and proficiency.

In addition to the required STCW assessments there is a sea service requirement to assist in bridging the gap between practical and academic knowledge, which builds experiential knowledge for all our graduates pursuing a USCG license. The graduate must have served a cumulative 360 days of sea service. Of the 360 days, a minimum of 180 days of the sea service requirement is met by requiring our cadets to take three 60–65-day sea training courses aboard a combination of our 500-foot diesel training ship, the Golden Bear (Sea Training I and III), and a "Commercial Cruise," aboard a commercial sea-going vessel (Sea Training II). The second half of the sea service requirement is met over the cadet's four-year tenure at CSUM by an aggregate of standing regular engineering "watches" aboard our training ship's fully functional engine room and time accrued in USCG approved courses.

Integration of Assessments into Curriculum

To ensure that our engineering graduates meet STCW compliance to obtain a USCG engineers license they must meet all the STCW KUP based assessments and earn the required sea service aboard ship. The training we have integrated into our curriculum to ensure STCW compliance bridges the gap between practical and theoretical knowledge by integrating them together with the STCW KUP based assessments leading to experiential knowledge based on fundamental and advanced academic concepts. To demonstrate how STCW requirements have impacted our curriculum, two of many curricular activities, ranging from the freshman to the senior curriculum, conducted to address STCW requirements and their assessments will be discussed in the current paper These include, but are not limited to, an understanding of automatic control systems and flash type distillation water plants.

Automatic Control Systems and Curriculum Integration

Students at Cal Maritime undergo extensive electrical training in order to successfully meet curricular objectives, meet USCG requirements and become successful and safe engineers aboard ships. During the Sea Training III course, which takes place between junior and senior year onboard the TSGB, the students must meet a competency that requires them to understand the basic construction and operating principles (BCOP) of automatic control systems. Automatic control systems are highly utilized in the shipboard environment. Simple systems may consist of engine cooling water temperature controls. More complex systems may include speed control of main diesel engines and the most complex may include entire engine room/vessel distributed control systems.

In order to achieve this competency, the students must undergo other classes both onboard TSGB and on campus, which will include completing other competencies. During Sea Training I on the

TSGB, the students experience their first electrical course. They are required to show a basic knowledge of electrical equipment, such as generators, breakers, batteries, controllers as well as basic electrical concepts such as voltage, current, frequency, and measurement. They are required to understand a basic level automatic controller that will automatically restore emergency power to a ship after a main power failure. This knowledge is assessed via written tests.

In the time between Sea Training I and Sea Training III, Engineering Technology students will take a circuits class and an electronics class. Mechanical engineering students will take a circuits/electronics class, automatic feedback controls, and instrumentation and measurement systems.

To teach and assess the understanding of automatic control systems, a PLC lab was developed (Fig. *1*) that requires students to program a PLC for various control requirements such as on/off control, proportional control, and proportional plus integral control. This lab is based off an IDEC PLC that was chosen due to the ease of programming. Ease of use was a major concern; while this training occurs the students do not have internet availability. The students must work through the solutions without the aid of Google, YouTube, GitHub, etc. The primary resource for the lab is the help file that is provided with the computer-based PLC programming software. Students are allowed to work collaboratively to an extent but must demonstrate their own competency with the lab.

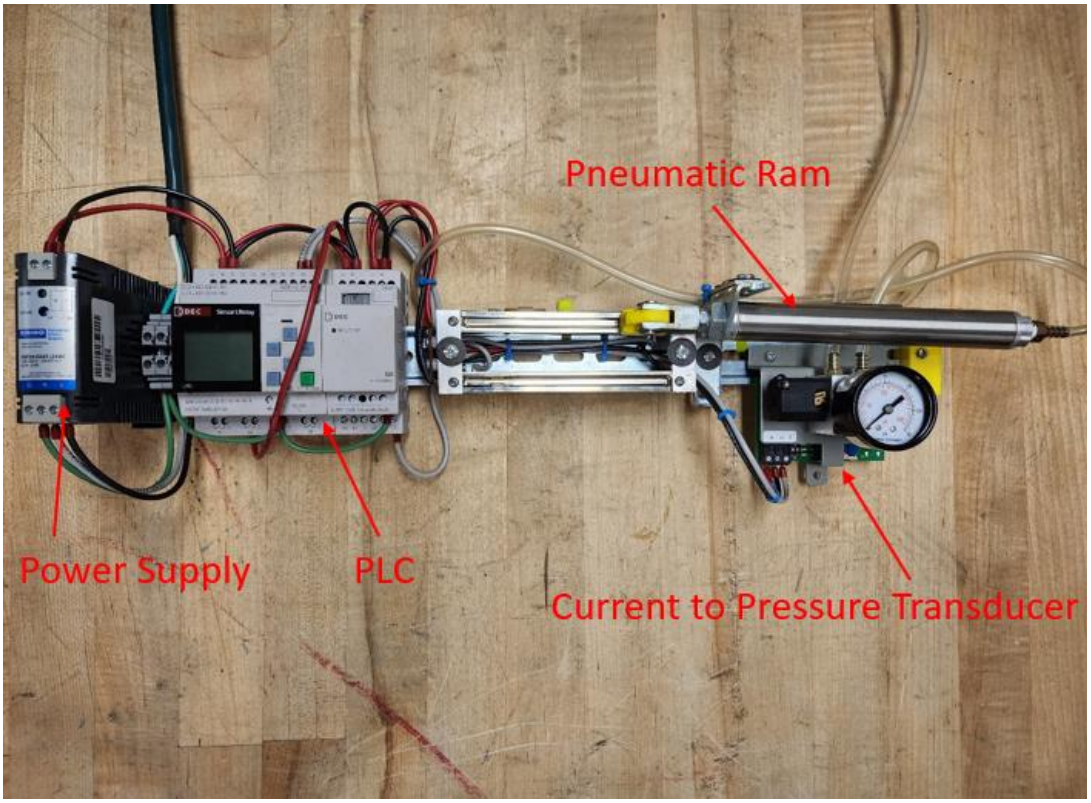

Fig. 1. PLC Trainer consisting of a power supply, PLC, and pneumatic ram.

The hardware consists of a PLC, a 4-20mA output PLC output card, a current to pressure transducer, a pneumatic ram, external normally open buttons (not shown) and two linear potentiometers. One of the potentiometers is attached to the pneumatic ram to provide position feedback. This lab requires an understanding of 4-20mA control signals, transducers (I/P), 0-10V control signals, ethernet networking, and function block-based PLC programming. The goal is to control the pneumatic ram in several ways.

The students are directed through a series of increasingly more difficult lab assignments leading up to Proportional and Integral positioning control of the ram. The series of assignments consists of

- Assignment 1 - Configure network control of the PLC with a computer. This includes assigning IP addresses and verifying communication using standard network tools.
- Assignment 2 - Move the ram to full extension by pressing a button. The challenge associated with this task is that the input to the PLC is digital, while the output is analog.
- Assignment 3 - Latch the ram to full extension by pressing a button, then release the ram by pressing the same button.
- Assignment 4 - Extend the ram by 25% increments by pressing a button, then retract and repeat the sequence
- Assignment 5 - Extend the ram by 25% increments by moving a linear potentiometer into a range.
- Assignment 6 - Develop a graphical user interface (GUI) on the screen of the PLC.
- Assignment 7 - Using proportional and integral (PI) control, have the ram position match the position of a linear potentiometer.

Different strategies to solve similar problems have been observed. Usually, the variance in strategies is observed between our two licensed programs. The engineering technology students have a background in Arduino programming, while the mechanical engineers have more of a background in LabVIEW. One example is from Assignment 7, which is programming PI control of the ram. A mechanical engineer programmed a simple implementation of PI control using a PI Control block (Fig. *2*), which is included in the PLCs standard commands. Another is a novel design for PI control specifically avoiding the PI block (Fig. *3*) that was completed by an engineering technology student.

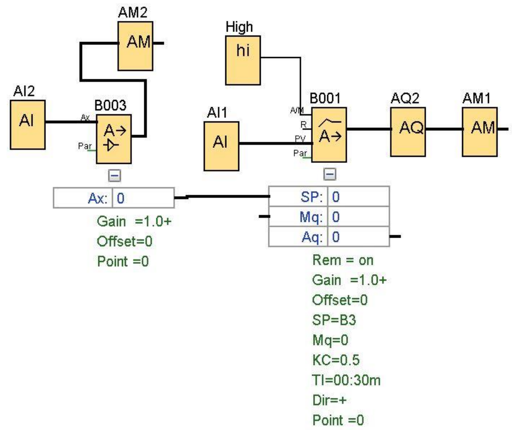

Fig. 2. Simple implementation of PI control.

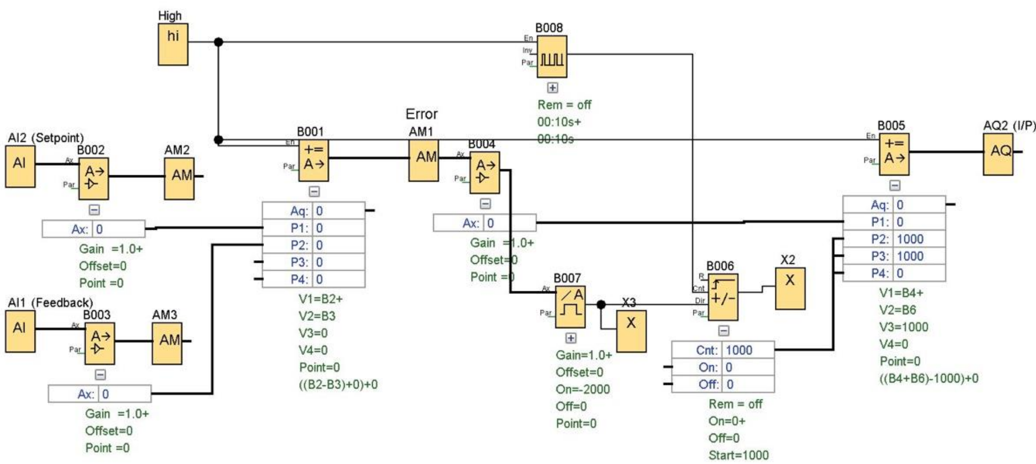

Fig. 3. PI control strategy.

Flash Type Evaporator Freshwater Generators and Curriculum Integration

Flash type evaporator plants are extremely common in the shipboard environment to produce fresh water with low TDS (total dissolved solids) from seawater. This is accomplished by heating seawater to near boiling point while under a vacuum causing the seawater to flash evaporate into steam. The steam is then condensed to obtain freshwater. The freshwater is used for potable and miscellaneous ship systems and their auxiliaries. These widely used and relatively simple systems can utilize waste heat collected from our main propulsion engines via the engine cooling water system, which is roughly 170 deg. F, or steam produced from our steam generators/boilers to heat seawater inside of a closed shell under a relatively high vacuum. This results in the separation of freshwater from the seawater through flash evaporation at well below boiling point of roughly 170 deg. F. This by product of the evaporation process leaves behind what is referred to as Brine, a concentrated combination of salts and miscellaneous minerals, which are disposed of overboard as effluent. The relatively salt free condensed freshwater is then retrieved from the shell and transferred to storage tanks aboard for later use. The evaporators aboard our training ship can produce a cumulative of 19,200 gallons per day of freshwater. The freshwater is utilized aboard for things like potable water, hotel use (galley service, showers, etc.), make up feed water to our boilers, and propulsion cooling water systems. Figures 4, 5, & 6 show the basic flash evaporator plant aboard the TSGB. The ability to operate comprehend, maintain, and troubleshoot this fundamental but necessary equipment as required by the STCW's, requires an aggregate of knowledge that must be amassed and introduced in progressively increasing levels of difficulty.

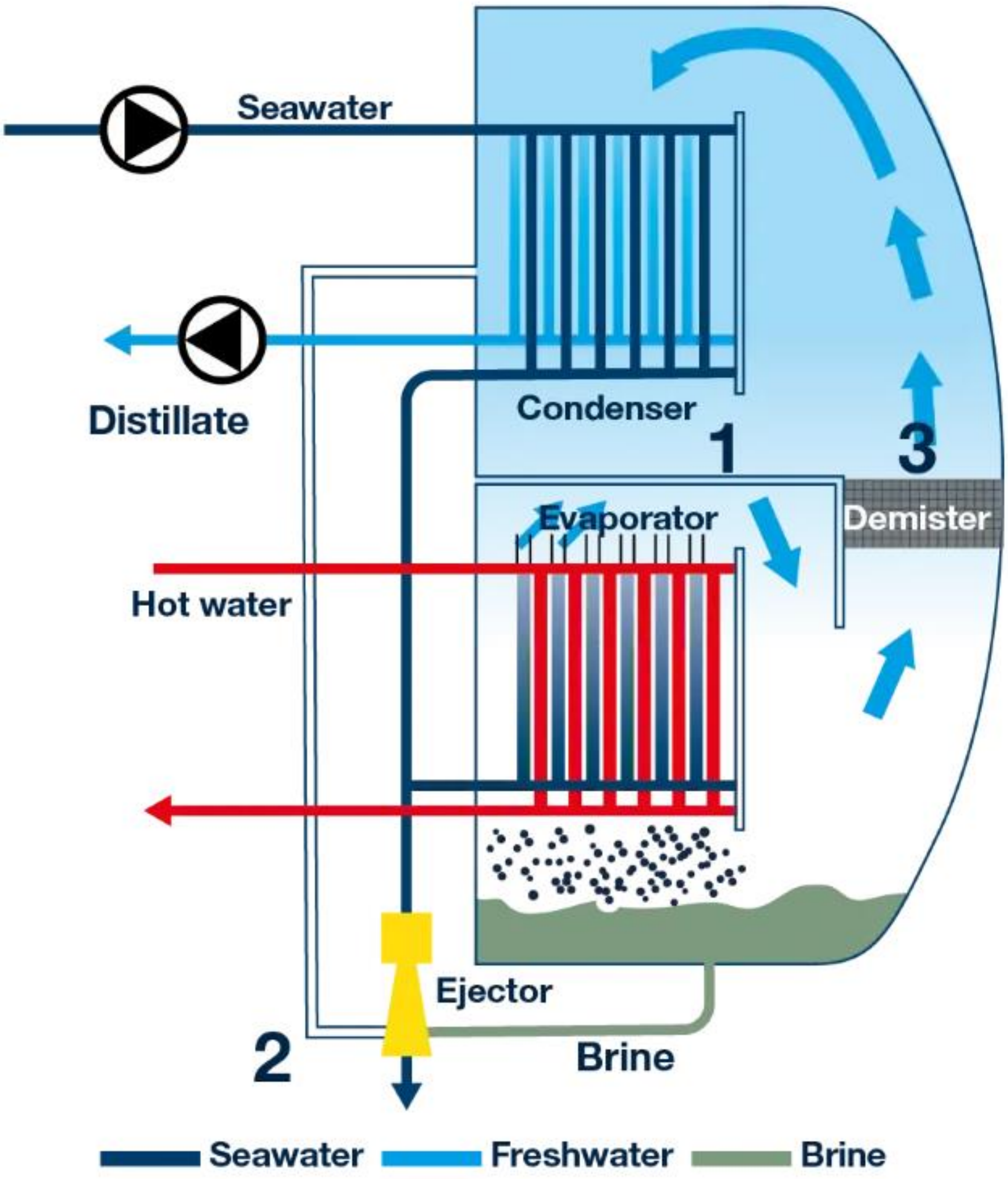

Fig. 4. Single stage fresh water flash type evaporator (courtesy of Wartsilla)

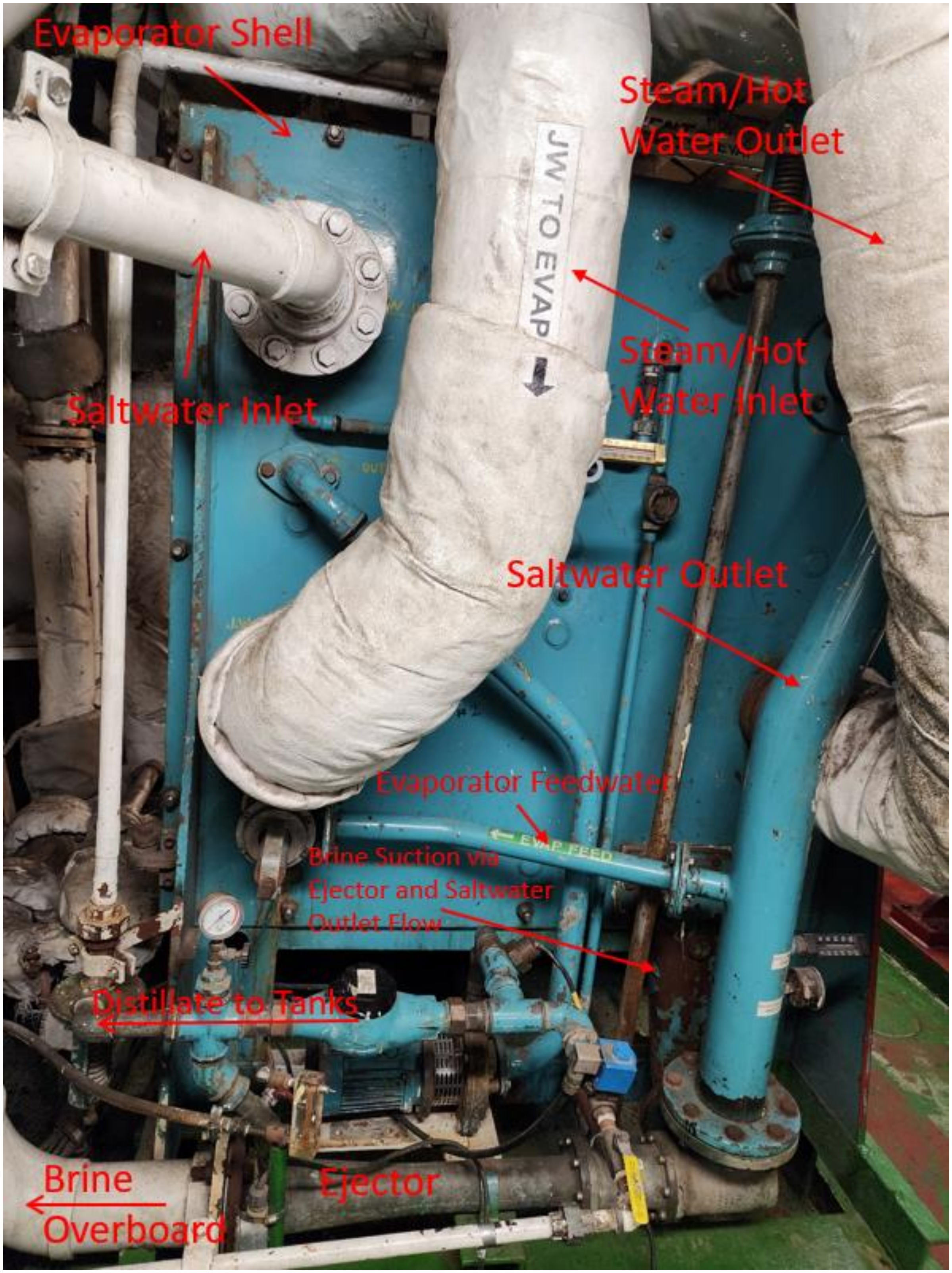

Fig. 5. Training ship TSGB flash type evaporator plant, aft view.

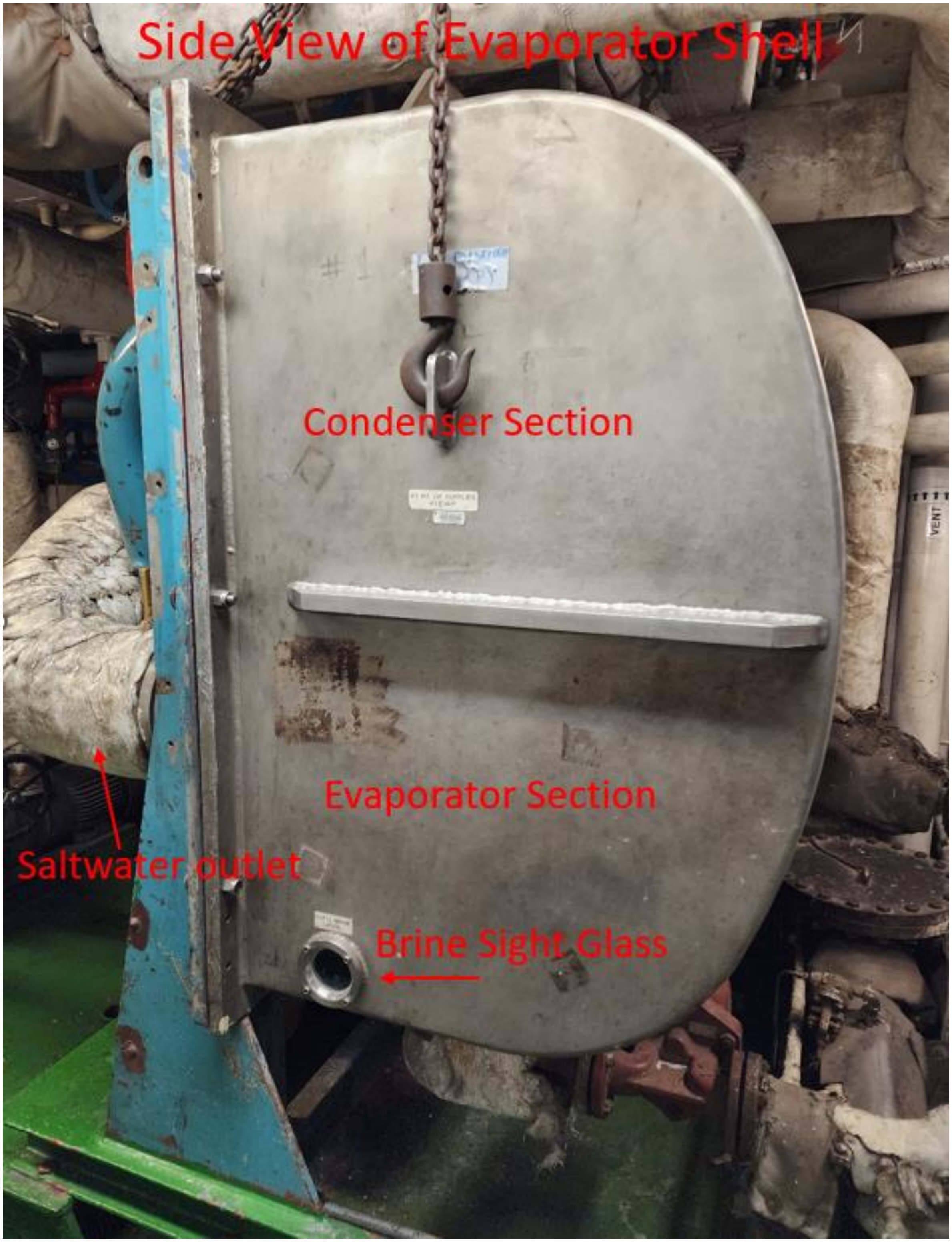

Fig. 6. Training ship TSGB flash type evaporator plant, side/shell view.

As previously mentioned, our students complete rigorous academic courses to meet their curricular objectives, meet USCG requirements and become successful and safe engineers aboard ships. During Sea Training I, between their Freshman and Sophomore years aboard our training ship the TSGB, the students must meet a competency that requires them to understand the BCOP of flash-type evaporator plants as can be seen below in the "TASK" section of the control sheet in Figure 7 for flash type evaporating freshwater generators. The Control Sheet utilized during the sea training course to ensure congruity and integration of our curriculum and STCW's, clearly defines the required assessment including the task to be completed, the performance condition, the performance behavior, and the performance standard for every assessment that must be completed during the student's sea training.

CALIFORNIA MARITIME ACADEMY
TABLE A-III/1

COURSE: CRU 150, Sea Training I, Engine

OFFICER IN CHARGE OF AN ENGINEERING WATCH

ASSESSMENT NO: CMAE 6-6B

FUNCTION: Marine Engineering at the Operational Level

COMPETENCE: Operate main and auxiliary machinery and associated control systems.

KNOWLEDGE, UNDERSTANDING & PROFICIENCY: Basic construction and operating principles (BCOP) of machinery systems, including:

- Other auxiliaries, including various pumps, air compressor, purifier, fresh water generator, heat exchanger, refrigeration, air conditioning, and ventilation systems.

TASK: Understand BCOP of fresh water generators.

PERFORMANCE CONDITION: Aboard the Training Ship.

PERFORMANCE BEHAVIOR: Understand the BCOP of a flash type fresh water generator

PERFORMANCE STANDARD:

1. Identify the main components and the operating mechanism of flash type fresh water generators.
2. Identify the main components and the operating mechanism of reverse osmosis units.
3. Competency is demonstrated through system drawings and instructions, either written or oral.

Fig. 7. Control sheet for students first sea training course - BCOP of freshwater generators.

To achieve the BCOP set forth by the STCW's for flash type evaporators during Sea Training 1 we have integrated the fundamental concepts of evaporators into our sea training curriculum to help the student comprehend both the theoretical and operational aspects of flash type evaporators. The Sea Training I curriculum familiarizes the student with the fundamentals of evaporators including their nomenclature, components, characteristics, construction, operating procedures, basic physics, fluid mechanics, and thermodynamic principles to aid in understanding the BCOP of flash type evaporators. Additionally, they will assist in the actual operation of our flash type evaporators, including start up, operating, and shut down. To ensure they understand the BCOP's of the flash type evaporating plant the student must successfully complete a written test with a minimum 70% passing score.

On campus, between Sea Training I and Sea Training III, the curriculum requires the students to complete academic courses relating to the fundamentals of flash type evaporating plants. These required courses help build upon the experiential knowledge gained during their first sea training experience. The courses include but are not limited to Thermodynamics, Fluid Mechanics, Physics I, Physics II, Steam Plant System Operations, and Properties of Materials. It was imperative that we integrate these courses into our curriculum as the academic knowledge gained is paramount for successful completion of Sea Training III, which generally takes place after the student's third year. Sea Training III includes many student assessments for successful completion that are built upon the foundations of Sea Training I and II, and our on-campus curriculum. As an example, one of the assessments during Sea Training III, to ensure the students have amassed both the theoretical and practical understanding of flash evaporators, they will be required to prove their KUP by properly starting and operating the flash type evaporating plant aboard our training ship without any assistance as set forth in the control sheet for Sea Training III and can be seen in Figure 8 below.

CALIFORNIA MARITIME ACADEMY
TABLE A-III/1
OFFICER IN CHARGE OF AN ENGINEERING WATCH

ASSESSMENT NO: CMAE 4.3.N (Old 6-13F)

FUNCTION: Marine Engineering at the Operational Level

COMPETENCE: Operate main and auxiliary machinery and associated control systems.

KNOWLEDGE, UNDERSTANDING & PROFICIENCY: Preparation, operation, fault detection and necessary measures to prevent damage for the following machinery items and controls systems:

- Steam boiler and associated auxiliaries and steam systems

TASK: Start fresh water evaporator.

PERFORMANCE CONDITION: Aboard Training Ship utilizing either of the fresh water distillers.

PERFORMANCE BEHAVIOR: Start one of the fresh water distillers utilizing steam or jacket water as the heating source. Describe actions as they are performed.

PERFORMANCE STANDARD:
1. Fresh water distiller is successfully started utilizing either steam or jacket water as the heating source.
2. Fresh water is lined up to one of the storage tanks.
3. Complete required steps as per attached checklist.
4. Start up includes knowledge of proper operating pressures and casualty control procedures.
5. All safety precautions are observed.

COURSE: CRU 350, Sea Training III, Engine

REFERENCES: NVIC 17-14 (CH 1), Tasks 4.2 and 4.3

Fig. 8. Control sheet for Sea Training III - BCOP of flash type evaporator freshwater generators.

As can be seen in the control sheets for both Sea Training I and III (Figure 7 & 8) we can begin to see the curriculum at CSUM and the STCW mandates complement each other leading to a progressively aggregate approach to education which builds on previous courses and experiences. During Sea Training I, the student is introduced and tested on the basic concepts and operations associated with flash type evaporators as per the STCW BCOP's. As the student progresses through our curriculum they must complete the theoretical classes involved with flash type evaporators such as thermodynamics and physics. Upon their third sea training, the students are required to demonstrate their accumulated knowledge, understanding, and proficiency of flash type evaporators by starting one and placing it online, which requires all their previously accumulated knowledge from their journey through CSUM.

Conclusion

By looking at the BCOP and KUP's of automatic control systems and flash type evaporator freshwater generation plants, our engineering curriculum requires the student to have accumulated an aggregate of experiential knowledge to meet the STCW competencies to meet the minimum requirements to apply for a third assistant engineer unlimited license. The students at Cal State University Maritime undergo extensive training in order to successfully meet curricular objectives, meet USCG requirements and become successful and safe engineers aboard ships. The STCW competencies are met by alignment and integration with CSUM's engineering curriculum to ensure a fundamental knowledge base is perpetually introduced and built upon during the student's career at CSUM. We ultimately aim to utilize the STCW competencies to ensure the academic and practical aspects of our curriculum creates experiential knowledge deeply rooted in a hands-on approach that is difficult to mimic in a purely academic setting.

Biographies

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