The Training Ship Golden Bear Ballast Water Treatment Testing Facility - from Concept to Activation to Inspiring the Next Generation

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Abstract. Ballast water from ships has been recognized as a vector for Aquatic Invasive Species (AIS). During 2006 key personnel from the California Maritime Academy were approached by the Maritime Administration, researchers from the University of Washington, and a marine engineering firm about a concept to develop facilities for testing ballast treatment systems on a U.S. training ship. The partnership formed sought grant funding from various federal agencies to design and construct the facility. As a result of these collaborative efforts for funding and partnerships, a unique facility was built onboard the *Training Ship Golden Bear*. Four years and much effort later the *Golden Bear* is now operating as a "Plug & Play" ballast treatment testing facility capable of performing scientific biological efficacy testing through to national and international standards through our partnership with Moss Landing Marine Laboratories.

The Golden Bear Facility (GBF) has been active testing commercial ballast water treatment systems to international standards. An enormous construction and retrofit effort took place during the winter of 2009 and extended through the spring of 2010 where the ballast system was tested and our first commercial treatment system was installed for International Maritime Organization (IMO) testing for type approval for a shipboard facility.

While bringing a ballast treatment testing facility to fruition has been satisfying and rewarding, the authors have realized a perhaps greater potential with broader appeal. By creating the space in which a wide array of environmental technologies can be developed and tested, the GBF, a Research, Development, Testing and Evaluation (RDTE) facility exists in a location where future industry participants live, train and learn their craft. Early experiences indicate that students are interested and engaged in learning about new issues and regulations that affect our industry, certainly as they relate to Ballast water and AIS.

It is our hope and belief that other technologies relating to exhaust emissions, solid waste stream, oil pollution, hull fouling and other potential risks to the marine environment will draw equal interest and engagement of our students and faculty providing impetus for discussion and a launching point for further study. We believe that by making green technologies a part of the experience and knowledge base of our future graduates we can affect the future of our industry. This development effort provides lessons learned that can benefit other maritime institutions that might develop a similar effort. This paper outlines the cooperative partnerships required, engineering and construction efforts, development of science team capacity and protocols, and the set-up of an administration structure to sustain operations.

1. INTRODUCTION

While shipping moves over 80% of the world's commodities each year, it simultaneously moves an estimated 3 to 5 billion tons of ballast water internationally. It is estimated that a similar volume may also be transferred domestically within countries and between regions. Ballast water for stability is considered essential to the safe and efficient operation of modern shipping, yet untreated or unregulated ballast may also pose a serious ecological, economic and health threat when discharged in a new location. [1]

Harmful aquatic organisms and pathogens (often non-native or non-indigenous species - NIS) that are released from ship's ballast water and sediment are recognized as a serious threat to global biological diversity and human health. Studies carried out in several countries have shown that many species of bacteria, plants, and animals can survive in a viable form in the ballast water and sediment carried in ships, even after journeys of several months' duration. Subsequent discharge of ballast water or sediment into the waters of port states may result in the establishment of these harmful organisms creating a detriment to the marine environment. The International Maritime Organization (IMO), as well as several port state authorities, has recognized the potential harm created by the transportation of non-indigenous species through ballast water. [2]

Ballast water has long been a major source for introducing non-native species into aquatic ecosystems where they would not otherwise be present. A species is defined as an invasive species when it is non-native to the ecosystem under consideration and when introduction of that species causes or is likely to cause economic or environmental harm or harm to human, animal or plant health. [3]

Aquatic invasive species present a significant threat to biodiversity in the world's coastal waters because they often have no natural predators and may out-compete native species for food in their new environment. Once established, invasive species can cause major environmental and economic harm as they multiply and spread. They can be very difficult, if not impossible, to control or eradicate following introduction into the receiving waters. Not all introduced organisms will become invasive species and harm native ecosystems. An example would be species taken onboard from a freshwater environment and discharged into saltwater. Due to the variability in organisms and complex environmental interactions affecting their establishment, it is not yet possible to accurately predict whether an introduced species will become an invasive species in a new location. [4]

In November 1997, the International Maritime Organization (IMO) issued voluntary guidelines, addressing ballast water management, which it recommended all maritime nations adopt. In January 2004 the IMO and the International Convention for the Control and Management of Ships' Ballast Water and Sediment established regulation D-2 that, once implemented aims to prevent, minimize and ultimately eliminate the transfer of harmful aquatic organisms and pathogens through the control and management of ships' ballast water and sediments. This Convention and associated IMO Marine Environmental Protection Committee (MEPC) Guidelines have been the impetus for Ballast Water Treatment System (BWTS) Type approval.

The U.S. Coast Guard, the primary U.S. federal agency charged with establishing controls on ballast water discharges, is working closely with the United States Environmental Protection Agency and other federal agencies to improve ballast water management by ships and to reduce the potential for introduction of invasive species by ships. Individual states which have been affected by invasive species from ballast water are also working to address the issue for their waters.

These issues and the desire for establishing environmental stewardship for our world's oceans through undergraduate education have prompted the Maritime Administration (MARAD) and California State University's California Maritime Academy and partners, to build the Golden Bear Facility (GBF).

2. PROBLEM DEFINITION AND BACKGROUND

The lead time required to develop and manufacture reliable, approved ballast water treatment systems is a limitation to rapidly phasing-in those units. It is only recently that ballast water treatment systems in any quantity are being prototyped, tested, and evaluated on board ships. Prototype ballast water treatment systems are critical to proving that these systems can perform reliably under the rough conditions at sea, constant wear and tear of vibration, extreme temperature and humidity, and salt air.

Testing protocol, such as that detailed in IMO G8 (see Fig. 1), must be used as an accepted standard to validate manufacturers' reliability and performance claims of any new treatment systems. These systems are required to pass through a rigorous Type Approval process, which certify that they will operate safely and properly in shipboard conditions, meet efficacy requirements according to the Convention, and meet toxicity discharge standards and review according to a special science panel at the IMO. Challenges exist; facilities equipped for performing the needed testing for these treatment systems are generally booked through 2012 or beyond, reducing the number of candidate systems available for approval. Availability is also delayed by new and developing standards, such as those from California and the United States, which are causing treatment systems to be further reevaluated.

The problem that invariably arises in scaling up to shipboard level studies is that effective scientific and controlled investigations are usually difficult to conduct on ships. It takes a great deal of negotiation to receive permission for shipboard research. Even after a ship is found, problems with tight and varying ship schedules, access to ship's tanks and plumbing, and lack of room for conducting laboratory analyses often make completing experiments time-consuming, technically difficult, and highly costly. The central goal of this project has been to provide a ship-based ballast technology testing facility that minimizes the problems described. [5]

	IMO Criteria		Proposed Modifications		
			Vessel	IMO Comparison	
	Shipboard	Land-based	Capability	Shipboard	Land-based
Ballast Tanks					
Control capacity (m^3)	1:1 scale	200	432/441	☑	☑
Test capacity (m^3)	1:1 scale	200	432/441	☑	☑
Holding time	N/A	5 days	5 days	N/A	☑
Treatment Rate Capacity (TRC)					
Less than 200 m^3/hour	1:1 scale	1:1 scale	349	200	200
200 to 1000 m^3/hour	1:1 scale	1:5 scale	349	349	1,000
Greater than 1000 m^3/hour	1:1 scale	1:100 scale	349	N/A	34,900
Sampling Collection > 50 µm					
Influent test pre-treatment	Three x 1 m^3	Three x 1 m^3	Three x 1 m^3	☑	☑
Influent test post-treatment	N/A	Three x 1 m^3	Three x 1 m^3	Exceeds	☑
Influent control	N/A	Three x 1 m^3	Three x 1 m^3	Exceeds	☑
Discharge test pre-treatment	Three x 1 m^3	Three x 1 m^3	Three x 1 m^3	☑	☑
Discharge test post-treatment	N/A	N/A	Three x 1 m^3	Exceeds	Exceeds
Discharge control	Three x 1 m^3	Three x 1 m^3	Three x 1 m^3	☑	☑
In tank test	N/A	N/A	Three x 1 m^3	Exceeds	Exceeds
In tank control	N/A	N/A	Three x 1 m^3	Exceeds	Exceeds
Measurements, Physical					
Temperature	Required	Required	In-line	☑	☑
Ballast water flow rate	N/A	Required	In-line	Exceeds	☑
Ballast water pressure	N/A	N/A	In-line	Exceeds	Exceeds
Treatment power consumption	N/A	Required	Portable	Exceeds	☑
Salinity	Required	Required	Sample	☑	☑
pH	N/A	Required	Sample	Exceeds	☑
Total suspended solids	Required	Required	Sample	☑	☑
Turbidity (NTU)[3]	N/A	Required	Sample	Exceeds	☑
Particulate organic carbon	Required	Required	Sample	☑	☑
Dissolved organic carbon	N/A	Required	Sample	Exceeds	☑
Dissolved oxygen	N/A	Required	Sample	Exceeds	☑

Figure 1. Comparison with Shipboard and Land-based IMO Guidelines [6]

3. BACKGROUND AND FUNDING HISTORY OF GOLDEN BEAR FACILITY

In the summer of 2006 during the *Training Ship Golden Bear (Golden Bear)* annual training cruise, a contingent from the University of Washington and the Glosten Associates (author) visited the vessel's Captain and Chief Engineer (author). The group was working on a U.S. Fish and Wildlife supported Phase I feasibility study that in turn had evolved from discussions between MARAD, concerned scientists and other interested parties seeking to speed up the development of ballast water treatment solutions. The concept on which the feasibility study was focused involved developing a facility to support research, development, testing and evaluation of multiple ballast treatment systems aboard a federal government owned vessel. MARAD manages a significant number of ships located in coastal regions around the U.S. The Maritime Academy Training Ships, part of the MARAD fleet, were proposed as an asset given their predictable schedules, association with educational institutions, and local distribution. Given the U.S. Pacific Coast focus of the study, California Maritime Academy was considered a prime candidate and a proposal for funding pursued.

The proposed *Facility* would help to combat the problems outlined above by serving as a shipboard ballast water treatment testing facility that would:

- Provide access to an operational ship with purpose-built laboratories to researchers working on ballast water treatment solutions.
- Reduce the high costs associated with current shipboard testing.
- Increases the standardization and quality control of shipboard experiments. [7]

The early agreement lead to stakeholder meetings and discussions with the principal investigators, vessel owner, the university, and various sponsors and matching fund contributors to seek grant funding for the proposed facility. In 2008 a successful proposal to the U.S. National Oceanographic and Aeronautic Administration (NOAA) – Sea Grant Ballast Water Demonstration Management Program was able to provide funding. This NOAA – Sea Grant proposal requested funding of $500,000 with $200,000 matching funds provided by MARAD and the California State Lands Commission (CSLC) to perform modifications to the *Golden Bear* required to support the dock-side shipboard research, development, testing and evaluation of multiple ballast treatment systems. The stated goal was to achieve modifications designed such that the resulting facility would meet or exceed the IMO Guidelines for shipboard and full-scale land-based ballast treatment test facilities. The funding was also requested to foster the education and outreach opportunities associated with the proposed project.

This initial grant was focused on designing and building a very basic facility capable of ballast treatment system integration. Laboratory capabilities, automation, and at-sea capabilities were engineered but not installed with the thought of expansion as funding and need dictated. Flexibility was a key component of designing to service rapidly developing technologies.

Funding became available late enough in the 2008/9 fiscal year that installation was impractical prior to summer 2009 cruise periods, so plans were shifted to purchasing of long lead and specialized elements for the facility construction. Construction contracts were ratified late 2009 and the basic facility was built from November 2009 through April 2010.

As these initial efforts took hold and plans began to gel for a late 2010 target for initial testing, two fortuitous events occurred to accelerate development: 1) MARAD funding had increased at the federal level to support environmental technology development, and CMA became a recipient of additional funding. The Pacific Ship's Initiative (PSI) agreement between MARAD and CMA provided funding to complete construction of the full facility. 2) CMA and partners were approached by a U.S. ballast water treatment vendor eager to perform IMO shipboard testing. This industry partnership was leveraged into rapidly completing the necessary construction to enable shipboard testing starting in May 2010, a full 6 months earlier than planned.

This rapid development of the facility and emergence into a very small U.S. and worldwide community of treatment testing facilities caught the attention of US Coast Guard and Environmental Protection Agency (EPA) sponsors to the program developing U.S. type-approval protocols. A USCG-EPA Environmental Technology Verification (ETV), request for proposal had been released seeking facilities who could attempt to test to these developing protocols. The Golden Bear Facility proposal was accepted and the additional modifications required to meet the protocol were funded by MARAD and the ETV contract itself.

The MARAD – PSI grant funding and additional, testing contracts, and the ETV project have encouraged and allowed continued construction and completion of the original concept facility as well as expanded capabilities in order to meet international and pending U.S. and Environmental Protection Agency type-approval protocols. The Golden Bear

Facility is now a fully operational ballast treatment RDTE facility, with room for additional development and studies.

4. THE GOLDEN BEAR BALLAST RDTE FACILITY

The Golden Bear Facility (Facility) is located on the 500-foot long *Training Ship Golden Bear* with 7141 cubic meters in total ballast water capacity. The ship generally spends eight-months docked in Vallejo, California, taking occasional and short trips in the Bay Area. The ship also takes two cruises for a total of four-months each year, often to remote locations such as the Far East or Australia. The ship is owned by the U.S. Maritime Administration and is operated by Cal Maritime as part of the California State University (CSU) system.

The Facility has a lead science team from Moss Landing Marine Laboratory (MLML), also part of the CSU system and has been outfitted to integrate containerized ballast water treatment systems with routine ship ballasting operations. Two ballast tanks, each with capacities of 432 cubic meters, and associated piping are outfitted to aid in conducting controlled biological efficacy testing. The pumping system can be varied between 90 and more than 400 cubic meters per hour at heads of two-bar. In this manner, the treatment system can perform routine operations under the stresses of ship operations during trans-oceanic voyages, and perform efficacy testing cycles under controlled conditions. The Facility physical plant meets the IMO G8 Guidelines for shipboard and the ETV requirements for land-based testing. [7]

Training Ship Golden Bear —Vallejo, California

The Facility was developed to conduct research, development, testing, and evaluation (RDTE) of technologies and operational practices that show promise for limiting the impact of marine vessel operations on the environment. Specifically, the Facility provides:

- Dedicated onboard laboratory to enable rapid biological and chemical analysis to support RDTE activities.
- Access to all ship equipment; including the ballast water system, hull and apertures, bilge water and de-oiling equipment, sanitation system, and diesel engine exhaust systems.

- Specialized equipment to support ballast water treatment system evaluation, including a dedicated pump and piping system, means of installing and integrating a treatment system, an automation system, and a water sampling system.

The Facility functions as a "plug and play" platform for research teams, regardless of how they approach the treatment challenge. Researchers can install their system in a standard 20-foot shipping container, using connection specifications provided by the facility to access ballast water tanks, electricity, and ancillaries. This enables them to set up their platform at their home location, and then easily transport it to Vallejo, California for loading aboard the facility without having to install their treatment system below deck.

Container-mounted treatment systems are supported by new below deck structure, and fasteners to secure up to two containers. A support services station is positioned nearby with compressed air, fresh water, electrical power receptacles, ballast water supply and sampling lines, and instrumentation.

Researchers have access to two existing ship ballast tanks (one treatment and/or one control), (see fig. 2), each with a capacity of 432 cubic meters and with large hatches for plankton net sampling. The pumping system can vary the flow capacity of the system and permits treatment on uptake and/or discharge, with variable and control tanks filled simultaneously. An onboard marine biology laboratory is outfitted with equipment to analyze samples.

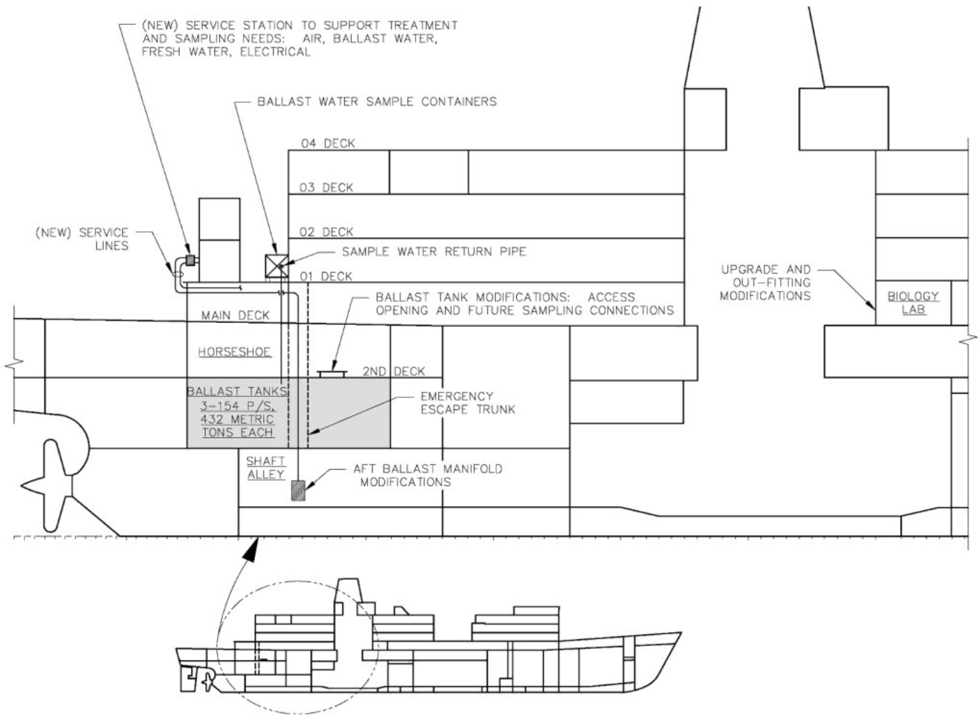

Figure 2. Profile view of keying testing facilities

4.1 Container Mounting System

The treatment systems to be tested are temporarily fastened to the ship's deck within the confines of standard ISO containers. Container mounted treatment systems are fastened to the 01 Deck level behind the aft house. The containers are positioned starboard of the centerline to avoid interference issues with the 30 ton crane immediately aft of the mounting area.

4.2 Support Services

A support services station is positioned near the ISO container mounts. Services include compressed air, fresh water, and 120 VAC and 440 VAC electrical power. Ballast water supply and sample tanks are also located at or near this station.

The Service Station on the 01 Deck level connects to treatment containers by means of hoses and cables. This provides a plug and play capability that allows treatment systems to be exchanged quickly and easily.

Electrical Power

The ballast water treatment systems can be provided with 440VAC and 120VAC power. The 440VAC receptacles for the treatment system have 100 amp & 50 amp circuits available, while the 120VAC receptacle utilizes a 30 amp breaker. For safety, all are provided with break-before-make contact pins.

Compressed Air

Ship Service Air, maintained around 100 psi with a 120 psi maximum pressure, is supplied to the Service Station on the 01 Deck. This compressed air source is available at all times, even when the ship is on shore power with the power plant secured.

Fresh Water

Potable water is supplied to the 01 Deck Service Station from on-deck wash-down spigot.

Automation

Connection and I/O for the treatment testing system to the Integrated Monitoring and Control (IMAC) system is provided adjacent to the ISO mounts

4.3 Pumping System

Piping modifications and additions to the ballast system allow ballast water to flow between the Shaft Alley seachest and the container mounted treatment system(s) on the 01 Deck. This Ballast Test System specifically utilizes a ballast tank pair directly above the Shaft Alley space. Other ballast tanks throughout the ship may be used for testing by means of a system crossover pipe.

The original sea chest in Shaft Alley is connected to a new ballast water treatment pump since the original fire/ballast pump was insufficient for test purposes. New manifolds and piping have been added to the original ballast system in Shaft Alley to provide a variety of ballast treatment modes including standard modes such as:

- Control Tank Fill – Filling one test tank with untreated ballast water.
- Treatment Tank Fill – Filling one test tank with treated ballast water.
- Control / Treatment Tank Discharge – Discharging either test tank overboard.
- Ballast Treatment on Discharge – Treating ballast water while pumping overboard.

Original piping was tapped in three places in order to provide suction to the new pump, overboard discharge from the Ballast Test System, and crossover to the majority of ballast tanks. All other piping for the Ballast Test System is new, including piping internal to the main test tank pair.

Ballast water is pumped to the 01 Deck by means of an independent treatment system pump. The pump is located in Shaft Alley on the port side of the space. The treatment pump is a double suction centrifugal pump, Goulds model 3410-17, 75 hp motor. The pump operates at a maximum speed of 1180 rpm with a shut-off head of 138 feet H_2O. The pump is also fitted with an ITT PumpSmart PS200 VFD drive that allows the pump to operate between 90 m^3/hr to 450 m^3/hr, depending on test conditions and requirements.

4.4 Tank Arrangement and Capacities

The seawater ballast tanks selected for use in this project are tanks 3-154-1 and 3-154-2, (see Fig. 3). Both tanks are similar in construction and mirrored about the ship's centerline, each with a capacity of about 114,210 gallons. These port and starboard ballast tanks have a 441 and 432 metric ton capacity respectively. The tank tops reside on the 2nd deck, approximately 33 feet above the keel. Both tanks are easily accessible through their tank tops. Both tanks extend down to the overhead of Shaft Alley, approximately 16 feet off the keel, and aft to frame 174, the forward most frame in the 3-174 aft peak ballast tank pair.

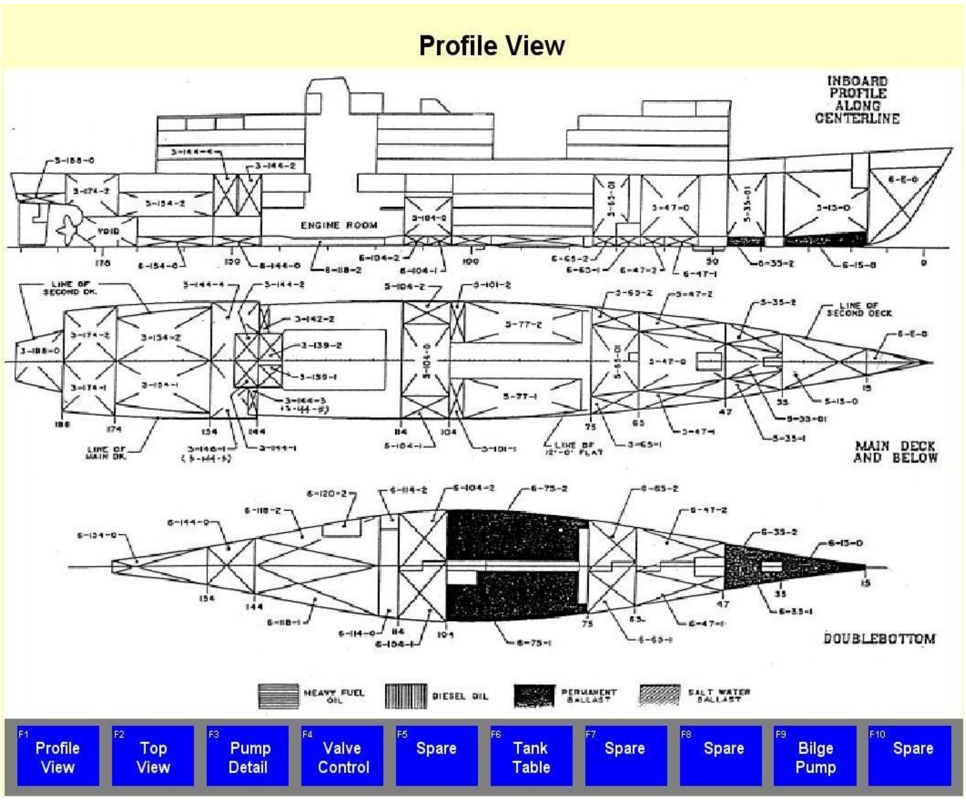

Figure 3. Ballast System Control Screen (Tank Arrangement)

4.5 Sampling System

The ballast test facility has adequate sampling to test the effectiveness of any ballast treatment systems installed on the 01 Deck.

Slip Stream Sampling System

The testing facility is equipped to take samples from one of three slip stream ports located on the Main Deck before and after treatment, which are used to collect samples in up to six (6) sample tanks located near the Main Deck slip stream ports. These ports allow testing of ballast water on uptake before treatment, uptake after treatment, and ballast discharge. Each of these six tanks uses a "flow through" design that allows continuous zooplankton sampling throughout the ballast test.

Ballast Tank Net Casting

Biological sampling access through the control and treatment tank-tops are possible by utilizing raised, quick acting watertight hatches. 24 x 24 inch clear opening provide ideal access for plankton net casting.

Figure 4. Slip Stream Sampling System

Ballast Tank Sample Collection

8 inch flanged pipe penetrations are installed in the ballast tank tops for discreet sampling connections. Flexible tubes can be installed throughout the ballast tanks and penetrate the tank tops through the flanged connections to provide information about treatment effectiveness at various locations within the tanks.

The sample tube system for each tank may consist of 3/8 inch or 1/2 inch plastic tubing connected to permanent fixtures, such as ladders and beams within the tanks, for support. A single diaphragm pump for each of the two manifolds can be used to draw seawater from the tanks through each sample tube.

4.6 Laboratory Facilities

The Facility's marine laboratory is located onboard the ship to provide researchers with the ability to rapidly assess the biological efficacy of tested BWTS. Additional facilities are located at Moss Landing Marine Laboratory (MLML), a two-hour drive from the Facility.

The ship's lab is outfitted with all equipment required to serve as the primary space for the majority of the sample processing/analysis required. The ship's lab (130 ft^2) is dedicated solely to work related to ballast water testing and provides bench space, fume hood, refrigerator/freezer space, and a wet sink area.

Figure 5. Marine Biology Laboratory

4.7 Automation Plant

An Integrated Monitoring and Control (IMAC) system with online data logging is installed in order to provide reliable monitoring and record keeping of data as well as visual cues to aid operators in system timing and operational modes. The IMAC system is comprised of a computer network which monitors and securely records a wide array of field sensors such as valve position indicators, sample flow meters, and water quality instruments. User interfaces are located throughout the Facility to provide visual indicators piping system, Ballast Water Treatment System (BWTS), and sampling system status to the Facility team. Further, the automation system facilitates the generation of reports based on the stored data.

IMAC includes an online information system consisting of a computer network for handling Facility documentation. Access is enabled for personnel to view standard and test specific procedures, access secure collected data, and manipulate data into useful information for reports. User forms allow online entry of data directly into the information system.

The system includes the following features:

- Passive automatic monitoring and logging of most system parameters, such as valve positions, ballasting flow rates, pressures, temperatures, water chemistry characteristics, tank levels and sampling flow rates.
- Active control of certain system devices, such as BWTS start and stop, Facility pumping rate, and key valve operators.
- User interface screens providing pictorial representation of system current operation; visual cues to Facility staff indicating details such as remaining time until tank will be full and pumping rates.
- Information access to procedures and protocols at any of the user terminals located through-out the Facility.
- Data entry forms, for on-line entry of various records and forms.
- Automatic generation of predesigned data reports, based on collected data. For example, system flow rate over time.

5. FACILITY USE AND STUDENT INTERFACE

The Golden Bear ballast facility has now completed operational testing work on two major projects and is proving to be a shipboard facility capable of both land-based and shipboard testing cycles. We expect in the near future to partner with principle investigators working in more of the development stages of technology as well as compliance testing.

The installation and construction project occurred during the vessel's in port period as it functioned as a campus lab and presented a great opportunity for training on methods and ship's structure. It is the actual testing and operations of the various ballast treatment systems that have proved truly outstanding training opportunities.

The shipboard testing that occurred during the 2010 cruise engaged students working side-by-side with faculty and staff operating the system in a unique way. Some of the positive feedback included:

- Faculty utilized the clear and well laid out system with a pump station located in a fairly quiet area in the shaft alley as a great platform for teaching systems design and operational logic.
- The Chief Mates on both cruises had significant tanker experience and utilized the ballasting ops to describe those processes.
- The modern variable-frequency drive and interface was a great means of teaching speed to load relationships and pump theory.
- The significant ballast operations required to perform biological efficacy testing required interesting stability and counter ballasting operations for training.
- Anecdotally, most students were positively motivated by the timely integration of testing and training to the latest regulatory requirements and new technologies.
- Having a marine biology team aboard, several of whom were CSU graduate students, provided our students and community a different perspective on maritime issues.
- The marine biology team also illuminated another potential career path for CMA graduates as they discussed research vessels.
- Well attended opportunity seminars were provided to give the participating students background on the science, operations and technology being tested.

Subsequent operations and testing while the ship is located on campus have shown additional interest and opportunity for integration with existing shipboard lab courses, work-study opportunity for interested students, and integration with the living and learning environment.

6. THE FUTURE

With growing support of State and Federal Agencies as well as a keen interest by CMA in developing a research institute associated with the *Golden Bear*, we are in process with CMA administration to develop a Golden Bear Research Institute (GBRI). Creating the GBRI would allow CMA to have an established grant and industry funded cost-center flexible enough to attract and manage a broad array of subjects our facilities and principal investigators could support.

Our hope is that the early success we've experienced with building and operating a ballast test facility could be leveraged into a center with a focus on lessening the environmental footprint of vessels. As part of the GBRI we have proposed the development of the Marine Vessel Sustainability Center. This Center will be focused around the following:

Mission Statement – Marine Vessel Sustainability Center

- Provide an effective platform, for the research, development, testing and evaluation of technologies and practices which reduce marine vessel environmental impacts.
- Advance United States merchant shipping and environmental technology business interests.
- Develop stewards of the environment through Cal Maritime student education, community involvement, and maritime business outreach.

Our vision now of what was originally a Ballast research facility taking a lead on promoting ballast treatment technology is expanding as per our mission statement above. This vision will allow us to branch out and provide a place to review and evaluate potential platform testing of many new "Green Ship" technologies, but also other related technologies that are not primarily shipboard or environmental. There are countless possibilities with some prime examples below:

- Ballast water treatment device testing for IMO G8 type approval.
- The use of biodiesel on the TSGB
- Reduction of, SOx, NOx and particulate matter (exhaust scrubbers)
- Exhaust Gas Recirculation (EGR) systems
- OWS technologies
- Electrical efficiencies: lighting, LED technology, etc.
- Recycling and reduction of shipboard waste
- Processing of shipboard waste and stowage of recycled products (aluminum, plastic)
- Local scientific institution partnership (shared resources)
- Engineering Technology faculty grants for combined plants for "steady" power production (wind turbine backed by gas turbine).

- Proposals to develop Green Ship "rating" system similar to LEEDS for the construction industry.

Working in these areas will provide dynamic educational opportunities for our various programs and also create opportunity to develop industry partnerships.

Our outreach and partnerships are already and will likely continue to include participation and networking at and with the following organizations as well as others to be determined:

- US Maritime Administration
- North Sea Ballast – Globallast – IMO
- International and US Ballast testing and research facilities.
- Maritime Events – Green Ship Technologies
- IMO – MEPC
- Local CA government offices, BAAQMD, CARB, State Lands, Fish & Game, etc.
- COAST (CSU Council on Ocean Affairs, Science and Technology)
- USCG, EPA
- Local Scientific institution partnership (shared resources) - MLML

It is our hope and belief that these efforts towards greening vessels will enhance the industry while providing opportunities to expose our students to the latest technologies, career opportunities and the nexus of regulation, science, and industry. The favorable juncture of circumstances that lead our team to take on ballast testing issues, has provided an opening to further possibilities. Our wish is that this exposure will inspire the next generation of mariners towards a better understanding of their relationship to the planet.

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