Test Plan for Performance Evaluations of Ballast Water Filter Systems

Maritime Environmental Resource Center

November 2010

Questions and comments should be directed to: Dr. Mario Tamburri
Maritime Environmental Resource Center
Chesapeake Biological Laboratory
University of Maryland Center for Environmental Science
PO Box 38 / One Williams Street
Solomons, Maryland 20688, USA
Email: tamburri@cbl.umces.edu

Table of Contents

Page No.

1. Background and Objectives of MERC Technology Evaluations

The Maritime Environmental Resource Center (MERC) is a State of Maryland initiative that provides test facilities, information, and decision tools to address key environmental issues facing the international maritime industry. The primary focus is to evaluate the mechanical and biological efficacy, costs, and logistical aspects of ballast water treatment systems and to assess the economic impacts of ballast water regulations and management approaches. A full description of MERC structure, products, and services can be found at www.maritime-enviro.org.

To address the need for effective, safe, and reliable ballast water treatment systems to prevent the introduction of non-native species, MERC has developed as a partnership between the Maryland Port Administration (MPA), Chesapeake Biological Laboratory/ University of Maryland Center for Environmental Science (CBL/UMCES), U.S. Maritime Administration (MARAD), National Oceanic and Atmospheric Administration (NOAA), Smithsonian Environmental Research Center (SERC), and University of Maryland (UM) to provide independent performance testing and to help facilitate the transition of new treatments to operations. Treatment evaluation efforts will also take advantage of expertise and the rigorous technology evaluation format/process developed by the Alliance for Coastal Technologies (ACT, www.act-us.info). ACT is NOAA-funded distributed testbed, headquartered at CBL/UMCES, dedicated to fostering the development and adoption of effective and reliable sensors for studying and monitoring coastal environments.

The following protocols describe how MERC will evaluate the performance characteristics of commercially available ballast water filtration systems through objective and quality assured "pilot-scale" testing (dockside testing at a nominal flow rate of 200m^3/hr). The goal of this specific MERC evaluation is to provide shipping lines, regulators, and flag states with an independent and credible assessment of filter performance under realistic conditions. Therefore, the data and information on performance characteristics will cover legitimate information that users need.

It is important to note that MERC itself does not certify technologies or guarantee that a technology will always, or under circumstances other than those used in testing, operate at the levels verified. MERC does not label or list technologies as acceptable or unacceptable but will present results in a way that can be used to determine regulatory compliance by appropriate agencies of certification societies. Final reports on technology performance will be reviewed by the MERC Advisory Board and provided to filter manufacturers and the MERC funding agencies prior to public release.

2. Introduction to Technology

The AutoFilt® RF3 automatic backflushing filter is a self-cleaning system for extracting particles from low-viscosity fluids. The principle application is the filtration of industrial water either as the main filter or as an offline filter. Its robust construction and automatic back-flushing capability make a major contribution to operational reliability and reduce operating and maintenance costs.

When designing the filter, state-of-the-art methods of flow simulation were employed. As a result the new conical slotted tube filter elements in stainless steel ensure highly effective separation of contamination particles with filtration ratings of 25 to 3.000 µm.

The contamination condition of the elements is monitored by means of differential pressure measurement. When the filter reaches a certain pressure drop, automatic cleaning begins, during which all the filter elements in turn are back-flushed with a small volume of fluid without interrupting the flow of filtrate. The special shape and arrangement of the conical filter elements allows an even flow through the filter, resulting in a low pressure drop and complete cleaning of the elements.

3. Protocols for Pilot-Scale Evaluations of Ballast Water Filter Systems

Basic Experimental Design:

MERC will evaluate the efficacy of ballast filtration systems onboard the MARAD vessel *M/V Cape Washington* while docked in Baltimore Harbor, Maryland (right). The ballast system of the *Cape Washington* has been modified to allow for ballast water at variable flow rates up to 700 m^3/hr and pressures up to 36 psi. A nominal flow rate of ≈200 m^3/hr shall be delivered to one filtration system at a pressure specified by the manufacturer. A detailed drawing of the modified ship ballast system can be found on page 9.

It is important to note that protocols will be the same for each system test. However, tests of different filters will NOT be conducted simultaneously, and MERC will NOT compare the performance of the systems evaluated. Thus, a final report specific to the filter evaluated will be written upon completion of the evaluation.

MERC will allow each filter system to conduct one calibration trial to assure proper operations. Three independent test trials will then be conducted at least twice during different seasons (to capture a range of natural challenge water conditions) and each test trial will be carried out over a single ballasting event. Individual test trials for each filter system tested will be separated by at least one day. The inability to successfully complete (without interruption) an

individual one-day test trial, will be considered a “failure”. If a failure is determined to be a result of problems associated with the MERC test system or process (e.g., problem with ship’s ballast system), the test trial will be discarded and repeated. If the failure is determined to be a result of the filter system (e.g., a mechanical failure resulting in an interruption of filtration during a test run), the results will be noted and included in the final report. Depending on the nature of the failure, two failures on the part of the filter system may result in the termination of testing prior to the anticipated date of completion. In such event, MERC Senior Management will make the decision to terminate testing, in consultation with filter manufacturer.

These evaluations will be based upon a simple comparison between organisms and suspended particles found in ambient challenge water upon ballasting (just upstream of the filter system) and organisms and suspended particles just downstream of the filter. Results will be presented as total concentrations of zooplankton (live plus dead), total concentrations of phytoplankton, total suspended solids (TSS), and particle size distributions (PSD), all measured both before and after the filter systems in independent trials. See Figure 1 and pages 11 and 12 for more details on the filter evaluation system design.

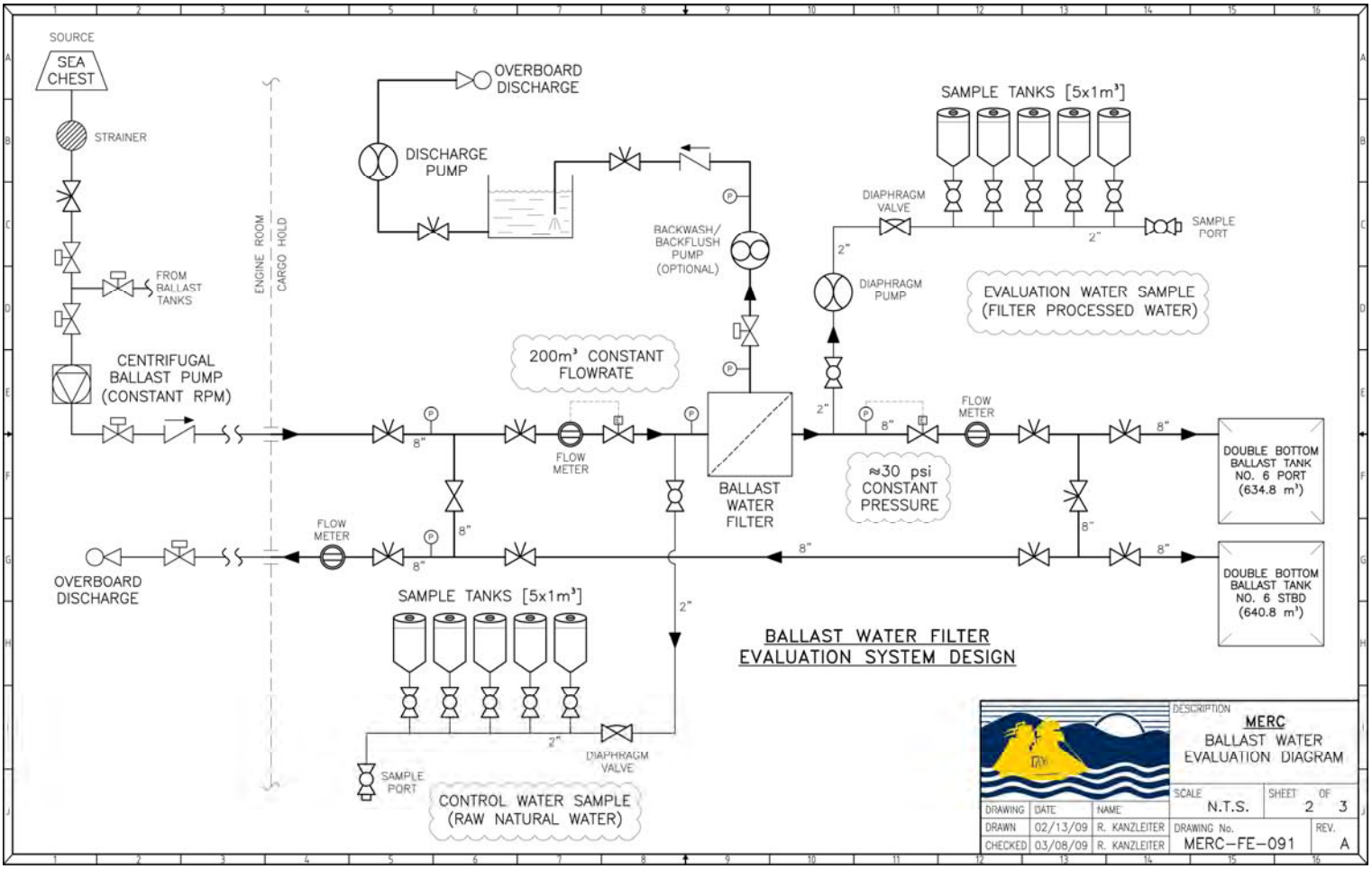


Figure 1. MERC Ballast Water Filter Evaluation System Design

Sampling Design:

Each filter system will be operated for five to six hour continuously during each test trial. The duration of each test trial is dependent upon a specific filtered amount of 1,000 m^3. During the initial 30 minutes, the middle 30 minutes and last 30 minutes, the following samples will be collected. To quantify organisms and particles in the ambient water, one mesocosm will slowly be filled to 1 m^3**,** from the sample port located just upstream of the test filter system during each of the 3 time points. The filter effluent shall be sampled during the same three 30-minute time periods. Three sequential replicate samples will be collected from the sample port located downstream of the filter system, but prior to overboard discharge. For each replicate, one mesocosm will be filled to 1 m3 over a 10-minute time period. All mesocosms will be sampled for zooplankton and phytoplankton, and samples for TSS and PSD will also be collected simultaneously at the sample port.

All sample ports include a valve and sample tube with a 90^o bend towards the direction of flow, placed in the center of the piping system (based on the design developed and validated by the US Naval Research Laboratory, Key West Florida). Sample volumes and details of the physical, chemical, and biological analyses for each sample are described below.

The conical bottom mesocosms (shown below) have been installed on the *Cape Washington* to allow for precise and controlled sampling during each test trial. One mesocosm will be used for initial samples and a second set of three replicates for post filter samples. Each mesocosm will be overfilled at a constant flow rate (controlled by a diaphragm valve), then the water sample lowered to the measured volume of 1.05 m^3. Each mesocosm filling will take place over 10 minutes. Immediately (< 5 minutes) after filling of each mesocosm, physical parameters of the water will be measured (see below), then the precise sample volumes described below will be collected for zooplankton, phytoplankton, TSS and particle size distribution by gravity draining through a bottom valve and tubing. After each use, all mesocosms will be top-down rinsed thoroughly using a freshwater hose a minimum of three times, then kept clean and dry between uses.

MERC test and sampling system on the *Cape Washington*.

Basic Water Quality:

A hand-held multi-parameter instrument will be used to measure temperature, salinity, and dissolved oxygen of the water in each mesocosm (described above) as it is collected. This is considered ancillary data and is simply meant to help characterize the ambient conditions during testing.

Total Suspended Solids (TSS):

Immediately after filling each mesocosm, a subsample of 2 liters of water will be collected, an appropriate amount filtered, then analyzed for TSS. Sample analyses will be conducted using standard US EPA methods by the certified CBL/UMCES Nutrient Analytical Services Laboratory (www.cbl.umces.edu/nasl).

Particle Size Distributions

Immediately after filling each mesocosm, a subsample of water will be collected, fixed, then shipped to a certified laboratory for analysis of particle size distributions. The size distribution of particles (range 0 – 2 mm) will be analyzed by the laser light scattering method (ASTM D4464).

Zooplankton

Exactly 1 m^3 of water from each replicate (n=5) control, and treated mesocosm will be drained through a 35 µm (50 µm diagonal dimension) plankton net to concentrate the zooplankton for examination under a dissecting microscope. Total concentration of organisms will be determined using standard techniques of fixation and analysis. Zooplankton samples will be fixed with buffered, 10% formalin in 125ml Nalgene bottles and transported to SERC for quantification. Total counts and general taxonomic classification will be conducted under a dissecting microscope at approximately 25X. In the case of samples containing high numbers of zooplankton such as the unfiltered or 'control', this assay may involve subsampling and scaling to report concentrations in the form of numbers per cubic-meter. Where numbers are very low, as may be if filtering is very effective, every organism in the sample will be individually counted. Larval forms of invertebrates will be identified to higher taxonomic levels such as order (e.g., Decapoda) suborder (e.g., Balanomorpha) or class (e.g., Bivalvia). Adults will be identified to species in most cases.

Phytoplankton

Finally, 500 ml of unfiltered water for each mesocosm will also be collected immediately after filling (in an amber Nalgene bottle) to determine concentrations of phytoplankton. These subsamples will be fixed with standard Lugol's solution and analyzed by using a Zeiss IM inverted microscope with (1 ml to 500 µl depending on cell density) direct counts under a Sedgewick rafter slide.

Sample and Data Management:

We will take advantage of the established SERC ballast water sample labeling and databases format and structure for this evaluation. Sample-labels and record keeping check-lists will be generated using SERC protocols, and data will be stored both in existing SERC databases (servers) and in a MERC repository for analytical data.

Data Analysis

Although multiple mesocosms, samples, and measures from each tank will be taken, to avoid pseudo-replication, the unit of replication for statistical analyses is each trial (n = 3+). We assume that all measures for a single trial provide one estimate of filter system efficacy. Thus, efficacy for any parameter is estimated as changes found before and after filtration (percent reduction). This approach controls for variation due to temporal changes in environmental conditions.

4. Evaluation Schedule (dates listed are based on current plan and may vary)

- MERC Test Plan for Filter System Evaluations completed and Evaluation Agreement signed by end of February 2010.
- Filter System(s) will be delivered to the Cape Washington in Baltimore by February 2010.
- Filter Systems will be installed and operational by May 2010.
- First evaluations of the Filter Systems initiated January 2011.
- MERC will complete sample analysis and compile data from the evaluation by March 2011.
- MERC will distribute a draft report on the performance of individual Filter System for review by the MERC Advisory Board and individual manufactures by end of May 2011.
- MERC will submit a final report to MPA, MARAD, NOAA and manufacturer by end of June 2011.

5. Data Recording, Processing, and Storage

This section describes methods employed during data recording, processing, and storage to minimize errors and assure high quality analyses.

Documentation and Records:

A variety of data will be acquired and recorded electronically and manually by MERC partners (CBL/UMCES, SERC, and UM) during this evaluation. Operational information and results will generally be documented in field/laboratory record books and on the data sheet/chain-of-custody forms (see below). Copies of these raw data will be transferred to the MERC office, which will store it permanently along with the rest of the study data.

Data Review:

All data are to be recorded directly in the field/laboratory record book as soon as they are available. Records are to be written in water-proof ink and written legibly. Any corrections will be initialed by the person performing the correction, will be crossed out with a line (not blackened or white-out), and will be dated according to the date that the correction was made. These data will include electronic data, entries in field/laboratory record books, operating data from the MERC test facility, and equipment calibration records. Records will be spot-checked within two weeks of the measurement to ensure that the data are recorded correctly. The checker shall not be the individual who originally entered the data. Data entries shall be checked in general for obvious errors and a minimum of 10 percent of all records shall be checked in detail. Errors detected in this manner shall be corrected immediately. The person performing the review will add his/her initials and the date to a hard copy of the record being reviewed. The MERC staff member will place this hard copy in the files for this evaluation. In addition, data generated by each MERC staff will be provided to the MERC Program Coordinator and reviewed before they are used to calculate, evaluate, or report results.

6. Quality Assurance/Quality Control

For details, review the Test Plans located at *http://www.maritime-enviro.org*, then click on Reports.

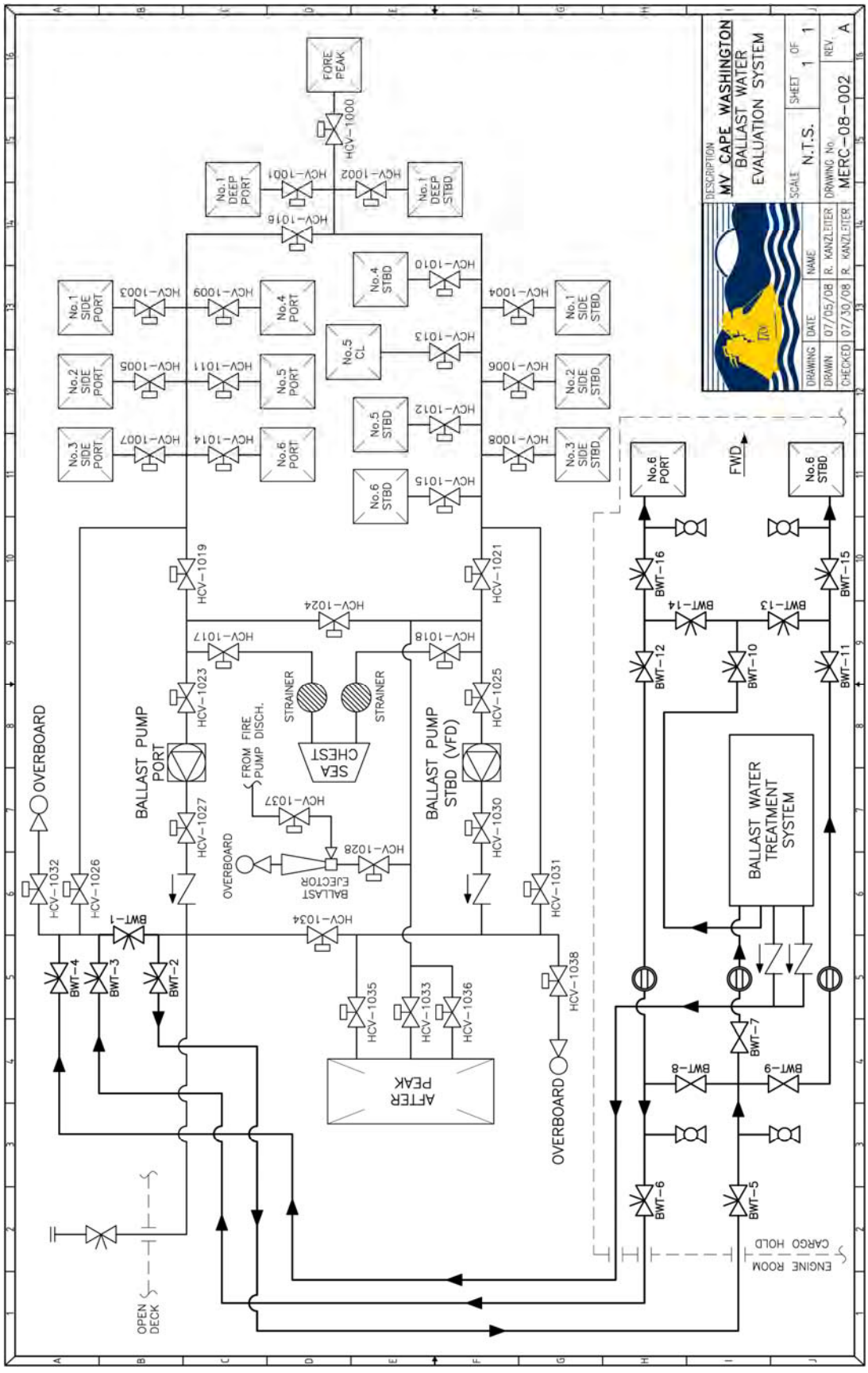
Treatment and filtration performance evaluations are implemented according to the Test/QA plans and technical documents (e.g., Standard Operating Procedures) prepared during planning of the evaluation. Prescribed procedures and a sequence for the work are defined during the planning stages, and work performed shall follow those procedures and sequence. Technical procedures shall include methods to assure proper handling and care of test instruments. All implementation activities are documented and are traceable to the Test/QA plan and SOPs and to test personnel.

7. Roles and Responsibilities

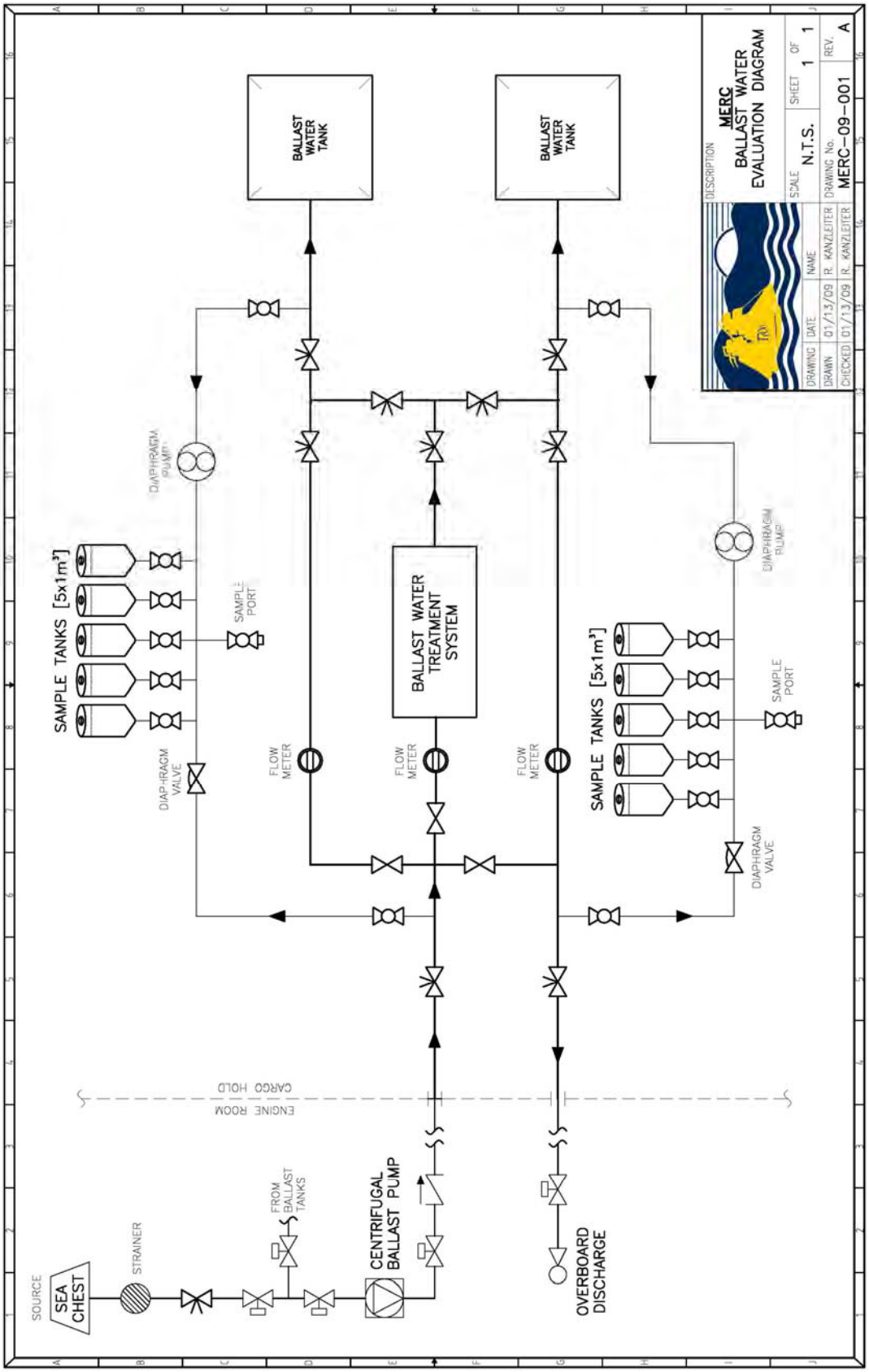
For details, review the Test Plans located at *http://www.maritime-enviro.org*, then click on Reports.

The evaluation is coordinated and supervised by the MERC Principal Investigator, Program Coordinator and MERC personnel. Staffs participate in this test by installing, maintaining, and operating the respective technologies throughout the test; operating the reference equipment, collecting the water samples, downloading the data from the instrument package, and informing the MERC Program Coordinator staff of any problems encountered. Manufacturer representatives shall train MERC staff in the operation of their filter system. However, the proper installation, calibration, maintenance, and operation of the systems is ultimately the responsibility of the manufacturer. QA oversight is provided by the MERC Program Coordinator. In addition to aiding the development of these protocols, the MERC Advisory Board will be consulted during the evaluation in the event problems occur, will assist in the analyses of results, and will review the final Filter Performance Report prior to release. Specific responsibilities are detailed below.

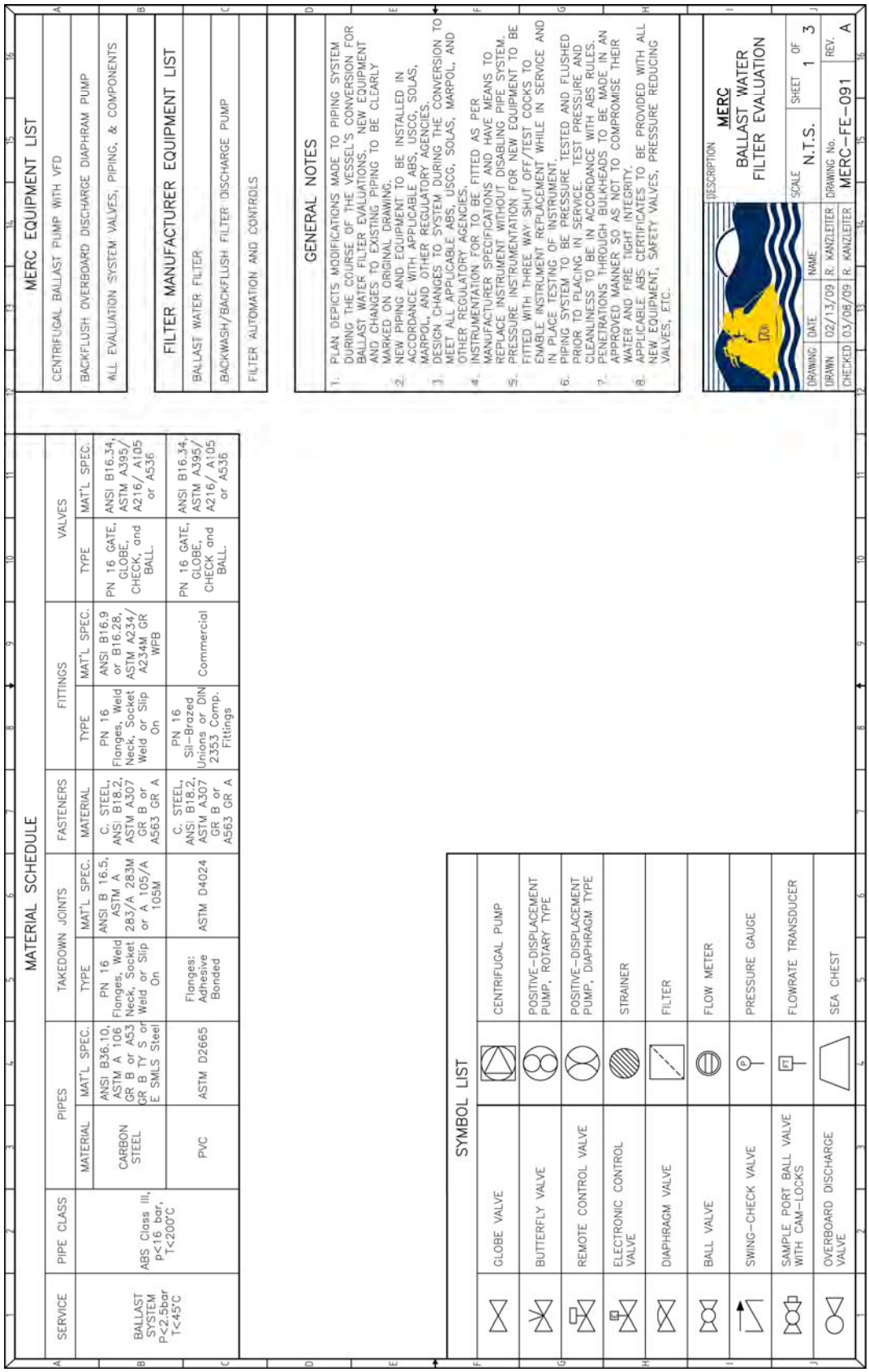
8. Modified *Cape Washington* ballast system to allow for treatment system testing by MERC.

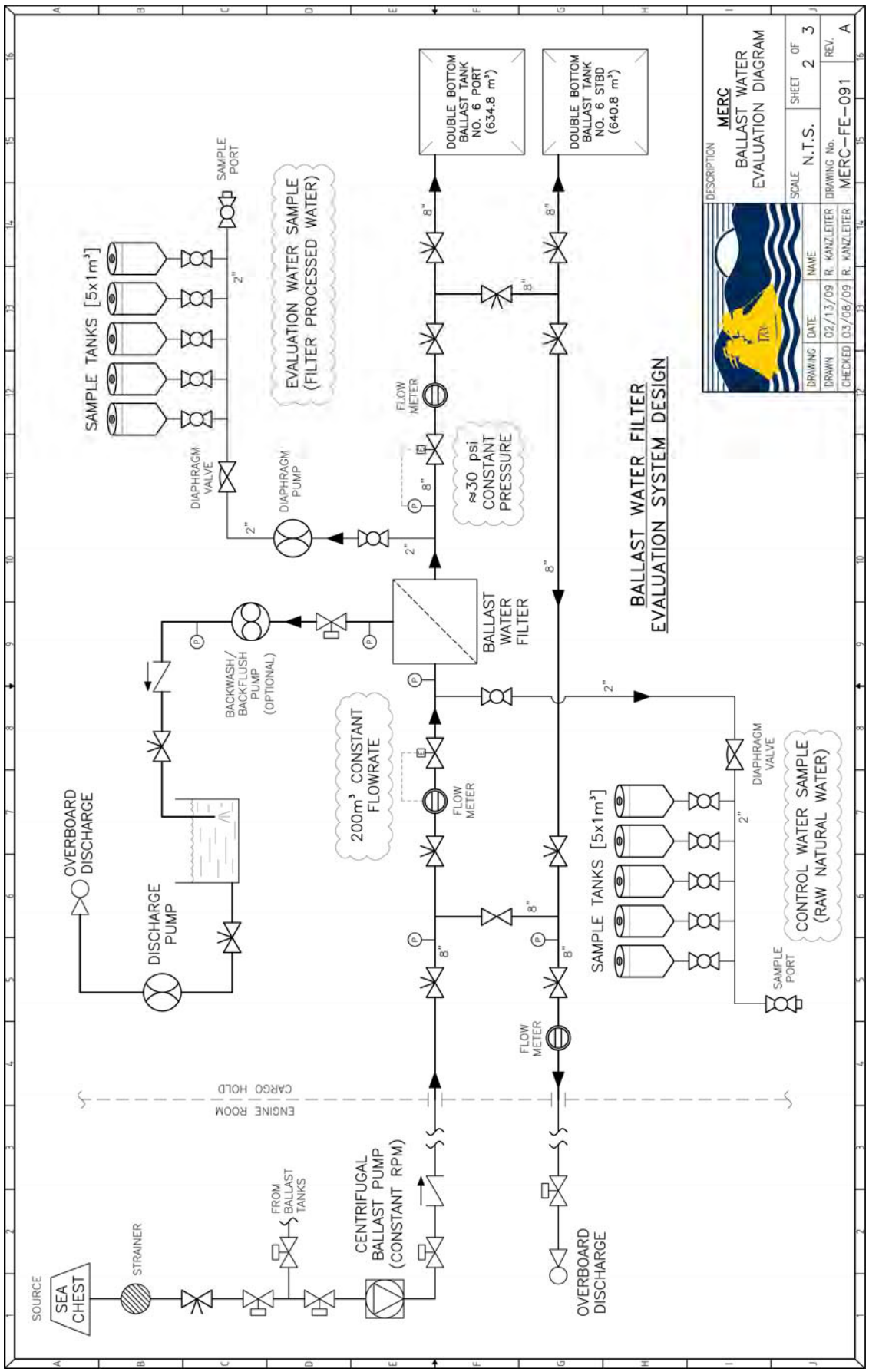


9. MERC *Cape Washington* ballast water treatment system test setup and sampling design.



10. MERC *Cape Washington* ballast water filter system test setup and sampling design.




BALLAST WATER FILTER
EVALUATION SYSTEM DESIGN
SOURCE
SEA CHEST
STRAINER
FROM BALLAST TANKS
CENTRIFUGAL BALLAST PUMP (CONSTANT RPM)
ENGINE ROOM
CARGO HOLD
OVERBOARD DISCHARGE
DISCHARGE PUMP
BACKWASH/ BACKFLUSH PUMP (OPTIONAL)
BALLAST WATER FILTER
200m³ CONSTANT FLOWRATE
FLOW METER
≈30 psi CONSTANT PRESSURE
DOUBLE BOTTOM BALLAST TANK NO. 6 PORT (634.8 m³)
DOUBLE BOTTOM BALLAST TANK NO. 6 STBD (640.8 m³)
SAMPLE TANKS [5x1m³]
DIAPHRAGM VALVE
DIAPHRAGM PUMP
SAMPLE PORT
EVALUATION WATER SAMPLE (FILTER PROCESSED WATER)
CONTROL WATER SAMPLE (RAW NATURAL WATER)
MERC
BALLAST WATER EVALUATION DIAGRAM
SCALE N.T.S.
SHEET 2 OF 3
DRAWING No. MERC-FE-091
REV. A
DRAWN 02/13/09 R. KANZLEITER
CHECKED 03/06/09 R. KANZLEITER