MH Systems, Inc

Final Report – October 31, 2008

PROJECT: INITIATE ACTIVITIES REQUIRED TO TEST BALLAST WATER TREATMENT BY GAS - SDUPD Document number 52470, Oct 12, 2007

In accordance with San Diego Port's Environmental Committee's agreement with MH Systems, Inc. we herewith submit the Final Report (Draft) for the Project: "Initiate Activities Required to Test Ballast Water Treatment by Gas."

All of the tasks for this Project were required to support the project objective to develop the Contract Design of MHS ballast water treatment system installed on R/V Melville, a ballasting oceanographic research ship operated by Scripps Institution of Oceanography. Ships coming to our harbor must empty ballast water prior to loading. Ships discharging their ballast water taken in any other port are contaminated or inhabited with species that are injurious to indigenous species in our bays/ports – these water-bodies generally are connected to a vast network of inland water ways. A ballast water treatment system is required that can economically de-contaminate or 'kill' Aquatic Nuisance Species (ANS) and thus protect indigenous species, and restore (both flora and fauna) species, that are natural to our bay or port area of waters.

Eliminating the pollution of the San Diego Bay by polluted ballast water protects the bay water habitat and encourages restoration of marine life being damaged by the pervasive pollution. The ballast water system that can protect the San Diego Harbor has been developed by the naval architects and marine engineers of MH Systems with marine biology scientists of Scripps Institution of Oceanography (SIO).

The system is planned to be tested in full scale on R/V Melville. The funding provided by SDUPD was utilized to prepare the contract design. The following are the specific tasks required to be completed in accordance with the agreement:

1. Select the Inert Gas Generator
2. Identify and Select all Sensors
3. Complete the Preliminary Design of Control System and Hardware
4. Ship Check R/V Melville and Design Verification
5. Optimize Diffuser System
6. Coordinate Design Activities
7. Program management and Report Submittal
8. Liaison w/SIO

Task Description and Work Accomplished:

1. Select the Inert Gas Generator

The inert gas generator is the heart of the ballast water treatment system. The ballast is treated by inert gas. The inert gas is bubbled through the ballast water via a row of pipes with diffusers located at the bottom of the tank. The inert gas is from a marine inert gas generator and is composed of approximately 84% nitrogen, 12-14% CO_2 and about 2% oxygen. The ballast water will be equilibrated with gas from the inert gas generator. Accommodating a marine inert gas generator onboard R/V Melville is a challenging task because of the cramped spaces of the vessel. A standard generator had to be re-designed to fit in the R/V Melville. Our engineer, Steve Donley, is extensively experienced in designing inert gas generator (IGG) installation into tankers. He was responsible for this task. Examination was conducted of the products of worldwide candidate manufacturers for functions, price and shipboard fit. The IGG of Transvac in England was selected. The president and Chief Engineer of this company visited our office to review the design of their IGG in Melville and the selection was consummated with an agreement.

2. Identify and Select all Sensors

The inert gas generators are similar to small auxiliary boilers – this equipment and valves are all automatically controlled, via sensors, with manual override. The MH Systems BW Treatment system utilizes infusion of inert gas (by bubbling) until the ballast water attains a state of hypoxia with a pH of nearly 5.5. The gassing is controlled by the remote and automated control valving system, which can permit sequential tank treatment, or multiple tank treatment simultaneously. These functions are monitored and or controlled from inputs from the sensors. Several design reviews were made to determine all of the required sensing that the installed sensors would have to do. It was finally determined that only two types of sensors would be needed to remotely and automatically sense conditions and relay the information to the central control station. One sensor would sense the amount of dissolved oxygen in the ballast water, and the other would sense the pH. In consultation with the Scripps scientists, the minimum accuracy of the two sensors was determined to be plus/minus 1% Celsius for the temperature sensor (local reading), plus/minus 1% dissolved O_2 and plus/minus .01 for pH. This requirement was incorporated into the BWT System specifications. The shipyard will select the least expensive sensors that meet the specifications

3. Complete the Preliminary Design of Control System and Hardware

The MH Systems controls are active dynamically during the period of infusion of inert gas i.e. bubbles in the ballast water. The oxygen concentration and pH of the water of each tank is monitored and recorded for each tank, sequentially, in real time. The control system software of this Ballast Water Treatment System includes self-diagnosis of failed sub-systems as well as all monitoring equipment. The Control System subcontractor prepared the specifications for the contract system, which was incorporated into the BWT System specifications. It is a functional specification describing all of the functions that the contract system must perform. The shipyard will select the hardware to accomplish these functions.

4. Ship Check R/V Melville and Design Verification

Comparison and verification of the existing drawings and plans of R/V Melville was required to ascertain that the drawings that MHS prepares are accurately based on R/V Melville's current configuration. The task required boarding the vessel and comparing the vessel's as-is configuration with the available existing drawings. Older vessels such as the R/V Melville generally get routine modifications, not reflected in any drawings. Two persons from MH Systems boarded the vessel in Koushung, Tawain to ship-check the vessel. During the ship check the two engineers determined the best compromise of the location of the inert gas generator. They also made tentative design decisions on how to provide the IGG with the necessary fuel, water and electricity. Of almost equal importance they made tentative design decisions on how the piping distribution of gas to all of the ballast tanks would be made through the various spaces in the ship.

5. Optimize diffuser System

The BWT system attains its lethality to "kill" organisms in ballast water by infusing inert gas. The 'infusion' of inert gas is done by diffusers, similar to those used in the wastewater treatment. Inert gas must be compressed to overcome the pressure head of the tank to add to the complexity of the design of diffusers; tank sediment is also a factor in the design of diffusers. Analytical work to derive the time required for optimal diffusion of inert gas into the ballast water was prepared. After comparing the physical and performance characteristics of diffusers from several manufacturers, the diffusers of Red Valve Co./Tidaflex of Carnegie, Pa. were selected. The services of a physical chemistry professor from the University of San Diego conducted analysis of the time-line for total diffusion.

6. Coordinate Design Activities

This task involved preparation of diagrammatic arrangements for Inert Gas Generator and IG distribution system, scrubber seawater supply system, effluent drain system, control air system diagram, tank sampling system diagram, etc. This task also included electrical power load analysis and electrical diagrams. The contract design set of drawings required for the ballast water system installation is listed below and included herein. Also the contract specifications were prepared and are enclosed herein.

Inert Gas Generator & IG Distribution System Diagram
52470-MHS-P0001
3 Sheets
Scrubber Seawater Supply System Diagrammatic Arrg't
52470-MHS-P0002
Effluent Drain System Diagrammatic Arrg't
52470-MHS-P0003
Control Air System Diagrammatic Arrg't
52470-MHS-P0004
Diesel Fuel System Diagrammatic Arrg't
52470-MHS-P0005
Enclosure CO2 System Diagram
52470-MHS-P0006
Enclosure Drainage System Diagrammatic Arrg't
52470-MHS-P0007
Inert Gas Distribution Piping Diagramatic Arrangement
52470-MHS-P0008
3 Sheets
Ballast Tank Sampling and Monitoring System Diagram
52470-MHS-P0009
Enclosure HVAC System Diagram
52470-MHS-P0010
BWT Electric Load Analysis
52470-MHS-E0001

7. Program management and Report Submittal

The function of program management included defining the program tasks, assigning budgets for each task, providing top-level management/guidance to all tasks, controlling expenditures of each task, submitting progress reports and rough Final Report, smooth Final Report and assisting in the presentation.

8. Liaison with SIO

MHS liaison with Scripps Institution of Oceanography's Marine Biology Research consisted of intermittent discussions and reviews of the required technical functions of the BWT system in Melville with the ongoing design of the physical installation. The MHS liaison with SIO Ship Operation and Marine Terminal Support (SOMTS) involved close coordination on Melville's movements to permit boarding and ship checking, (the ship was met in Koahsuing, Taiwan), receiving engineering interface information to install BWT system on R/V Melville and design reviews to insure that the installation will not interfere with any of the multitudinous missions that Melville must be capable of performing.

MH Systems, Inc.

Progress Report - April 30, 2008

"Initiate Activities required to Test Ballast Water System by Inert Gas"

Note: The report includes percentage completion of tasks upto April 30.

Task	Inv #1	Inv #2	Inv #3	Inv #4	Inv #5	Inv #6	S.Tot for 6 Mo Expenditure	Task Compl. in %	Current Budget	**Suggested Revised Budget**
1. Select the Inert Gas Generator	$ 660	$ 168	$ 654	$ 1,170	$ 840	$ 1,200	$ 4,692	55%	$3,492	$ 8,492
2 Identify and Select all Sensors	$ -	$ -			$ -		$ -	Yet to Start	$1,529	$ 3,529
3. Complete the Preliminary Design of Control System and Hardware	$ 330	$ -	$ 84	$ 240			$ 654	20%	$1,835	$ 1,835
4 Ship Check R/V Melville and Design Verification	$ 820	$7,252	$ 745	$ 1,200			$ 10,017	75%	$14,707	$ 10,707
5 Optimize Diffuser System	$ 360	$ 360	$ 720	$ 1,320	$ 1,320	$ 1,920	$ 6,000	60%	$4,586	$ 8,000
6 Co-ordinate Design Activities	$ 252	$ 360	$ 360	$ 6,554	$ 4,098	$ 5,028	$ 16,652	75%	$19,221	$ 23,221
7 Program Management and Report Submittal	$ 770	$ 440	$ 880	$ 1,540	$ 1,120	$ 1,100	$ 5,850	50%	$10,930	$ 10,930
8 Liaison w/SIO	$ 240	$ -		$ 1,320	$ 1,560	$ 960	$ 4,080	50%	$7,552	$ 9,552
Travel	$3,048	$ 941					$ 3,989	70%	$4,704	$ 5,704
Subcontractor - Contract Design -**Note #1**							$ -	$ -	$22,974	$ 9,560
Subcontractor - Control System						$ 5,340	5340	80%	$8,470	$ 8,470
	$6,480	$9,521	$ 3,443	$ 13,344	$ 8,938	$ 15,548	$ 57,274		$100,000	**$ 100,000**

Note#1 - The design is being done in house due to the requirements for close review and information feed as subsequent technical identification is developed. Review by subcontractor is still desirable if funding p[illegible] permits, since they are design agent for several tanker companies

MH Systems, Inc

Matching Fund Contribution
For
San Diego Unified Port District Agreement
To
"Initiate Activities Required to Test Ballast Water System by Inert Gas"

October 2007

Purpose: (a) To visit Singapore Shipyards for Installation of BWT on R/V Melville,
(b) obtain support from International Flag State (Singapore) and
(c) support from Singapore National University for BWTS

Singapore Trip Air Fare $ 1710 +$879 = ...	$2,589.00
Deduct personal Trip to Bangladesh	$ - 300.00
Sub Total	$2,226.00
Labor 8 days –8x8hrs= 64 hrs x $120/hr = 7,680	$7,680.00
Hotel, Meals, etc.	$2,400.00
Sub Total Singapore	$11,969.00

February 2008

Purpose: Request for Congressional Appropriation funding for BWTS installation on R/V Melville for $880,000

Washington Trip Air Fare	$ 240.00
Hotel and Meals	$ 625.00
Labor 5 days – 5x8 = 40 hrs x $120/hr = 4,4840	$4,480.00
Total Washington Trip	$5,345.00

July 2008

Purpose: To attend the IMO meeting regarding Ballast Water Management guidelines work sessions, including G(8) guidelines that regulates systems such as the MHS BWT Systems.

To visit Derbyshire factory where Transvac is designing an Inert Gas Generator for R/V Melville

London Air Fare	$1,095.00
Train Fare	$ 200.00
Hotels & Meals	$3,000.00
Labor 5 days – 5x8 = 40 hrs x $120/hr = 4,480	$4,480.00
Total UK Trip	$8,775.00

Total Matching Fund Contribution Up to April 30, 2008 **$26,089.00**

BALLAST WATER TREATMENT SYSTEM FITTED TO THE SCRIPPS OCEANOGRAPHIC RESEARCH VESSEL R/V MELVILLE

Inert Gas Generator System Installation Spec

Introduction:

Recent regulations adopted by IMO will require that all oceangoing vessels eventually will be fitted with some means of ballast water treatment (BWT) to enable the killing of organisms entrained in the ballast water taken aboard the vessel, before the subsequent discharge of the ballast into protected waters. These regulations are intended to curb the proliferation of non-indigenous species, which currently are being transported from one ecosystem to another, often causing widespread destruction of the native marine inhabitants.

MH Systems, Inc. has developed a method of killing the organisms entrained in the ballast water using "inert gas" which is bubbled up through the water within the tanks which acts to essentially suffocate the organisms by depleting the oxygen content within the ballast water.

By "inert gas" we mean a low oxygen content gas consisting of primarily nitrogen and CO_2. This gas is generated by the combustion of diesel fuel and air within a combustion chamber, which is subsequently cooled and "scrubbed" to create a cool, clean gas that can be directed through a distribution piping system to the tanks, then injected into the ballast water through a series of diffusers located so as to most effectively treat the entire ballast tank contents.

The inert gas generator (IGG) that we envision using is a standard, commercially available type of unit that is typically used on marine tankers to blanket the cargo oil within the cargo tanks to minimize the risk of explosions by creating a low oxygen, non-explosive, inert atmosphere within the tanks. Here the MH System's BWT system had adopted these IGG's to provide the inert gas needed to treat the ballast water, thereby obtaining an effective, clean and simple means of killing the non-indigenous species within the sea water.

Having developed the concept for this treatment system, MH Systems has undertaken a scaled down laboratory testing program, as well as a regulatory body system certification program, and is now ready to expand the testing to not only larger scale land based testing of the IG, but also ship-board testing of an actual installed IG generation, distribution and diffuser system. This shipboard testing may be conducted on a number of different vessels, of different types, but the intent here is to describe the specific design and installation of the system that has been designed for installation on the Scripps Institute's oceanographic research vessel, the R/V Melville.

The Melville, AGOR 14, was originally designed and constructed in the 1960's, and has undergone two major modifications in the intervening years. However using the latest drawings, and following a shipcheck conducted last year, MH Systems has been able to develop a contract design that will be used to not only provide the customer, Scripps Institute, with an overview of the system, and it's operation and performance, but will also be used by a shipyard to prepare an estimate of the cost to perform a detailed design package and estimate.

This overview and installation spec will be basically divided into four main groups: IGG and support systems, inert gas distribution and diffuser system, tank monitoring and system control system, and auxiliary systems to support the installation.

The inert gas generator will be a commercial off the shelf unit that usually comes skid mounted and is comprised of the main combustion chamber and cooling tower elements, as well as a combustion air fan(s), fuel pump(s), and various valves and controls which are pre-assembled and pre-piped. However there are certain ancillary services that need to be provided including a fuel source, a cooling water source, dry compressed air for systems controls, and electrical power for various power and control services.

The inert gas distribution piping and diffuser portion of the design consists of the piping from the IGG discharge, routed through the ship to the various ballast tanks to be treated, and the in-tank diffuser delivery components.

The system control and monitoring system consists of the electronic and manual monitoring systems including in-tank continuous monitoring sensors that measure O_2, temperature and pH levels in the ballast water, manual sampling devices for in-service sampling, as well as testing phase sampling provisions.

The auxiliary systems include those systems required to support, but are not part of, the IGG systems, such as space drainage, HVAC systems and firefighting systems.

Note that the contract design is based upon preliminary data and assumptions as to the BWT system arrangement and sizing, and after testing of the system in both land based and at sea installations, refinement of the system capacity and operating parameters will need to be performed, and final sizing of the equipment, piping and electrical requirements undertaken during the detail design phase.

A. Inert Gas Generator and Ancillary Systems

Reference Drawings:

A1. Dwg No. 52470-MHS-P0001, *Inert Gas Generator and IG Distribution System Diagram (3 sheets)*

A2. Dwg No. 52470-MHS-P0005, *Diesel Fuel System Diagrammatic Arrangement*

A3. Dwg No. 52470-MHS-P0002, *Scrubber Seawater Supply System Diagrammatic Arrangement*

A4. Dwg No. 52470-MHS-P0003, *Effluent Drain System Diagrammatic Arrangement*

A5. Dwg No. 52470-MHS-P0004, *Control air System Diagrammatic Arrangement*

As noted the IGG will basically be a commercial off-the-shelf unit that is widely used for cargo inerting on tank vessels. The design and installation of tanker inert gas systems on US flag vessels are typically governed by the requirements of USCG 46CFR, Subchapter H, and ABS Steel Vessel Rules (SVR) 5/1/7-25. But installed on tankers the inert gas system is a safety system installed to minimize the potential of an explosion in the cargo tanks, and the system typically serves categorized hazardous tanks and compartments. On the Melville the inert gas system which is being installed for treatment of the ballast water on board is an anti-pollution system, not a safety system. And on the Melville installation the ballast tanks are not classified as hazardous spaces. Because of this differing nature of the use of the IG system on the Melville for BWT, as compared to the use of IG on a tanker in protecting the cargo tanks, a number of the rules and regulations are superfluous to our installation.

Those regulations that would not seem to be justified in our BWT installation include redundant equipments including fuel and seawater pumps and the fitting of protective devices including the deck water seal and the P/V breakers, as well as numerous monitoring and control functions. In light of this apparent lack of justification for fully complying with the current tanker IG regulations, MHSystems contacted ABS Houston to argue the case that full compliance with the rules would not be justified for our installation. ABS agreed and have adopted the position that for our installation strict adherence to all of the rules should not be required. Their stated position is that they will relax some of the regulations for IG systems used for BWT, and the extent of that relaxation will depend on the type of vessel on which the BWT system is installed. In general, since the BWT is not a safety system, the redundancy requirements for fuel and seawater pumps will not be enforced. However for protective devices and control and monitoring functions, the relaxation of the current regulations will be broader on a non-cargo vessel like the R/V Melville, whereas some of these protective device requirements will remain in effect for installation of the BWT system on tank vessels. However during detailed design the extent of the compliance with the regulations will need to be revisited with the regulatory bodies as they review the deign products.

This being said, the IG Generator and IG distribution piping system was designed assuming a modified compliance with the ABS IG Rules.

In November of 2007 two engineers from MHSystems visited the Melville in Taiwan to determine the ideal location for the IGG and it's associated equipment, as well as getting an idea of how piping might be routed throughout the vessel. Our preference was to find a usable location within the ships machinery or service spaces that could accommodate the IGG with minimal impact to the ship's existing machinery arrangement.

Unfortunately we were unable to locate a space for the placement of the IGG that had minimal impact on the existing machinery and piping, didn't encroach on the ship's mission areas or didn't require major structural work to enable shipping of the IGG into the vessel. Therefore it was concluded that the placement of the IGG within it's own separate enclosure that could just be landed at an unobtrusive location on the weather deck would offer the best solution to the IGG placement issue. There is currently a relatively clear deck area on the 02 level just forward of the house front which not only is out of the way of mission operation, but is also conveniently located for routing of IGG support system piping.

The typical commercial IG generator provides clean inert gas derived from the combustion of an air-fuel mixture. The ancillary systems required to be provided to support the IGG operation include a combustion air supply system, a fuel supply system, a seawater supply system which is used for both cooling and scrubbing of the combusted gas, a drain system used to discharge the effluent created by the cooling/scrubbing process, usually low pressure dry compressed air for control functions, and occasionally fresh water for washdown purposes. Sheet 1 of Reference (A1) provides a piping diagram that shows all of these subsystems in a comprehensive view, along with how they interface to the existing ship's systems which supplies the auxiliary services.

Most often the generator comes complete with the combustion air fan and the fuel service pump. These items can be supplied either co-located on a single skid assembly, or they can be provided as separate skids that can be located as is most convenient for the system arrangement. For the Melville we have proceeded assuming that the IGG will be provided with a main generator skid, and with the fan skid and the fuel pump skids being provided separately.

Combustion Air System: As noted above the air required for the combustion process required for generation of the inert gas is provided from a combustion air fan that is provided by the IGG vendor. For this stage of the design we opted to assume that the fan would be provided on a separate skid assembly which we felt would provide more flexibility in the arrangement of the machinery within the IGG Enclosure. During the detailed design phase this decision can be re-examined to see if an integrated skid arrangement could be used to save space within the enclosure.

In most IGG installations the combustion air is taken directly from the space in which the IGG is located, although the air can be ducted from the weather if desired. If ducted from the weather measures must be incorporated into the system arrangement to ensure that the air to the IGG is free of any entrained water. In HVAC treated spaces this option allows the combustion air to bypass any heating or cooling processes, which might be beneficial if the combustion air volume is relatively large compared to the ventilation air flow. Our calculations for the Melville IGG Enclosure HVAC requirements led us to believe that there was no major benefit to directly ducting the combustion air from the weather, so we opted to take the combustion air directly from the IGG Enclosure.

The combustion air fan skid comes complete with the fan, motor and motor controller, an inlet filter/silencer and a discharge relief valve. All system components such as valves and flexible expansion joints are already fitted on either the fan skid or the main generator skid, so, as shown on Reference (A1), the only responsibility for the shipyard is to provide the piping from the fan discharge flange to the generator inlet flange.

The combustion air piping is to be as specified on the material schedule on sheet 3 of Reference (A1) and, according to the vendor's installation criteria, the fan should be located close enough to the generator should so that the piping does not exceed 7 meters in length, with a minimum number of bends.

Fuel System: Inert gas generators require fuel for combusting with the air in the production of the inert gas. On the Melville the existing ship's fuel system is diesel fuel which is most often the fuel used for the IGG's. In performing our ship check it was noted that a fuel day tank serving the Emergency Diesel Generator (EDG) and the ship's waste incinerator was located on the 02 level in close proximity to our IGG enclosure. This tank, which is divided into two sections serving the respective equipments, supplies diesel fuel to the incinerator and the EDG which are located in spaces immediately below the tank on the 01 level. While it probably would not be possible to utilize the EDG section of the day tank for supplying the IGG, since the size of the EDG tank is dictated by ABS sizing criteria, it should be possible to use the section of the tank that is currently used to supply the incinerator fuel to also supply the IGG. This might require a more frequent filling of the day tank by the ship's fuel transfer system depending on the frequency and duration of waste incineration and of BWT operations. During the detailed design phase this tank size will need to be evaluated, and possibly the incinerator tank size will need to increase if it is determined that the additional service warrants it.

As shown on Reference (A2) it is recommended that the IGG fuel pump skid would be located in the Incinerator Room. There is a sheet metal storage shelf assembly along the inboard bulkhead, and it is envisioned that the pump assembly could be set on the deck under these shelves. It may be necessary to remove all or part of the lowest shelf to allow adequate vertical space for access to the fuel pump skid. An existing 1" fuel supply line runs into the Incinerator Room from the day tank. As designed a new ½" line would be teed off of this supply line and led to the suction of the IGG fuel pump. From there a ½" line will run from the pump discharge to the fuel connection on the IGG skid located in the enclosure. A single supply connection is provided at the IGG burner with all other piping being pre-piped by the inert gas generator manufacturer. Also there is a connection provided on the generator to return excess fuel back to the tank. Again as designed a ½" fuel return line will be led from the IGG connection to tie into the existing ¾" incinerator fuel return line that is coming out of the Incinerator Room going back to the fuel tank.

It is suggested that the amount of hot work on existing fuel piping be minimized by maximizing the use of take down joints in the existing piping, and possibly new replacement spools as appropriate.

The fuel system piping is as defined on the material schedule found on sheet 3 of Reference (A1).

Seawater Supply System: Seawater is supplied to the IGG to provide for cooling of the combustion chamber which typically is jacketed with cooling water. Then the water is used to directly cool and clean (scrub) the combustion gas by direct contact with the gas flow stream before the gas is delivered to the distribution system going to the tanks.

Normally the seawater supplied to the inert gas generator is provided from two different sources, with one usually being a dedicated seawater scrubber pump. However as discussed earlier it is felt that ABS will provide relief from some of the redundancy requirements that are usually required for safety systems. So for the subject Melville installation currently we are envisioning a single seawater supply source as being required. Because of congestion within the existing main and auxiliary machinery spaces we investigated using an existing seawater service pump for also supplying the IGG. However none of the currently installed pumps have both sufficient capacity and head to supply the IGG located on the 02 level.

We then investigated using the firemain to supply the required IGG cooling water. Unlike typical Navy design, the USCG and ABS usually discourage using the firemain for supplying non-fire services, unless they are relative small loads or if the "parasitic" loads are added onto the capacity of the fire pumps. However both regulatory bodies have occasionally allowed the use of the fire systems for supplying non-fire systems if it can be ensured that in the event of a fire that the "parasitic" load can be easily and conveniently secured to allow full flow to go to the firemain. This usually involves either manifolding the branch supplying the auxiliary load off of the firemain at the fire pump discharge, or more commonly by fitting a remote operable valve in the branch that can be controlled from the location of the fire pump controls. We had discussions with ABS on this issue, and while not enthusiastic about it, they implied that with sufficient safeguards provided they would probably approve it.

On the main deck level, almost directly below the IGG enclosure on the 02 level, there is a 3 ½" firemain running fore and aft in the overhead of the main passageway. It is

intended to take a 3” seawater supply line directly from this firemain header routed up to the IGG, as depicted on Reference (A3). This branch will be fitted with a motor operated isolation valve, as shown on Reference (A1), that will be arranged to be remotely operated from the ship’s fire control station.
Since the firemain pressure is higher than the maximum seawater pressure of ½ bar (7 psi) allowed at the seawater inlet connection, a reducing station is installed in the supply piping immediately upstream of the generator connection.

The firemain materials are as noted in the material schedule on sheet 3 of Reference (A1).

Note: During the detailed design phase, when diagrams are submitted to ABS for approval, further discussions may be required to obtain final approval of the use of the firemain for this service, and a disapproval would require the installation of a dedicated seawater pump to serve the IGG.

Effluent Drains System: As mentioned earlier the seawater supplied to the generator is used to both cool and clean the combustion gas before it is delivered to the distribution system. A by-product of this scrubbing process is an effluent created by the mixing of the seawater with the constituents contained in the combustion gas. This effluent, which is very corrosive, is collected in the bottom of the generator, then it drains overboard by gravity.

Due to the acidic nature of this effluent, bare metal materials are not recommended for use as the drain piping. Usually either rubber-lined metal pipe or FRP fiberglass pipe are used for the scrubber effluent drain piping. The rubber-lined pipe is difficult to procure, costly and requires special handling and installation procedures to ensure that the internal coating is not damaged. Fiberglass pipe, while also potentially costly (especially for fittings) is more easily installed, and is recommended for use here as prescribed in the material schedule on sheet 3 of Reverence (A1).

Basically the drain line routing is as shown on Reference (A4) wherein the piping is led from the drain connection down through the vessel to the Auxiliary Machinery Room where it ties into the existing auxiliary seawater system overboard header.

The sizing and routing of the effluent drain piping are very critical to the proper performance of the IGG, and the vendor has provided a number of installation guidelines to ensure satisfactory system operation. These guidelines and restrictions are provided within the diagram and the general notes contained on Reference (A1). Most important is the drain sizing. Although the drain flow could be accommodated by a much smaller pipe, to ensure that entrained gas is adequately vented from the water flow, the minimum drain size has been specified to be 6”. Therefore after coming out of the generator at 8”, the drain will be immediately reduced in size to 6”.

Also to ensure that the combustion gas in the generator doesn’t just escape through the gravity drain system, a loop seal is required to be fitted in the drain line. To minimize the height of the loop seal we had to negotiate with the prospective vendor to lower the combustion chamber pressure, and now the minimum height of the loop seal is specified to be 1 ½ meters (5 feet). Also it is required that the run of piping from the generator to the loop seal be perfectly straight in the vertical. To accomplish this we have located the enclosure on the 02 level such that the drain piping, along with all other service piping, can be led vertically against the passage way bulkheads at each deck level of the vessel. In the case of the drain line it is led down through each decks passage way until it enters the auxiliary machinery room then is routed outboard to tie into the seawater cooling system overboard header. Also, even downstream of the loop seal the piping is supposed to be routed as vertically as possible, with a minimum of horizontal runs of piping, and even then the pipe should be sloped.

As noted previously the effluent is extremely corrosive, and unprotected metal piping should not be used. Therefore the existing overboard header that the drain system ties into should have the spool upstream of the overboard valve replaced with a rubber-lined spool.

Control Air System: Most inert gas generators use compressed air for operation of the associated valve actuators, and sometimes other control functions. The air is required to be dry control air. The Melville has a control air system that supplies not only the ship's machinery, but also provides dry air to the science labs. The closest dry air branch to the IGG enclosure is on the main deck aft serving the Lab/Darkroom. A new ½" line, with materials in accordance with sheet 3 of Reference (A1), will be tapped off of the existing 1" header and be routed up to the IGG enclosure as shown on Reference (A5) and be connected to the IGG air connection.

Fresh Water Flushing: Most inert gas generator manufacturers require a means for flushing the SW system and the generator with fresh water. As shown on the diagram on Reference (A1) a hose connection is fitted to the seawater supply piping immediately upstream of the seawater connection on the IGG for the injection of fresh water. It is intended that the fresh water be supplied from the potable water system, however due to the extensiveness of the potable water system in the accommodations immediately below the IGG enclosure it was not felt necessary to produce a system diagrammatic during this contract design phase.

The potable water can be provided from an existing hose bib if one is in the vicinity of the IGG, or, if required, a hose connection, fitted with a vacuum breaker, may need to be added to a potable water line in a location that can easily be connected to the IGG flush connection via a hose.

B. Inert Gas Distribution Piping and Diffuser Arrangement

Reference Drawings:

B1. Dwg No. 52470-MHS-P0001, *Inert Gas Generator and IG Distribution System Diagram (3 sheets)*

B2. Dwg No. 52470-MHS-P0008, *Inert Gas Distribution Piping Diagrammatic Arrangement (3 sheets)*

The inert gas generated by the IGG will be used to treat the ballast water in the ballast tanks by killing all the non-indigenous organisms that are entrained in the water that was taken aboard in a prior port visit. The inert gas is distributed to the ballast tanks via a piping network led from the IGG gas discharge connection to a diffuser grid located in the bottom of each tank which will enable the gas to be bubbled up through the ballast water contained in the tanks.

Inert Gas Generator Delivery – The gas produced by the IGG is discharged to the pre-piped inert gas discharge piping manifold which includes one line going to the IG discharge connection via the Main Delivery Valves supplied with the generator. Another branch line is the vent line that vents excess gas capacity to the weather via the gas vent valve. The two valves are controlled by the IGG control system, and work in conjunction with each other with one valve opening as the other valve closes. The two valves will be controlled by a pressure control signal from downstream of the Main Delivery Valve; more gas will be delivered as the discharge pressure decreases and less gas as the pressure increases.

Typically an IGG serving tanker cargo tanks discharges gas at about 2 ½ to 3 psi to blanket the cargo tanks. However for BWT operations the gas, which will eventually be bubbled up through the ballast tanks, will need to be supplied at a pressure sufficient to overcome the head of water in the tank, which will generally be greater than 3 psi. In the case of the Melville, to overcome the deepest tank head of water it is estimated that the gas will need to be supplied at over 15 psi. We discussed with the vendor the possibility of increasing the IGG discharge pressure, and it was determined that would not be a viable alternative for the required pressure, therefore we have had to incorporate a booster compressor into the shipyard supplied delivery piping downstream of the IGG delivery connection. It was decided that the best way to account for the potential of varying demands on the BWT system was to fit the booster compressor with a variable speed motor that would be controlled by the IG main pressure.

This arrangement of IGG delivery via an IG booster compressor is depicted on Reference (B1).

Inert Gas Distribution System – The inert gas delivered by the IGG and the booster compressor will be distributed to each of the ballast tanks diffuser assemblies by a network of piping the will be led from the IGG enclosure to the ballast tanks forward and aft as shown on Reference (B2). From the forward and aft mains individual branch lines, fitted with remotely operated isolation valves, will direct the gas to the tanks as selected by the operator.

The inert gas distribution piping will be heavy wall steel pipe, which will be epoxy coated. To ensure a completely coated system no hot work may be performed on the piping after coating, which means that sufficient flanged take down joints or flexible couplings will need to be incorporated into the design to allow installation without welded field joints.

Inert Gas Diffuser Grids - The gas will be delivered to each tank via a diffuser grid located at the bottom of each tank, which will allow the gas to bubble up through the ballast water for treatment. The diffuser arrangement as shown on Reference (B2) is notional based upon rough approximations of the diffuser performance. A refined grid arrangement and diffuser location will need to be developed based upon future shore based testing currently being planned. Further rearrangement of the diffusers may need to be conducted after the preliminary testing conducted onboard the R/V Melville.

Currently it is assumed that the nozzles will be US Filter Assembly #82 with ½" orifices, however future effectiveness testing may dictate either a different nozzle size, or possibly even a different diffuser model or even make.

During detailed design for the Melville the grid piping assembly should be fabricated in such a way as to allow for easy rearrangement of diffuser quantities and locations and pipe branch lengths and take off locations.

C. Ballast Tank Monitoring & Control System

Reference Drawings:

C1. Dwg No. 52470-MHS-P0009, *Ballast Tank Sampling and Monitoring System Diagram*

On the R/V Melville there will be various sampling and monitoring systems installed, as well as a control system to integrate the monitoring functions as well as providing system operational control.

For the BWT shipboard testing phase there will be systems fitted to monitor and sample the conditions of the ballast water during and after the treatment to gauge the treatment effectiveness. During this testing phase the ballast water treatment system will be operated and data will taken to relate IG flow and oxygen content, treatment durations, ballast water conditions and treatment effectiveness in killing the entrained organisms.

After the testing has been completed, and any system modifications incorporated, there will be installed systems to allow both continuous monitoring and occasional sampling of the treated ballast water.

Operation and monitoring of the IGG is provided on a local control panel mounted on the generator skid, however monitoring data showing the BWT effectiveness in the ballast tanks will be collected and recorded in a centralized system which will also provide control and operation of the inert gas distribution system.

Ballast Water Sampling Systems – During the Melville shipboard testing phase there will be a requirement to take samples of the treated ballast water to be subjected to tests in a lab to verify the effectiveness of the BWT system in killing the various marine organisms entrained in the ballast water in the tanks. Currently on the R/V Melville there is a Bilge & Ballast System that serves the ten ballast tanks arranged throughout the vessel. The suction/fill tailpipes tie into forward and aft ballast manifolds which are then piped to the bilge & ballast pump. As shown on Reference (C1) a new valved sampling pipe will be fitted to each tailpipe immediately upstream prior to the manifold. The intent is that as each treated tank is pumped overboard, a sample can be drawn via these sampling connections into a bucket or other container, then removed for future laboratory analysis.

After the testing phase has concluded, and the system is in full operational mode, small samples can be easily taken from each treated tank, as required, using a closed sampling system, MMC or equal, which will be fitted to each tank as shown on Reference (C1).

Ballast Tank Monitoring System – Each ballast tank will be fitted with in-tank sensors, as shown on Reference (C1) to measure the ballast water entrained oxygen levels, temperatures and the pH levels both during and after treatment. The positioning of the O_2 and *pH* sensors may have to be adjusted based upon both the shore based testing and the subsequent shipboard testing. These sensors shall be wired into a data collection system to collect, display and record the measurements. The temperature sensing device shall be integral with the oxygen sensor.

In addition to the oxygen and pH levels in the ballast tanks, a measurement of the ballast volume will need to be taken and factored into the BWT performance assessments. Currently tank levels are taken using individual tank sounding tubes as required by the ABS rules. However now that we will be treating the ballast tanks with inert gas, open gauging of the tanks is not advisable, especially if the sounding fittings are located within enclosed spaces. Therefore the existing sounding tubes will need to be either removed, or permanently capped off. The closed sampling standpipes installed for the in-service sampling of the tank contents can also be used to take tank ullage measurements using closed gauging tapes, MMC or equal, again as shown on Reference (C1). This use of the closed gauging systems for tank levels will require the development of new tank sounding tables that reflect the new gauging locations, the use of ullage measurements vs. sounding measurements, and the required straight routing of the standpipes in lieu of sounding tubes that where possibly installed with some degree of curvature or offset.

In addition to the fitting of the closed gauging devices, new tank level indicators shall be fitted to each ballast tank. The TLI's shall be of the pressure transducer or float type, and shall be wired into the BWT data collection system for remote monitoring.

Ballast Water Treatment Control & Monitoring System - A system shall be provided and installed to provide centralized monitoring and control of the BWT system. A complete system will be provided comprised of commercial off-the-shelf components suitably enclosed for the marine environment, that will consist of, but may not be limited to, the following major components:

A. One programmable logic controller capable of opening and closing ten (10) remote, electrically operated valves. If necessary for proper operation, relay interfaces shall be provided.

B. One LCD display capable of displaying open/closed position of the remote valves, tank ballast water level and volume, temperature of the ballast water and the condition of the ballast water (dissolved oxygen and pH level). This display may be part of item (C) below.

C. Equipment necessary for programming and operating the programmable logic controller (keyboard, software, etc.). Programming and operation may be performed by a ruggedized portable (laptop) computer.

D. One tank level indicator, one dissolved oxygen sensor, with integral temperature sensor, and one pH sensor for each of the ten ballast tanks. Accuracy of the sensors shall be: +/- 1 degree celsius for temperature, +/- 0.1% for dissolved oxygen level and +/-0.01 for pH.

E. Two storage devices (one master and one backup) capable of storing the readings from the sensors described above. The storage devices shall be capable of storing a minimum of 100 gigabytes of data.

F. All necessary electrical cabling for proper operation of the control and monitoring system.

G. One uninterruptible power supply for the control and monitoring system capable of 4 hours of operation in the event of a main power failure.

D. IGG Enclosure Auxiliary Systems

Reference Drawings:

D1. Dwg No. 52470-MHS-P0006, *Enclosure CO_2 System Diagram*

D2. Dwg No. 52470-MHS-P0007, *Enclosure Drainage System Diagrammatic Arrangement*

D3. Dwg No. 52470-MHS-P0010, *Enclosure HVAC System Diagram*

D4. Dwg No. 52470-MHS-E0001, *BWT Electrical Load Analysis*

As previously described the BWT inert gas generator will be housed in it's own enclosure and placed on the 02 level immediately forward of the accommodations. Section A of this spec detailed the systems within the enclosure that are required to support the IGG operation. In this section we will describe the services that are required to support the enclosure itself.

The enclosure will need to be designed, fabricated and fully outfitted with essential services (lighting, power, compressed service air if none is available in the vicinity, portable firefighting devices as required by the rules, etc.), personnel doors and maintenance accesses.

Because the enclosure will be located on a weather deck forward it will need to be structurally rugged so as to be able to withstand any wave action to which it may be subjected. Also, the location of the enclosure, on the 02 Level centerline, is currently a space reserved for landing of a ship's mission support container. This container will now have to be stowed on the same level to the starboard of the current location. This rearrangement of heavy concentrated loads on the 02 Level will require analysis of the deck strength, with requisite reinforcement of the deck structure.

Since the enclosure will be setting atop, and immediately forward of, accommodation areas a noise analysis will need to be conducted and remedial measures incorporated, including noise, and thermal, insulation of the enclosure, as well as possible resilient mounting of the IGG fan and booster compressor.

CO_2 System: Since the enclosure houses fuel burning equipment, it is required by the regulations to be fitted with fixed firefighting system. Since this is a relatively small, normally unmanned, space CO_2 was selected to provide the fire protection for the enclosure. As shown on Reference (D1) the system will consist of the requisite quantity of CO_2 cylinders located within the enclosure itself. After the final sizing of the enclosure calculations will need to be preformed to verify the quantity of CO_2 required and the number of cylinders.

The CO_2 system will be arranged for automatic release initiated by heat detectors located within the enclosure. Also the system will be capable of manual release from both the bottles and from outside of the enclosure access door.

The CO_2 gas will be delivered to the space via a piping distribution system fitted with nozzles located within the enclosure. The distribution main will be fitted with a time delay, a warning siren and pressure switches that are wired to secure openings into the enclosure from the HVAC and drainage systems, as described in later subsections.

Reference (D1) shows preliminary quantities of CO_2 cylinders, nozzles and heat detectors, as well as preliminary piping sizes. However during the detailed design phase, and after the enclosure is sized and arranged, working with a CO_2 system vendor will be required to verify component quantities and sizes and locations.

Enclosure Drains System: Since both water and fuel is piped to the inert gas generator within the IGG enclosure, it is necessary to provide a system to drain the enclosure. And since there is the possibility of a fuel spill within the enclosure, the drains cannot just be lead to the weather or overboard, but need to be lead to the ships oily waste collection system. As shown on Reference (D2) the deck drains serving the enclosure are combined into a common drain downcomer that will be lead down to the Auxiliary Machinery Room where it will be dumped into a bilge well the will enable the drains to be picked up and processed by the ship's oily waste system.

On Reference (D2) we have notionally shown two deck drain fittings serving the enclosure, one forward and one aft, however during the detailed design phase, after the final size of the enclosure has been determined, and after the equipment had been located within the enclosure, a final determination as to the necessary quantity and locations of the deck drains will have to be made.

The common drain downcomer is fitted with a solenoid valve that will be arranged to be automatically secured upon release of the enclosure CO_2 system so as to ensure containment of the fire fighting gas within the enclosure.

Also, as shown on the Reference (D2) diagram, the manual drain line fitted at the bottom of the loop seal serving the effluent drain piping (See Reference (A3)) will be tied into the enclosure drain downcomer to enable drainage of the effluent drain loop seal to the bilge well.

Enclosure HVAC System: The IGG enclosure is required to be fitted with an HVAC system to provide ventilation air to the enclosure and combustion air for the firing of the generator. Additionally the enclosure will need to be thermally insulated to ensure adequate HVAC system performance based upon detailed HVAC calculations, which will need to be performed. The following HVAC system design description is based upon preliminary calculations and assumptions.

The HVAC design, as shown on Reference (D3), was based around a system of mechanical supply and natural exhaust with a fan supplying air into the enclosure. Both the supply and exhaust ducting are fitted with motor operated dampers, which are arranged for automatic closure upon activation of the enclosure CO_2 system. Also both the supply and exhaust weather openings are provided with water excluding hoods fitted with manual closures and screens.

The supply fan was sized to provide both the ventilation air for the enclosure, which was determined by calculations, plus the required combustion air for the IGG, which was estimated by the IGG vendor. Since no air conditioning system is provided, the sufficient ventilation air needs to be provided to maintain the temperature within the enclosure at not more than 113^0 F, which was the temperature limitation imposed by the IGG vendor for the space ambient condition, with an assumed outside temperature of 105^0 F.

For operation during winter conditions, with an outside air temperature estimated to be 0^0 F, unit heaters are to be fitted within the enclosure to maintain the enclosure ambient temperature at a minimum of 40^0 F so as to prevent the water from freezing within the IGG and cooling water piping. As discussed in Section A of this spec it was determined that the additional power required to heat the incoming combustion air was insignificant, and therefore it was decided that the combustion air need not be ducted directly from the weather to the IGG, and could be delivered to the space in combination with the ventilation air.

Miscellaneous Enclosure Outfitting: In addition to the systems identified above, the enclosure will also need to be fitted with miscellaneous fixtures and electrical systems such as lighting and electrical outlets. Also the requisite rules will need to be followed with regard to portable firefighting appurtenances. Other minor outfitting items shall be provided as felt necessary during detailed design.

Electrical System Loads: The installation of the Inert Gas Generator and other components required by the BWT system, as well as the auxiliary systems required to support the enclosure, will have an impact on the ship's electrical plant load. Reference (D4) reflects an estimate of the additional electrical requirements, based upon preliminary vendor data and assumptions. During detailed design more precise electrical loads for the various added equipment shall be obtained, and a revision to the existing ship's Electrical Power Load Analysis will need to be performed. However at the contract design stage it was sufficient to just verify that the anticipated increase in electrical loads will not overburden the installed electrical plant and it will not be necessary to increase the electrical generating capacity, which is shown to be the case in Reference (D4).

MH SYSTEM'S BALLAST WATER TREATMENT SYSTEM
R/V MELVILLE PROTOTYPE INSTALLATION

RETROFIT ELECTRICAL LOAD IMPACT

References:

(a) MH Systems Dwg No. 52470-MHS-P0001, *Inert Gas Generator & Inert Gas Distribution Piping System Diagram*

(b) Woods Hole Dwg No. 9000-1A, *R/V Melville Power & Lighting System Load Analysis*

Table 1 below provides a summary of the estimated electrical load impact associated with the installation of the MH Systems Diffused Inert Gas based Ballast Water Treatment (BWT) System. The system, which is shown on Reference (a), is comprised of an off-the-shelf topping up inert gas generator (IGG), which is to be installed within a separate self contained enclosure, with the generated cooled and scrubbed inert gas distributed throughout the vessel and injected into the ballast water via a diffuser array within each tank.

The electrical loads identified in Table 1 are preliminary estimates, and will need to be refined during detail design, and after specific equipment selection. The purpose of estimating the loads at this stage of the contract design is to ensure that there is sufficient excess installed electrical generating capacity so as to allow operation of the BWT system without impacting other ship operations that might be occurring simultaneously.

In the current power system analysis, Reference (b), the electrical loads associated with different ship's operating conditions are calculated. The load conditions are Cruising, Dynamic Positioning, Trackline and In-Port. It is assumed that the operation of the BWT system will be conducted during the vessels cruising condition since both the dynamic positioning condition and the trackline condition are mission related operations, and as such it is unlikely that they would be performing additional operations, such as BWT, at these times, and BWT operations would be conducted before entering port, so in-port would not be a considered condition.

Per Reference (b) the current cruising condition electrical load is 2435.2 kW. With our additional BWT estimated load of 110.8 kW the adjusted electrical load for the cruise condition with ballast water treatment is estimated to be 2546 kW.

In accordance with Reference (b) the installed electrical plant, as currently configured, consists of three (3) 1090 kW Ship's Service Generators, one (1) 560 Ship's Service/Port Generator and one (1) 200 kW Emergency Generator. Although not stated, it is assumed that during normal at sea operations that two of the large generators and the smaller SS/Port generator would be running, leaving one of the large generators as a stand-by generator. Consequently the available at sea load would be 2740 kW (2 x 1090 + 560). This means that our additional BWT electrical requirements, when added to the existing cruising condition load, still falls well within the current capacity of the ships electrical generating plant, and as such no increase in electrical generation will be required.

TABLE 1 – R?V Melville BWT Electrical Load Estimate						
Subsystem	Equipment	Qty	Power, HP	Unit Load, kW	Total Load, kW	Source
Inert Gas Generator	Combustion Air Fan	1	-	5.5	5.5	Transvac Proposal
	Fuel Pump	1	-	0.55	0.55	Transvac Proposal
	Control Panel/Supply Power	1	-	1	1	Transvac Proposal
Cooling Water	Cooling Water Pump[1]	-	n/a	n/a	n/a	n/a
Gas Delivery	IG Booster Compressor	1	30	22.4	22.4	McKenna Proposal
Enclosure HVAC	Ventilation Supply Fan	1	7.5	5.6	5.6	Estimate
	Supply & Exhaust Dampers	2	½	0.37	.75	Assumption
	Unit Heaters	2		32.5	65	Preliminary Calc's
Motor Operated Valves	IG Tank Delivery Valves	10	½	0.37	3.73	Assumption
	Cooling Water Supply Valve	1	¾	0.56	0. 56	Assumption
	Drain Solenoid Valve Power	1	-	0.2	0.2	Estimate
Monitoring & Control Power[4]	Various IG Monitoring & Control Systems	n/a	-	3	3	Assumption
	In Tank pH, O_2 & Level Sensors	n/a	-	1.5	1.5	Assumption
	CO_2 System Control Power	n/a	-	.5	.5	Assumption
Misc. Elec. Loads[4]	Enclosure Electrical Outlets & Lighting	n/a	-	.5	.5	Estimate
Total Elec. Load					110.79	

1. Most IGG's require a dedicated scrubber pump for cooling/scrubbing water supply. The R/V Melville contract design assumes that the firemain will supply the seawater. If the Regulatory Bodies do not approve, then a pump will be required to be added.