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TANK ACCESS FOR BALLAST WATER SAMPLING

FINAL REPORT
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16. Abstract (MAXIMUM 200 WORDS)

New United States Coast Guard regulations will mandate ballast water exchange for ships entering U.S. waters from beyond the 200-mile Exclusive Economic Zone boundary. In order for the Coast Guard to verify compliance, boarding teams must physically collect ballast water samples from tanks or discharges to analyze them with portable on-site equipment. In order to maximize the number of ships checked and minimize interference with ships' operations, the sample collecting and testing must be as simple as possible. To this end, easy access to ballast tanks is of paramount importance. This report presents an overview of typical ballast tank arrangements and identifies five different ballast tank accesses generally found on ships that make U.S. port calls. The practicality of using each of these five accesses is discussed, with particular regard to the use of state-of-the-art ballast water sampling equipment. This report recommends modifications to certain existing ballast tank accesses in order to provide easy and convenient access for obtaining samples.

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EXECUTIVE SUMMARY

The U.S. Coast Guard is in the process of developing regulations that will mandate ballast water exchange for ships entering U.S. waters from beyond 200 miles from shore. As part of the enforcement process to ensure compliance, boarding teams must physically collect ballast tank water samples and analyze them with portable on-site equipment. To this end easy ballast tank access is of paramount importance. This report presents an overview of the ballast tank arrangements and accesses of the types of ships that make U.S. port calls, reviews physical tank access requirements for sampling equipment and recommends modifications to existing ballast tanks.

During 2002, which is the latest year from which data are available, 6,114 ships made 56,596 visits to U.S. ports. The number of port calls, reduced number of crews on ships, U.S. Coast Guard personnel constraints, quick port turnaround times and normal ship operations all place pressure on the sample collecting and testing process to be as simple and quick as possible. The 6,114 ships that visited U.S. ports in 2002 can be divided into seven major types of ships including:

1. Tanker
2. Container
3. Dry Bulk
4. Roll On /Roll Off (RO/RO)
5. Gas Carrier
6. Combination
7. General Cargo

Cruise ships are not included in this list because they have very small quantities of ballast water, and voyage legs are often so short that no discharge of ballast is required. Typical ballast tank accesses onboard ships include:

1. Bolted manholes
2. Sounding tubes
3. Overflow/vent pipes
4. Ballast pump discharge and overboard discharge piping
5. Cargo hatch

All of the above accesses except for the overflow/vent piping system are suitable for ballast water sample collection. Which access is chosen depends many factors such as which ballast tank is selected to be sampled, whether or not the opening is "accessible," the availability of the crew to assist the boarding personnel, ship operations and the physical requirements of the sample collection equipment.

Sample collection equipment available for ensuring compliance includes:

1. Remote-actuated collection bottle
2. Syringe sampler
3. Pumps
4. Bucket
5. Rigid hose
6. Portable water analysis probe

From a logistical and sample contamination point of view, the equipment that can be easily handled by the boarding crew includes the remote actuated collection bottle, the syringe sampler, the bucket and the probe. The dimensions of the sampling device and the volume of water sample needed dictate the size of the required tank access.

Where top access allows, the best means to accommodate sampling equipment is through the installation of a quick-acting hatch cover or an ullage cover in an existing watertight manhole cover. If the manhole cover is normally inaccessible, it is recommended that covers either be installed in the tank top or in another accessible location. Installation of these covers requires prior engineering analysis and approval by regulatory authority and owner.

If top access is not available, the best option is to install a sampling valve in the ballast pump discharge piping. Sounding tubes and cargo hatches can also provide convenient sampling sites and normally do not need modification in order to allow access to the ballast tank contents.

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LIST OF ACRONYMS

AC	Alternating current
ASTM	American Society for Testing and Materials
CDOM	Colored dissolved organic matter
DC	Direct current
DWT	Deadweight
ft	foot
ID	Inside diameter
IMO	International Maritime Organization
IPS	Iron pipe size
LNG	Liquid natural gas
LPG	Liquified petroleum gas
LT	Long ton
MarAd	Maritime Administration
mL	Milliliter
OBO	Ore/Bulk/Oil
OD	Outside diameter
oz	ounce
P/S	Port/Starboard
RO/RO	Roll-On/Roll-Off
TEU	Twenty foot container equivalent units
U.S.	United States
USCG	United States Coast Guard
USDOT	United States Department of Transportation

1.0 INTRODUCTION

The United States Coast Guard (USCG) is in the process of developing regulations that will mandate ballast water exchange for ships entering U.S. waters from beyond 200 miles offshore. As part of the enforcement process, water samples will be taken from a ship's ballast tanks prior to the ship being allowed to commence cargo operations. Onboard analytical tools will test ballast water samples to measure the effectiveness of the ballast water exchange and compliance with the regulations. The purposes of this report are to provide an overview of the ballast tank arrangements and accesses of the types of ships that make U.S. port calls, to review current state of the art compliance tests with regard to their physical tank access requirements and to recommend modifying openings as needed to provide the required access.

2.0 OVERVIEW OF SHIP TYPES, BALLAST TANK CONFIGURATIONS AND ACCESSES

2.1 Ships Calling on U.S. Ports

Deep draft oceangoing ship types of interest to this report are those common in commercial trade to the ports of the United States. The data presented in the following paragraphs have been taken from *Vessel Calls at US Ports* (USDOT MarAd, 2004). Ports included are those located in the contiguous 48 states, Alaska, Hawaii and Puerto Rico. This report classifies ships into seven categories as follows:

- **Tanker**: Petroleum Tankers (Product and Crude), Chemical Tankers.
- **Container**: Container Carriers, Refrigerated Container Carriers.
- **Dry Bulk**: Bulk Vessels, Bulk Containerships, Cement Carriers, Ore Carriers, Wood Chip Carriers.
- **Roll On/Roll Off**: RO/RO Vessels, RO/RO Containerships, Vehicle Carriers.
- **Gas Carrier**: Liquified Natural Gas (LNG) Carriers, Liquified Petroleum Gas (LPG) Carriers, LNG/LPG Carriers.
- **Combination**: Ore/Bulk/Oil (OBO) Carriers, Bulk/Oil Carriers.
- **General Cargo**: General Cargo Carriers, Partial Containerships, Refrigerated Ships, Barge Carriers, Livestock Carriers.

Table 1 shows a comparison of the type and number of ships calling on U.S. ports and the number of port calls made by each type.

Table 1. Ship type and U.S. port calls by the world's fleet for the year 2002.

	Number of vessels calling on U.S. ports in 2002	Number of U.S. port calls made by those vessels in 2002
All Types	**6,114**	**56,596**
Tanker	1,456	17,320
Product Tanker	-	10,949
Crude Tanker	-	6,371
Container	1,026	17,138
Dry Bulk	2,488	11,112
RO/RO	425	5,632
Vehicle	307	3,605
Gas Carrier	120	739
Combination	92	761
General Cargo	507	3,894

Table 2 (USDOT MarAd, 2004) shows the average deadweight capacity of the ships in the world fleet that visited U.S. ports in 2002. Only oceangoing, self-propelled vessels of 10,000 long tons (LT) deadweight (DWT) or greater have been included, since in 2002, (the last year that data are available), ships of this size accounted for 98 percent of all commercial vessels calling at U.S. ports.

Table 2. Ship type vs. average DWT capacity for ships making U.S. port calls for the year 2002.

	Average vessel size calling on U.S. ports in 2002 per call DWT or TEU
Average All Types	**47,625**
Tanker	69,412
Container	42,158
Dry Bulk	42,876
RO/RO	20,376
Vehicle	17,528
Gas Carrier	32,099
Combination	84,459
General Cargo	23,496

Deadweight refers to the cargo-carrying capacity of ships in long tons. Cargo loads on containerships are sometimes also given in values of TEU (Twenty foot container Equivalent Units), where the TEU number refers to a normalized number of containers carried. For example, assuming a standard 20 ft container having a width of 8 ft and a height of 8 ft, a 40 ft x 8 ft x 8 ft container would be the equivalent of 2 TEU.

2.2 Ballasting Ships

Deep draft oceangoing ships of all types use ballast tanks to carry seawater in order to control the draft, trim, stability, strength and seakindliness of the vessel by adding weight in designated ballast tanks. Generally, a vessel fully loaded with cargo will be carrying virtually no ballast so the weight of the cargo is maximized. If this vessel then discharges some of its cargo or burns fuel, it may take on ballast and will be in what is called a partial ballast condition. When a vessel is empty of all cargo and sailing with only ballast is it said to be "in ballast."

While loading or discharging cargoes a vessel may ballast to adjust the trim of the vessel. Vessel trim is the vertical position of the bow relative to the stern of the vessel. Ballasting can also compensate for vessel heeling. As cargo weights are added or removed from a vessel or shifted in or amongst the holds, ballast is added, removed, or shifted to keep the vessel floating at the desired trim. Vessels also ballast to deepen the draft of a lightly loaded vessel to make it ride and handle better at sea, or to ensure proper propeller immersion. Due to increased motions and possible slamming of the bow, ocean transits in a light ship condition are harder on the ship and crew than transits in a loaded condition.

Most modern vessels, less than 30 years old, have dedicated ballast tanks, which are tanks designated for the sole purpose of holding clean ballast water. This is different from some older vessels in which certain tanks could be used for cargo or fuel when not ballasted. On such vessels, as fuel was used up in a tank and the vessel switched to a new fuel tank, the empty tank would be ballasted. When fueling took place the tank would be deballasted and again filled with fuel oil. This practice of using dirty oil ballast tanks has been abandoned because of the issues of environmental safety and overboard residual oil discharge. Table 3 presents the average age of ships that visited U.S. ports in 2002 (USDOT MarAd, 2004.)

Table 3. Ship type and average age of ships making U.S. port calls for the year 2002.

	Less than Ten Years	10-20 Years	More than 20 years
All Types	**26,489**	**18,962**	**11,145**
Tanker	8,107	5,309	3,904
Container	9,687	5,281	2,170
Dry Bulk	5,263	3,965	1,884
RO/RO	1,351	2,525	1,756
Vehicle	1,078	1,747	780
Gas Carrier	275	172	292
Combination	222	434	105
General Cargo	1,584	1,276	1,034

2.3 Ballast Systems

A typical ballast system consists of ballast tanks, ballast pumps and interconnecting supply and discharge piping. To ballast the ship, the ballast tanks are partially filled by gravity and then the ballast pump finishes the ballasting procedure by taking suction on a sea chest. Gravity and the same pump can be used to pump out the tank (deballast) through either a dedicated discharge piping system, or the same piping used for ballasting, to an overboard discharge. Ballast lines are run from each tank back to a manifold in the engine room in which the flow to and from each ballast tank is controlled. Though relatively uncommon, some ships have separate ballast tank suction and discharge piping systems.

In order for a ballast system to operate properly and safely, ballast tanks are fitted with vent lines (also called air escapes or breathers), sounding tubes and overflow lines. Configurations of ballast tanks vary from vessel to vessel, but as a general rule ships of a certain type are designed similarly. This is to say that vessels of similar purpose will be comprised of the same types and arrangements of cargo tanks, ballast tanks, fuel tanks and hull structure. The number of tanks and location nomenclature may vary depending on vessel size and specification but similar components exist in all ships.

In addition to salt water ballast, ships are sometimes fitted with fresh water liquid ballast that is permanently installed and is isolated from the salt water ballast system. This is sometimes seen on ships that have a regular fixed route and cargo load. Recently, one new U.S. Flag RO/RO ship was built with a closed ballast system comprised of treated fresh water, which is transferred within the ship to control trim and heeling. This ballast system was installed to minimize ballast water exchange issues. The ship also has a separate salt water ballast tank system.

2.4 Ballast Tank Arrangements

In an attempt to place into perspective the ballast water capacity in tanks of various ship types, Table 4 shows for each ship type, the typical range of ratios of ballast water capacity to cargo deadweight capacity (ABS, 2004.)

Table 4. Ship type vs. average ballast water capacity as a percentage of deadweight capacity.

Type	Ratio Ballast/DWT	
Single Hull Tank Ships	0.27 – 0.63	
Double Hull Tank Ships	0.31 – 0.55	
Container	0.15 – 0.42	
Dry Bulk	0.22 – 0.61	
RO/RO / Vehicle	0.14 – 0.68	
Gas Carrier	0.22 – 0.85	
Ore/Bulk/Oil (OBO)		0.45 – 0.48
General Cargo	0.10 – 0.50	

Tank types vary from vessel to vessel, but the most common types of ballast tanks include forepeak and aftpeak tanks, deep tanks, double bottom tanks, wing tanks, cargo holds used as ballast tanks and dedicated hold ballast tanks. Tanks are usually designated port and starboard and numbered from bow to stern.

A forepeak tank (e.g. Figure 1) is a vessel trimming tank located at the extreme forward end of the vessel, usually forward of the collision bulkhead. An aft peak tank is a ballast compartment in the after end of the vessel abaft of the aftermost watertight bulkhead, also often used for trim or to increase propeller immersion. Deep tanks (e.g. Figure 1) are arranged forward and aft and extend almost the entire depth of the ship. They too are used primarily for controlling vessel trim. Forepeak and deep tanks may be on the order of 30 to 40 feet deep.

Double bottom tanks (e.g. Figure 3) are located below cargo holds between the inner bottom and the bottom shell plating. They will generally be divided on centerline into port and starboard tanks. Centerline double bottom tanks with outboard port and starboard double bottom tanks are also seen on some ships. These tanks, typically with depths of 5 to 6 feet, are often used for stability and seakeeping.

Wing tanks (e.g. Figures 3 and 4) are located outside of dry or wet cargo holds, between the holds and the side shell of the ship. Wing tanks may be split horizontally into upper and lower tanks. Occasionally they may be combined with double bottoms into one tank. These tanks are often used for stability, trim, seakeeping, and where in-port cargo operations require control of the ship's list. Used as part of a heeling system, a ship's crew can pump a fixed quantity of ballast in wing tanks or outboard deep tanks from side to side as needed to compensate for movement of cargo weights.

Ballast tanks are also arranged outboard of cargo holds into lower outboard tanks at the turn of the bilge and upper outboard tanks at the sheer line or weather deck level (e.g. Figure 9.) Bulk cargo holds are often used as ballast tanks when the holds are empty of cargo and are used for stability, strength and seakeeping considerations. The following paragraphs present descriptions of typical ballast tank arrangements for various ship types.

Tankers

Tanker ballast tank arrangements are divided into two configurations, single hull and double hull. The ballast tank arrangements for a single hull tanker are shown in Figure 1. Forepeak, forward deep and aft peak ballast tanks can be seen in the profile view. The plan view also shows dedicated clean ballast tanks outboard of the centerline cargo tanks No. 2 and No. 3. This clean ballast tank is a result of international legislation in the 1970's that required segregated ballast tanks (tanks which are never used to carry oil) and other non-cargo carrying spaces arrangements on tankers to be designed so as to limit the outflow of oil in a collision. Figure 2 shows the midship section of the single hull tanker.

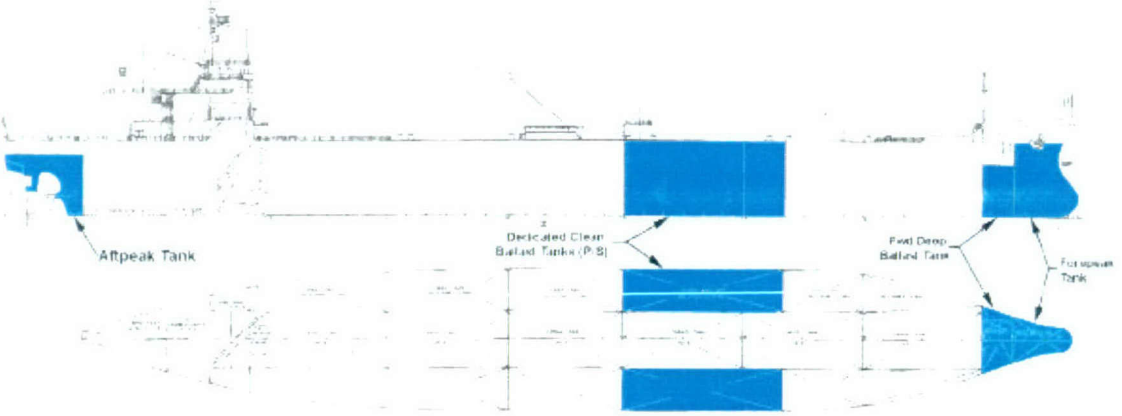

Figure 1. Single hull tanker profile and tank top plan.

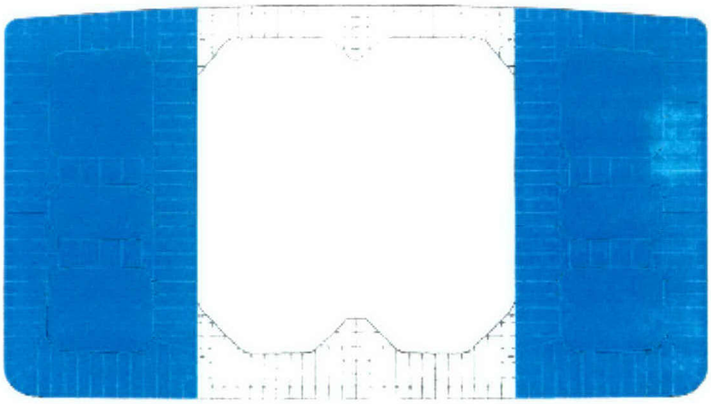

Figure 2. Single hull tanker section in way of dedicated clean ballast tanks.

Figures 3 and 4 show the ballast tank arrangements for a double hull tanker. Double hull tankers have been constructed during the past ten years as a result of the Exxon Valdez oil spill in the early 1990's. Single hull tankers are being phased out and replaced with double hull tanker designs. A double hull tanker has full depth wing ballast tanks along the entire length of the cargo block. Similar to a single hull tanker, a double hull tanker has forepeak, deep and aft peak ballast tanks. Figure 5 (Lamb *et al.*, 2004) shows several possible double hull tanker wing tank configurations.

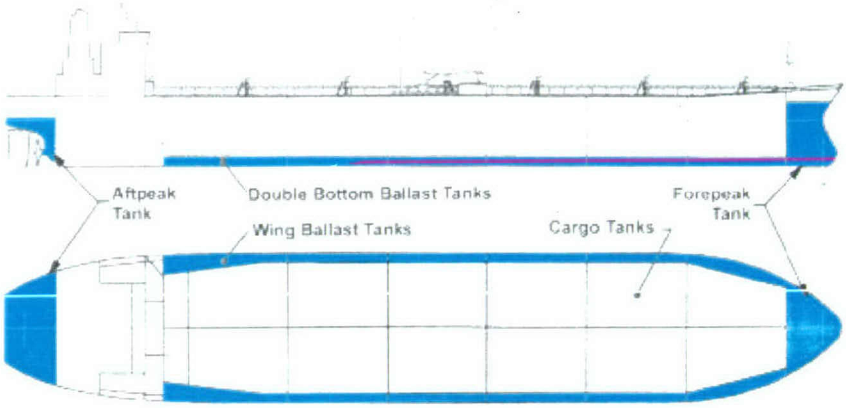

Figure 3. Double hull tanker profile and hold plan.

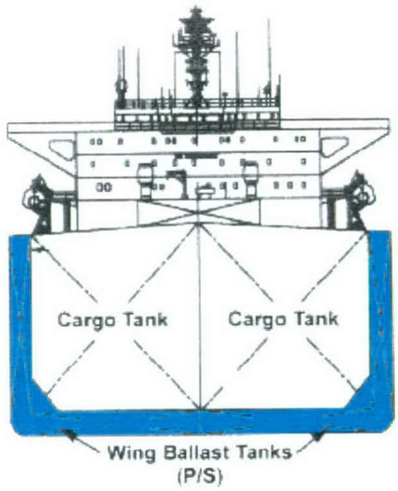

Figure 4. Double hull tanker midship section.

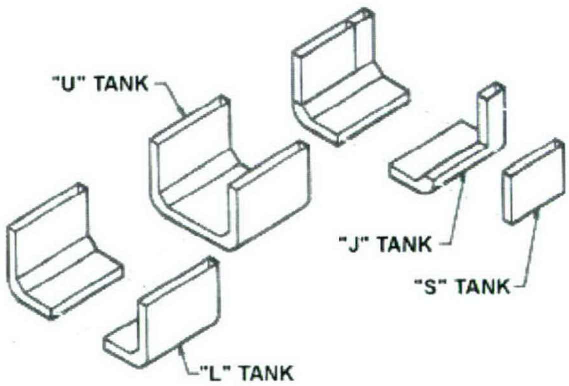

Figure 5. Typical wing tank configurations.

Container Ships

Container ships have many ballast tanks due to their varying cargo loads. There are normally forepeak tanks, several forward deep tanks, aft peak tanks, upper and lower wing tanks and double bottom tanks (see Figures 6 & 7). Sometimes permanent fresh water ballast with a rust inhibitor is carried in double bottom tanks.

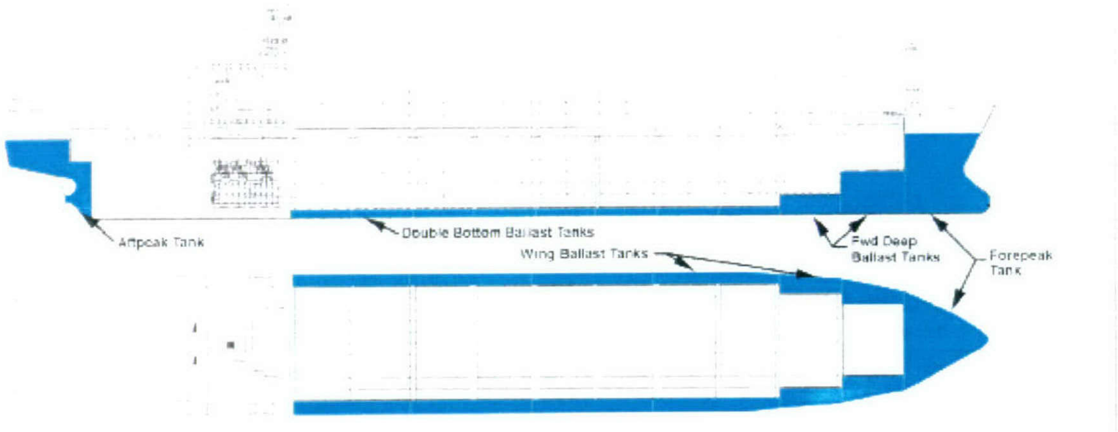

Figure 6. Container ship profile and deck plan.

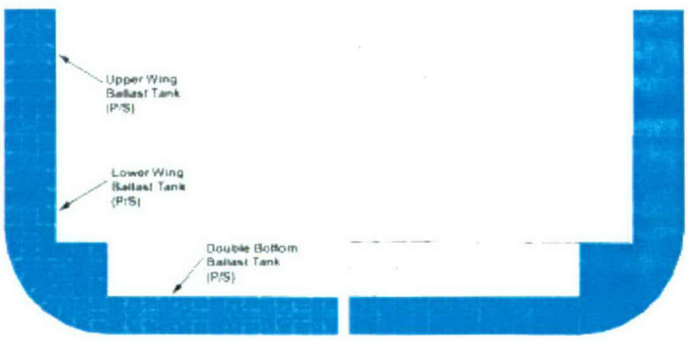

Figure 7. Container ship midship section.

Dry Bulk Ships

Typical dry bulk ship ballast tank configurations are shown in Figures 8 and 9. A forepeak and aft peak ballast tank are shown. In addition the double bottom, upper side shell tanks and lower side shell tanks (e.g. Figure 9) outboard of the cargo block are used as ballast tanks. Double bottom tanks can be either deep or shallow depending upon the density of the intended cargo. Cargo holds are also often used as ballast tanks.

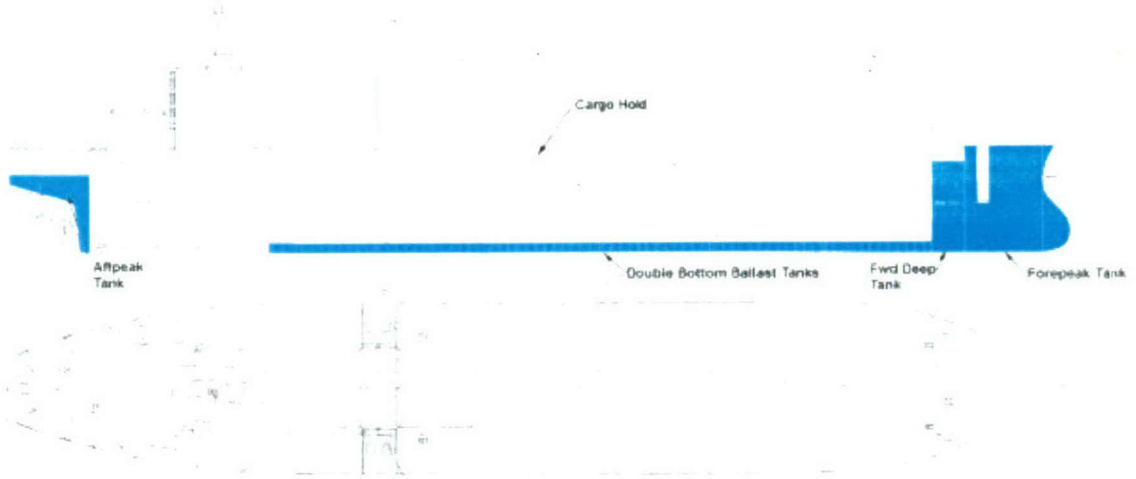

Figure 8. Dry bulk ship profile and deck plan.

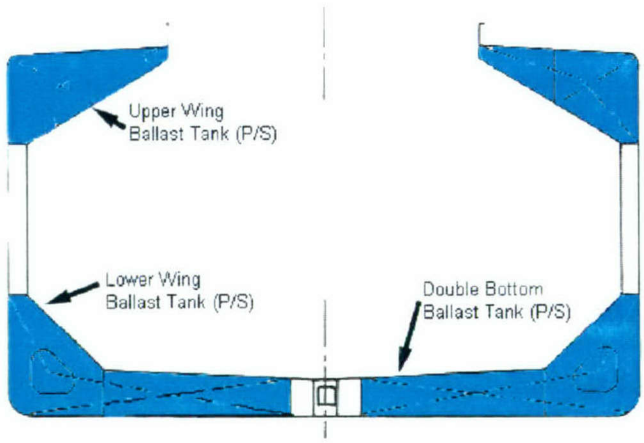

Figure 9. Dry bulk ship midship section.

<u>RO/RO Ships</u>

Similar to container ships, RO/RO ships have many ballast tanks due to their varying cargo loads. There are normally forepeak tanks, several forward deep tanks, aft peak tanks, upper and lower wing tanks and double bottom tanks. Permanent fresh water or inert drilling mud is sometimes carried on RO/RO ships. As stated earlier, a new RO/RO ship, placed in service in

2003, has a permanent movable fresh water ballast system to avoid the whole ballast water exchange requirements. Figures 10 and 11 show typical ballast tank arrangements for a RO/RO.

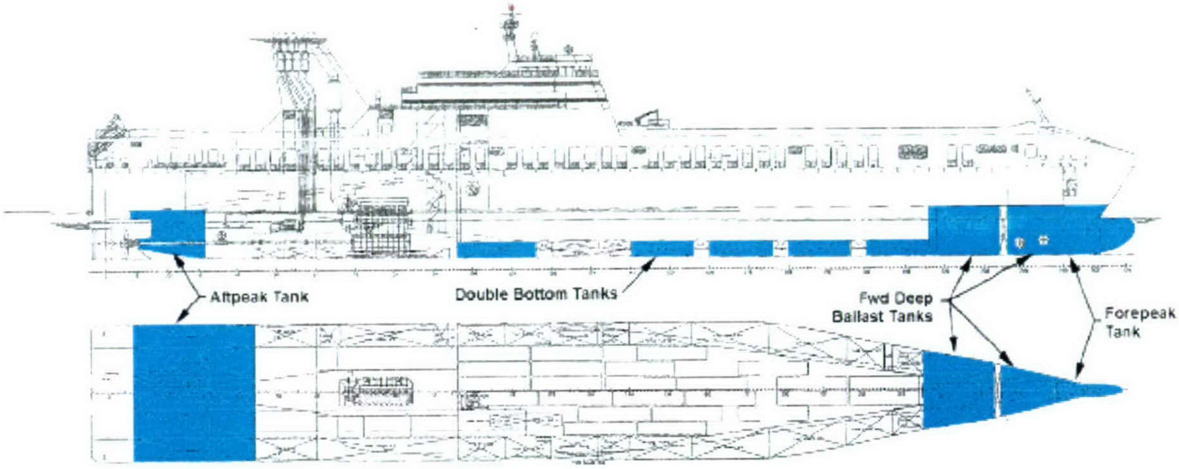

Figure 10. RO/RO ship profile and tank top plan.

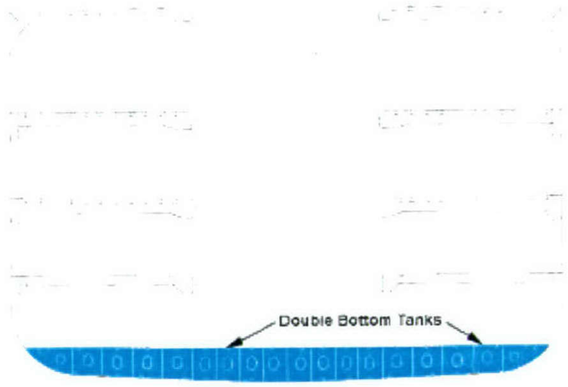

Figure 11. RO/RO ship midship section

<u>Gas Carriers (LNG)</u>

Typical gas carrier ballast tank configurations are shown in Figures 12 and 13. The tank arrangements normally include forepeak, forward deep, aft peak, upper and lower tanks and double bottom tanks.

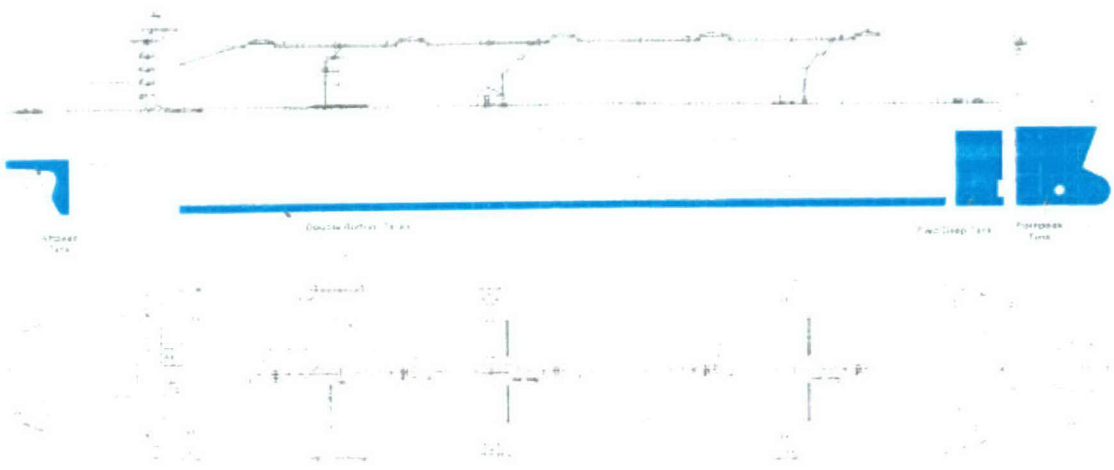

Figure 12. Gas carrier profile and deck plan.

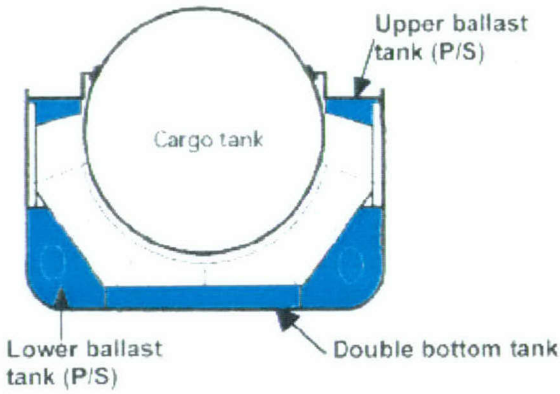

Figure 13. Gas carrier midship section.

Combination Ore/Bulk/Oil Carriers

Typical combination ore/bulk/oil carrier ballast tank configurations are shown in Figures 14 and 15. The tank arrangements normally include forepeak, aft peak, wing and double bottom tanks.

General Cargo Ship

Typical general cargo carrier ballast tank configurations are shown in Figures 16 and 17. The tank arrangements normally include forepeak, forward deep, aft peak, wing and double bottom tanks.

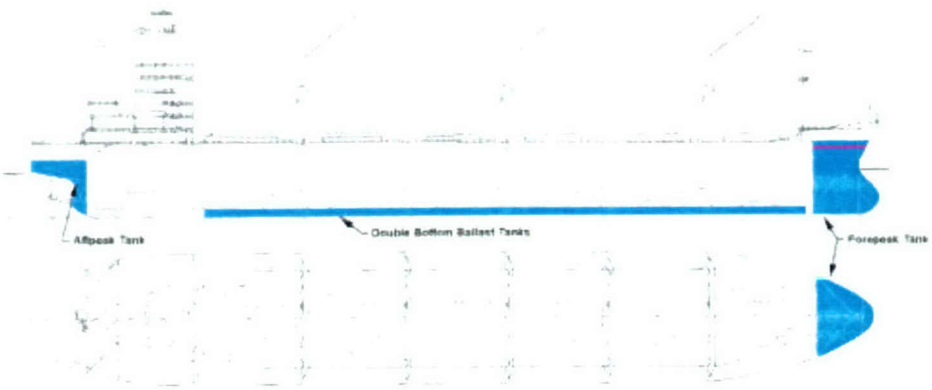

Figure 14. Combination Ore/Bulk/Oil carrier profile and hold plan.

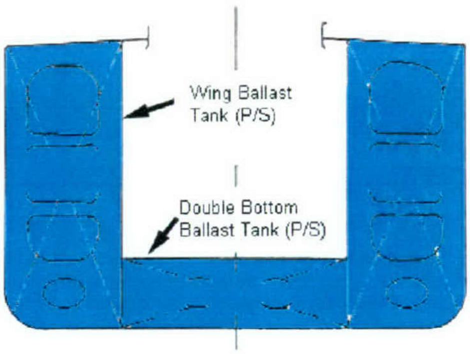

Figure 15. Combination Ore/Bulk/Oil carrier midship section.

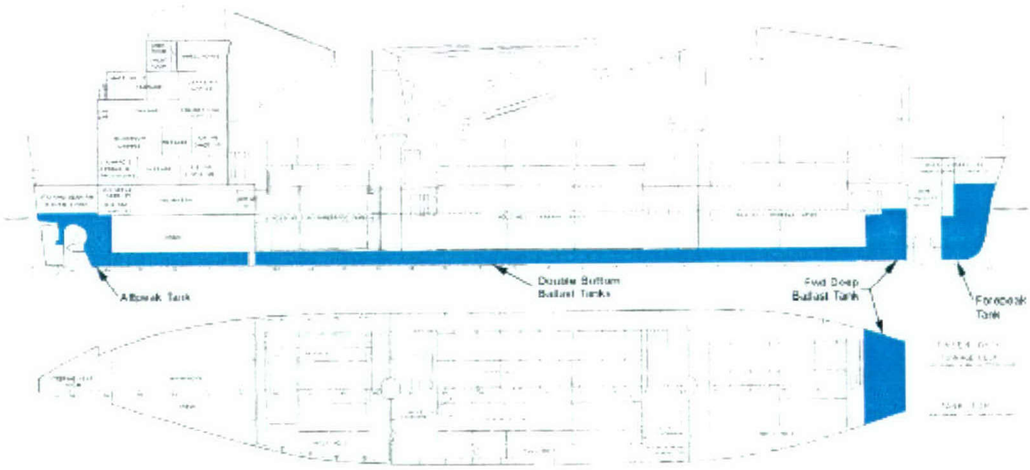

Figure 16. General cargo ship profile and deck/tank top plan.

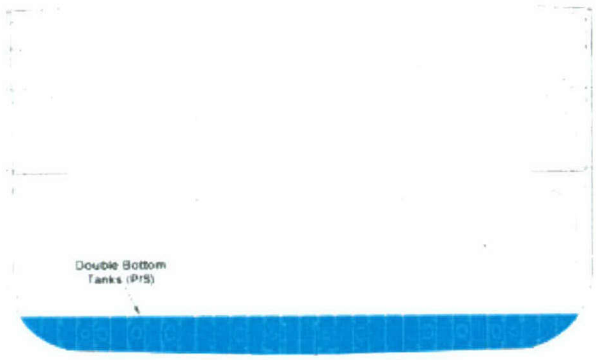

Figure 17. General cargo ship midship section.

2.5 Ballast Tank Access

Typical means of access to ballast tank contents for ballast water sampling are as follows:

1. Manholes
2. Sounding tubes
3. Overflow/vent pipes
4. Ballast pump discharge and overboard discharge piping
5. Cargo hold hatch

All of the ships types being considered in this study have access openings 1 through 4 above available as possible sampling points. Bulk carriers and OBO's have the additional sampling point of the cargo hold hatches.

2.5.1 <u>Manholes</u>

The main access to ballast tanks for inspection, maintenance and repair is through bolted steel manholes (see Figure 18). Manhole accesses will be found normally in the tank top, but may also be found on the sides of tanks, particularly on lower wing ballast tanks as found on container ships. Manholes are either oval or round. The covers are bolted down on flexible gaskets. For typical ship construction the minimum clear opening for a round hole is 18-20 inches in diameter and 15-inch by 23-inch for an oval opening. Manholes can be either flush or raised. A flush manhole cover can vary in plate thickness from ¼-inch to ½-inch depending upon the application. Closely spaced steel studs threaded or welded into a reinforcing ring with nuts secure the cover. ASTM (1995) is one source for typical shipboard manhole specifications.

Raised manhole tank accesses and covers are sometimes also used. Raised manhole covers are bolted to the flange of an inverted angle welded around the edge of an opening. The boundary angle prevents liquids or dirt from spilling into a tank when the cover is removed.

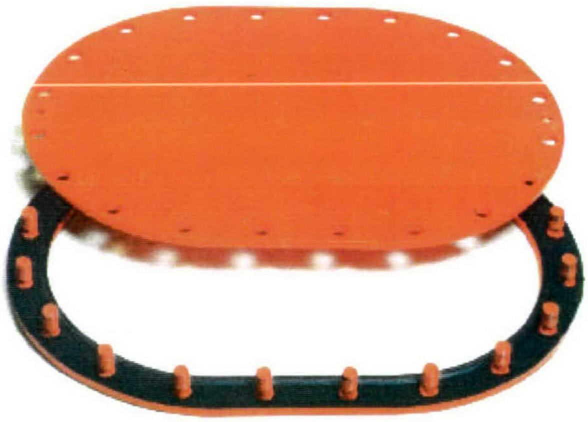

Figure 18. Typical manhole cover.

2.5.2 Sounding Tubes

Sounding tubes are installed to ascertain the height of the ballast water in the tank. Sounding tubes are usually located in the deepest part of the tank. A weighted tape measure is dropped down through the sounding tube and the level of water is read off the tape and compared to sounding tables which give water capacity vs. depth of water in the tank.

Sounding tubes are generally fabricated with a minimum 1½-inch iron pipe size (IPS) pipe (internal diameter of 1.61 inches). They generally extend 30 to 36 inches above the tank top or local deck. They are sometimes fitted with caps on the bottom end to prevent the sounding tape weight from damaging the tank bottom plate. In other instances the bottom end of the tube is open and there is a striker plate welded to the plate just below the bottom of the tube. The striker plate protects the tank bottom plate. Sounding tubes can be solid or perforated with holes along their length. The top of the sounding tube is fitted with a self-closing gate valve if the sounding tube terminates below the bulkhead deck. As a general rule almost all ballast tanks have sounding tubes. Sounding tubes are run as straight as possible, ideally with a minimum bend radius of 10 feet. Figure 19 shows a typical sounding tube termination above a deck.

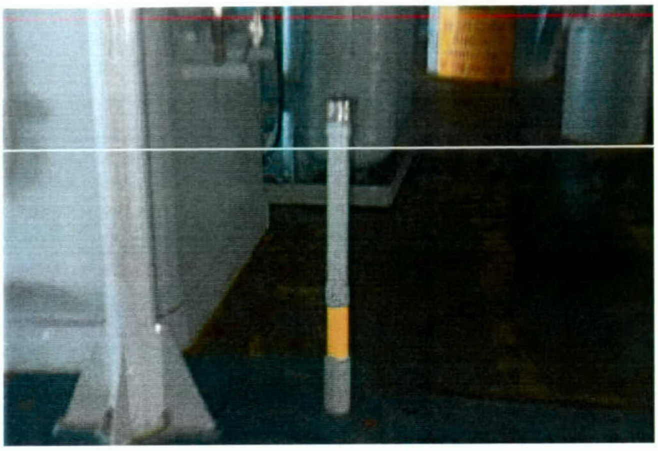

Figure 19. Typical sounding tube.

There are numerous problems with using sounding tubes as ballast tank accesses. These include limited internal diameter of the pipe (typically 2 inches at the maximum), biofilm buildup, corrosion and the fact that the water in the tube may not be a representative sample of the entire ballast tank contents.

2.5.3 Tank Vents and Overflows

Vent lines must be installed for all tanks fitted with flooding and discharge lines unless, similar to a cargo hold, they are open to the atmosphere. The vents will allow the tanks to be flooded or emptied by pressure or by gravity. When the tanks are filled or emptied by pump pressure, vent lines are normally sized to be 125 percent of the effective area of the filling pipe. Classification society rules normally require a minimum vent pipe size 2-inch IPS (minimum internal diameter of 2.06 inches). Vent lines also prevent a tank from being subjected to a vacuum when deballasting. Ballast tank vent lines that terminate above the weather deck are fitted with non-return valves. More than one vent line is often fitted if the tank is oddly shaped. Several vent lines from different tanks are sometimes combined into one riser.

When a tank is filled under pressure it must be protected with overflow lines that are open to the atmosphere. Overflow lines are sized so that the combined static head and dynamic head in the overflow line during an overflow condition will not exceed the test head of the tank. In some ships standpipes are installed instead of overflows to minimize the impact of large overflow pipes on vessel arrangements. Overflow lines must not have any shutoff valves. In addition, they must terminate to the weather, either above the weather deck or through the side shell above the load waterline. Overboard discharges through the side shell have a non-return valve arrangement on the inside, the arrangement and type of which depends upon the location of the discharge relative to the load waterline.

Vent lines may be taken from the top of tank overflow lines, but weather deck terminals cannot be used for the dual purpose of tank venting and overflow. All vent lines must extend above the top of overflows to a height where overflow lines cannot discharge through the vent terminals.

It should be noted that the vent and overflow lines are separate systems from the ballast tank fill/discharge lines. They do not have perforations. They often contain many bends and small radii, and unlike sounding tubes that extend down to the bottom of the tank, they extend down only to the top of the tank.

2.5.4 Ballast Tank Pump Discharge and Overboard Discharge Lines

Ballast water can be sampled from taps either downstream from the ballast pump discharge line or, depending upon the location of the overboard discharge, from the ballast piping system overboard discharge through the shell of the ship. The overboard discharge may be located in the side shell, but more often than not, the discharge is located in the bottom shell, below the light-load water line. The discharge side of the ballast pump may have a small valve from which water could be bled.

2.5.5 Cargo Hold Hatches

Accesses on a weather deck to ballast tanks are usually raised access hatches as shown in Figure 20. The access has a diameter (roughly 48 inches) that is large enough for a person to climb through it. The figure also shows a smaller ullage hatch. The ullage hatch allows soundings to be taken while underway. This type of access is seen most often on tankers or bulk carriers. Container ship and bulk carrier cargo holds have large sliding or lift off covers instead of ullage hatches, which must be moved with the assistance of a shore side or ship mounted crane.

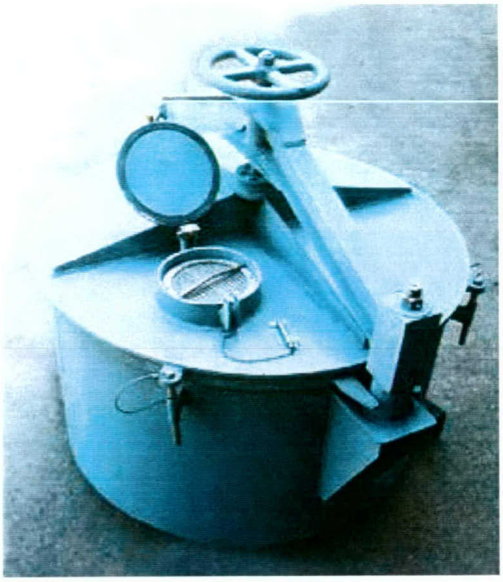

Figure 20. Cargo hold access hatch.

2.6 Ballast Tank Access Suitability for Sampling

There are four primary methods employed to collect ballast tank samples:

1. Nets
2. Pumps
3. Discrete water depth samplers
4. Sampling water from ballast water discharge pipe

Much of the following discussion is taken from Sutton (1998). There are many factors involved in deciding which sampling technique is to be employed such as:

1. Ballast tank configuration
2. Tank accessibility
3. Physical constraints of tank access
4. Invasive species or water chemistry for which screening is being conducted
5. Requirements of sampling technique
6. Ship's schedule

7. cooperation and availability of crew

This section gives the pros and cons of item number two from the list immediately above, (tank accessibility), with regard to the five ballast tank accesses described in Section 2.5.

2.6.1 Manholes

Considerations when sampling via manholes:

Pros

- Relatively direct and simple to access
- Open access to drop pump, net or water profiler
- Obtain samples from different levels
- All ballast tanks have manholes

Cons

- Not always accessible, blocked by cargo
- Crew required to remove many cover nuts, which can be time consuming
- Internal tank structure may block access
- Limits size of sampling equipment
- Light entering tank may bias biological sample
- Watertight gasket may be damaged
- If seas are rough and the ship is rolling, water may slosh onto deck
- Tank may be under a static head that prevents removing the cover
- Tanks may be pressed up for stability considerations and are not to be opened

2.6.2 Sounding Tubes

Considerations when sampling via sounding tubes:

Pros

- Simple and fast
- As a general rule all ballast tanks have sounding tubes
- Sounding tubes are almost always accessible
- If sounding tube is perforated, samples from different levels are possible
- Pumps can be used to obtain samples

- No crew assistance required
- Good access for measuring salinity or chemical composition of contents
- Sediment samples may be possible

Cons

- Biofilm may build up in tube and contaminate or bias sample
- If tube is not perforated sample will not be representative of tank contents
- If pumps are used, capacity of pumps may be limited due to tank depth and head capacities of pumps. Different types of pumps are required for different tank depths
- Sampling of large motile species may be missed
- Sediment may contaminate sample if taken from bottom of tube only
- Some experience and training needed to quickly and accurately determine water level on sounding tape
- Sounding tube internal diameter limited to approximately 1½ inches
- To filter a volume of water equivalent to that sampled by a net requires long pumping times, particularly when tanks are partially empty
- A power source for the pumps with correct voltage and receptacles is necessary. Use of a gasoline pump may be prohibited.

2.6.3 Tank Vents and Overflows

Considerations when sampling via tank vents and overflows:

Pros

- Samples can be obtained when tanks are being "pressed up" or filled to overflowing

Cons

- Ship must be in process of pressing up in order to obtain sample when overflowing
- Many vent or overflow deck terminations are combined from several tanks
- Actual vent terminal and non-return mechanism make it difficult to obtain access into the pipe itself
- Piping systems were never designed for the practical insertion of probes

2.6.4 Ballast Pump Overboard Discharge Piping

Considerations when sampling via ballast pump overboard discharge piping:

Pros

- Theoretically, sampling tank contents from an overboard discharge provides a reliable cross section of the diversity, number and viability of invasive species
- Bucket sampling is the only practical method
- Samples can be taken over the entire deballasting cycle
- Samples can be taken either while tanks are emptied by gravity or under pump pressure

Cons

- Samples must be taken when the ballast pump is operating over a long period of time
- Contents of tank are being discharged into the receiving waters
- Access either by hanging a bucket over the side of the ship or using a small boat alongside, which is only somewhat practical in a calm, protected area
- The overboard discharge has to be through the side shell, above the water line

2.6.5 Ballast Pump Onboard Discharge Piping

Considerations when sampling via ballast pump discharge piping:

Pros

- Allows accurate sampling of water chemistry from different strata as tank is drawn down
- A sampling valve or cock can be installed directly in the piping
- Samples can be taken over the entire deballasting cycle
- Samples can be taken either while tanks are emptied by gravity or under pump pressure
- Samples can be taken during transfer between onboard tanks

Cons

- Samples must be taken during deballasting operations
- Contents of tank must be discharged into receiving waters
- Biological samples may be damaged by high velocity of discharge flow
- The long duration of time involved to ballast different tanks will allow different species to be picked up as a function of the tide, and the samples taken may not be representative of the entire tank contents
- Crew needed to operate pump
- Sampling valves may need to be installed
- May be some uncertainty as to from which tank sample is taken

2.6.6 Cargo Hold Used as a Ballast Tank

Considerations when sampling cargo holds used as ballast tanks:

Pros

- Direct and quick access throughout depth of hold
- Pump, net and whole water sampling methods can be used, depending upon size of access

Cons

- Potentially dangerous to personnel leaning over open hatches
- Light may contribute to sampling bias (biological sampling only)
- Requires much assistance from the crew, possibly cranes
- May be very impractical from a ship operations point of view
- Hold contents may be contaminated by cargo carried prior to loading ballast water

2.7 Tank Accessibility

The arrangements of ship's cargo can lead to ballast tanks being completely inaccessible. In addition, tank internal structure can interfere with the ability to drop a sampling device to the lowest depth of the tank.

Forepeak, deep and aft peak tanks are almost always accessible, unless one deep tank is on top of another. Access to double bottom, deep and lower wing ballast tanks is often blocked by cargo. Ships that have weather deck access to wing ballast tanks can still present a problem to sampling since they may be oddly shaped (e.g. Figure 5). Due to this configuration, sampling access to the lowest part of the tank near centerline is not possible. Tank top accesses are often off to one side so that there is not a clear path to the deepest part of the tank in forepeak and aft peak tanks, which typically have significant curvature of the tank side shell. If a lower wing ballast tank access is not blocked by cargo, access may still be prevented due to the tank being under a head of salt water.

Taking discrete samples from different points in a double hull tanker wing ballast tank can be hard to accomplish because the tank section under the cargo block may not be accessible directly under the access hatch. The newer double-hulled tankers are constructed to have as little structure within the cargo tank as possible to facilitate easier tank cleaning and cargo flushing. This means, however, that the adjacent ballast wing tanks contain all the framework and strength members for the cargo block. Sampling from the access hatches is difficult since the sampling device would have to pass through and around many of the structural members to obtain multi-depth samples.

Often for safety in entering empty tanks, the access hatches will have a ladder that extends partially into the tank and ends at large horizontal girder that acts as a landing. The ladder then extends from the side of that landing down farther. This is done to prevent a person who may fall off the ladder from falling completely to the tank's bottom. This is good for personnel safety but makes access to stratified samples difficult. Newer requirements for easy tank access from the International Maritime Organization (IMO) may expedite tank sampling. These new rules require that there be a clear access from the tank bottom all the way to the weather deck so that an injured person can be lifted out of the tank in a litter. Figure 21 shows typical internal tank structure for a tank ship with the inboard wing tank plate removed.

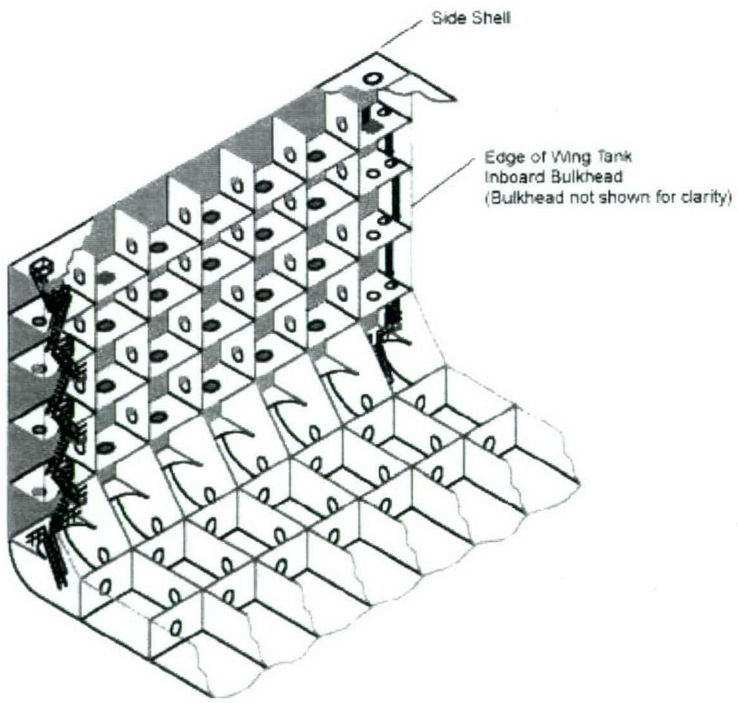

Figure 21. Typical tank structure

3.0 THE EFFECT OF SAMPLING METHODS ON ACCESS REQUIREMENTS

The entire ballast water verification process is, in effect, a decision tree which begins with the reason for testing, either compliance or research. In turn, determining which ballast tank to test depends on tank arrangements, time available, ship operations and crew availability. The invasive species or water chemistry to be identified, the physical constraints of the tank access and the physical constraints of the portable testing equipment further determine the approaches taken by sampling personnel. Ballast water can be tested for the presence of many different invasive species, contaminants and characteristics of water chemistry, including:

1. Sediments
2. Temperature
3. Salinity
4. Nutrients
5. Heavy metals
6. Biofilm pathogens
7. Phytoplankton
8. Zooplankton

Whereas invasive species research might address all eight of the above items, practical onboard methods for determining ballast water exchange require protocols that can quickly and easily show compliance. Compliance testing protocols therefore focus on water chemistry.

The issue of successfully validating ballast water exchange rests upon the ability to easily differentiate between coastal waters and open ocean waters. Currently the most promising sampling tests (the details of which are presented in Murphy *et al.*, 2003) include the following chemical analyses for verifying compliance with ballast water exchange requirements:

1. Salinity
2. Trace metals
3. Colored dissolved organic matter (CDOM)
4. Radium

According to Murphy *et al.* (2003), the test for radium requires a large sample (approximately 55 gallons), the test for salinity is conducted by a probe, and tests for trace metals and CDOM require samples of 10 mL and 100 mL, respectively. Testing for the presence of phytoplankton and zooplankton is performed more for research than compliance. Sutton *et al.* (1998) provides a good summary of ship types, ballast water sampling locations on board, sampling methods and sampling equipment used in worldwide research over the past 10 to 15 years.

Currently ballast water exchange testing for water salinity is performed by the USCG on ships entering the Great Lakes. Sampling is performed using a piece of ½-inch PVC pipe suspended on a sounding tape. Ballast water exchange compliance is tested for with a handheld refractometer. Within the constraints of the testing program, the preferred method of tank access is the tank sounding tube.

3.1 Sampling Equipment

Possible sampling equipment used in ballast water exchange testing are:

1. Remote-actuated collection bottle
2. Syringe sampler
3. Pumps
4. Bucket
5. Rigid hose

It should be kept in mind, as described in Murphy *et al.* (2003), that the use of any of the aforementioned sampling equipment requires all samples to be conscientiously protected from contamination so as not to invalidate the results. This reference identifies many onboard sources of contamination such as clean metal structures, rust, fuels, aerosols, dust, sediments, organic matter, human hands, sampling equipment and storage containers.

3.1.1 Remotely Activated Collection Bottles

Remote actuated collection bottles are used to collect a volume of ballast water at a desired tank depth. They require a manhole or hatch cover to be opened for access into the ballast tank in order to lower the bottle manually and collect the sample at a desired depth. Obstructions in the tank such as ladders or framework may inhibit the ability to obtain samples from desired places and depths in the tank. Remote actuated bottles can also be used to obtain samples for testing for the presence of phytoplankton and zooplankton.

There are many remote actuated bottles used in limnological and oceanographic water sample collection protocols. Typical collection devices include Nisken bottles, Van Dorn vertical water samplers, Kemmerer water samplers and Ruttner bottles. All of these devices are lowered down a messenger line and are "tripped" by the operator to collect a water sample. The average overall diameter for these instruments to obtain a sample volume capacity of 33 ounces is approximately 7 inches. All of these samplers require access to the ballast tank via an open manhole or open cargo hatch.

A remote actuated water sampling device that is smaller in size to the bottle samplers is the bomb sampler which is a device with a plunger assembly that is activated automatically when the sampler contacts a hard surface such as the bottom of a tank, or it may be activated by the operator at various depths with the use of a pull line. One stainless steel model has an OD of 1-1/8 inches and a length of 15 inches. The sample size collected is only 4 oz, but it may have an application if used in sounding tubes.

3.1.2 Syringe Samplers

Syringe samplers are used to collect discrete water samples of approximately 60 mL where the only access is through a small opening. With an OD of 1¾ inches the syringe sampler could be used in some sounding tubes if the ID of the tube is greater than 1¾ inches. As with the actuated sample bottle samplers the syringe is lowered into the tank by hand to collect a sample. The syringe is removable, which helps to prevent contamination of the sample by reducing handling and transfer of the sample.

3.1.3 Pumps

Pumps are useful in that they can provide a variety of flow volumes and can be used to draw a sample though sounding tubes, open manholes and open cargo hatches. The most common portable shipboard pumps are driven by electricity or air. Portable pumps can also be driven by a battery or gasoline. On-deck power sources, tank access and head vs. flow characteristics of the pumps dictate the best pump to use. Air is usually available on the decks of most ships. Gas powered pumps would be the least desirable option because of regulations on the use of gas engines on tankers, gas carriers, and any ship being tested in port during fueling operations. Portable AC powered electric pumps brought onboard would require various electrical accessories and transformers to ensure compatibility with shipboard power. DC powered pumps are powered by batteries that are brought on board by the testing personnel.

Pump types commonly used to collect ballast water samples include diaphragm, centrifugal, inertia pumps and submersible pumps. Diaphragm pumps are driven by air, electricity or gasoline. Air operated diaphragm pumps are relatively lightweight and provide a flow rate between 13 and 40 gallons per minute for sampling tanks where the water will have to be lifted no more than 25 feet. A length of hose fitted with a foot valve will aid in priming the pump.

Centrifugal pumps are normally driven by electricity and sometimes gasoline. They are used in shallow tanks where the lift requirements do not normally exceed 25 feet. Representative flow rates are 1 to 3 gallons per minute.

To accomplish testing of deep tanks with a lift greater than 25 feet, an inertia pump is used. Inertia pumping is accomplished by the action of pushing a semi-rigid hose fitted with a ball type foot valve up and down in the confines of a pipe similar to a sounding tube. The lift capacity would handle any lift range encountered on a vessel at varying flow rates up to 3 gallons per minute, depending on hose size and length.

Single stage or multi-stage battery-operated 12-volt submersible pumps, designed for well purging and testing, can also be utilized. Battery operated pumps are available in a variety of styles with lift ranges to 70 feet. This type of pump will develop sufficient flow for testing at rates up to 4 gallons per minute but the 9½-inch body length of the pump may not pass through sounding tubes with small radii.

Pumps are used to obtain ballast water samples from sounding tubes, manholes, vent and overflow lines and in-line ballast piping. Using pumps to collect samples through sounding tubes is by far the easiest and quickest method to access ballast tanks without modifications, and with minimal assistance from the ship's crew. Sutton *et al.* (1998) recommends that using pumps in sounding tubes is a very practical sampling method where larger than discrete fixed volumes of ballast water are required, such as in the case of obtaining zooplankton samples; however, due to the potential of sample contamination due to the presence of a biofilm in the sounding tube, the use of pumps is only recommended if a sequential method of ballast exchange is performed. In other words, the ballast tank must be completely emptied and then refilled. If the flow-through method of ballast exchange is used, in which "new" ballast water is continually pumped into the tank as the "old" ballast water is pumped overboard, then the water in the sounding tube may not fully exhange, and therefore may not properly represent the water in the tank. Likewise, biofilm may be present and contaminate samples.

3.1.4 Miscellaneous Sampling Equipment

Other sampling equipment includes buckets and rigid hoses. Buckets are used in full or partially full tanks to obtain water samples from the surface. Buckets are also used to collect samples from overboard discharges. If sampling from an overboard discharge is not practical, buckets require open manholes or hatch covers due to their size. Finally, rigid tubing is used to obtain a small sample by lowering the tube, generally through sounding tubes, capping off the top and withdrawing the tube. Use of rigid tubing is considered to be impractical due to the length of tubing that would have to be carried by the boarding teams.

3.2 Summary of Sampling Equipment Considerations

As the previous paragraphs have described, several different pieces of equipment can be used to collect the same sample. The choice of equipment is dependent upon what type of testing is being conducted, either research or compliance. Research tests will generally have more time allotted to sample gathering and will allow the use of more complicated support equipment such as portable pumps and crew assistance. Portable pumps require compatible power sources, proper head and flow characteristics, hoses and coordinated logistics, which will not generally be available to the on-site regulatory compliance team. The logistics of using a smaller multi-stage pump is not as onerous on the sampling team as is the use of the larger centrifugal, inertia or diaphragm pumps. Long stiff hoses are heavy, bulky and hard to keep "sterile." Remotely actuated collection bottles, syringe sampler, or a small, direct-measuring probe on the end of a long cable are the most practical sampling devices.

4.0 RECOMMENDED DESIGNS OF ACCESS PORTS FOR BALLAST TANK SAMPLING

Sections 2 and 3 presented various common ballast tank configurations, accesses and ballast water sampling equipment. In order to provide access for ballast water sampling, from a practical point of view, it is necessary to provide quick and easy access to the ballast tanks. In-port times are busy, and with newer ships carrying fewer crewmembers, crew availability to assist sample takers may be limited. There are also issues with regard to safety, knowledge of tank access locations, the level of liquid in the ballast tanks and interference with ship operations, all of which complicate the sampling exercise; therefore, it is imperative that ballast tank accesses be "as accessible" as possible so that the sampling procedure interferes as little as possible with ship operations.

Section 2 presented possible points of access to ballast tank water which include bolted manholes, sounding tubes, vent and overflow lines, ballast pump discharge piping and cargo hatches. Section 3, in part, indicated that a maximum access dimension of 8 inches is required to accommodate practical onboard testing equipment. With due regard to these findings, this section addresses only manholes and ballast discharge piping as existing accesses that can be readily retrofitted. Access through cargo hatches requires the removal of the hatch cover itself. Sounding tubes cannot be modified practically, and testing equipment must be chosen to fit the dimensions of the sounding tubes. Vent and overflow lines are impractical points of access since often the lines from several tanks are combined into one riser and weather deck fitting. In addition, unlike sounding tubes, there are usually many sharp bends in the vent and overflow lines since they were never designed or installed with the intention of dropping probes down their length.

One other alternative for ballast tank access is the installation of a new pipe penetration with a valve into the side or the top of a ballast tank, through which ballast water samples could be drawn off as required. This type of tank access holds some merit, but the cons outweigh the pros. Multiple pipe penetrations must be installed at different heights in order to avoid any stratification in the ballast water. Most ballast tanks are bounded either by the ship's side shell or bulkheads. The other sides of bulkheads are usually cargo holds or tanks, which may be blocked due to the presence of cargo. Even if the bulkhead is accessible with multiple penetrations arranged vertically, there may be a problem with access to the valves due to the height of the penetrations. The penetrations are also vulnerable to damage. Penetrations in the side of a tank would only be practical for drawing off samples similar to those obtained from deck hydrants or ballast pump discharges. It is possible to install large valves in tank tops that will provide 8 inches of clear access through the body of the valve, but the valve would be very expensive, and a more cost-effective option would be to install accesses as described in the following paragraphs.

4.1 Manholes

The least disruptive retrofit for easy access to a ballast tank is to insert a quick-acting sampling hatch within an existing bolted manhole cover. Time and effort is obviously saved if the many nuts and washers associated with a bolted manhole cover do not have to be removed. This retrofit is only applicable to a bolted manhole cover in the tank top of a ballast tank. If an existing manhole cover were blocked, another alternative would be to install a new quick-acting sampling hatch in the tank top. Installation of sampling hatches in the sides of tanks is not recommended, as it would require having to drain the tank below the level of the access prior to opening the hatch. Also, as a rule, most side access bolted manhole covers are blocked by cargo.

The installation of a quick-acting sampling hatch must be engineered prior to cutting steel. Common shipboard tank ballasting practice is to fill a ballast tank until the water is overflowing through a weather deck vent or overflow. The static head of water in the overflow line above the tank top places the top of the tank under an internal pressure. The sampling hatch must be capable of withstanding this internal head pressure. A practical aspect of the sampling procedure is that the sampling hatch cannot be opened, and the sample cannot be taken, until the static head is reduced. Cutting holes in a manhole cover or a tank top require prior approval from the ship's owner and the classification societies. Basic plans and engineering calculations must be submitted and approved to ensure adequate strength to maintain the integrity of the tank top. The installation might be performed while underway, if the tank is not being used. Any welding will require hot work permits. The location of new holes in the tank top must be considered carefully with due regard to its location to other tank top openings, particularly if the tank top involved is the strength deck.

Each tank top or existing manhole will have its own internal pressure requirements. There are two generic types of quick-acting sampling hatches that are recommended for retrofitting to existing ships. Type A is a quick-acting flush hatch with an integral handle, and the hatch forms a watertight seal through the action of a dogging or clamping system. Type B is an ullage cover, which was originally designed primarily to provide easy access into cargo oil tanks for sounding when open cargo filling and discharge operations with venting to the atmosphere were allowed. An ullage cover is often contained within another larger watertight hatch which provides personnel access into the cargo oil tank. This same arrangement of an ullage cover within a larger hatch is used for access into ballast tanks on double hull tankers, an example of which can be seen in Figure 20.

Type A Sampling Hatch Cover

A Type A sampling hatch cover is a flush, quick-acting, watertight deck hatch commonly used in the marine industry. Hatch materials can be ductile steel or aluminum to suit the individual installation with regard to strength required. Cover weights range from 7 pounds for an 8-inch aluminum cover to 21 pounds for an 8-inch ductile iron cover. This type of hatch is quick-acting, requiring only a quarter of a turn to open the hatch immediately. The handle is built in. There is positive locking with a four dog clamping arrangement. The hatch is normally installed flush, but it can also be installed on a raised coaming. The gasket/sealing arrangement of the ductile steel hatches can withstand an internal pressure of 136 feet of salt water, and the aluminum hatch can withstand an internal pressure of 68 feet of salt water. The aluminum covers can be supplied with a steel ring for insertion into a steel deck or manhole cover. All components are designed for marine use, and the dogging mechanism can be adjusted periodically to ensure proper operation and sealing.

Many of these hatches already have classification society type approvals for certain specific intended uses that may or may not be applicable to individual installations under consideration within the scope of this report. This type of hatch is very common in the marine industry on smaller vessels; however they are not seen as often on large ships, which is probably a matter of tradition and shipbuilding practice, more than any other factor. This hatch can be retrofitted into an existing manhole cover or directly into the tank top. Figure 22 shows the installation of a Type A hatch cover in a manhole cover.

Costs associated with the installation of an 8-inch Type A sampling hatch in a manhole cover plate are estimated to be $3000 in a representative U.S. yard. This price includes engineering, material costs, cutting the cover, installing the ring insert, testing and classification society approvals.

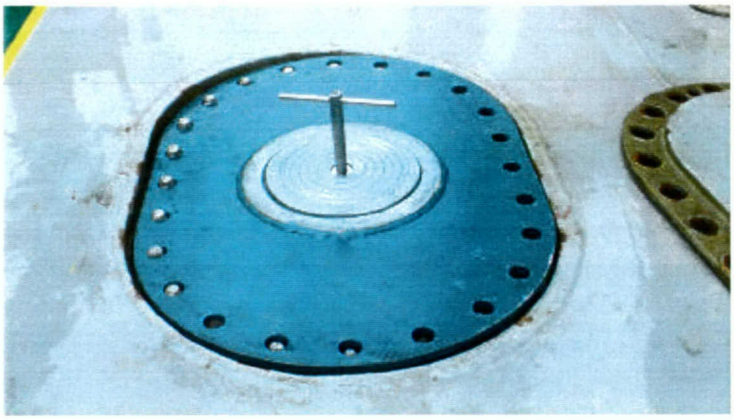

Figure 22. Sampling hatch in manhole cover.

The main disadvantage with the Type A cover is that if the tank is under a static head, once the hatch is opened there is a good certainty that it cannot be closed again. In addition the hatch might cause an injury to the crew opening the hatch due to the upward force that the internal pressure causes. It is recommended that this type of hatch only be installed in locations where the internal head can be determined prior to having to open the hatch.

<u>Type B Sampling Hatch Cover</u>

The Type B sampling hatch cover has been in common use for many years on board ships. Figure 23 is a drawing of a typical ullage cover. Ullage covers can be placed in manhole covers or directly into the tank top. Their height makes them more susceptible to damage. Just as with the quick-acting hatch covers, they should not be opened unless the ballast water level is below the tank top.

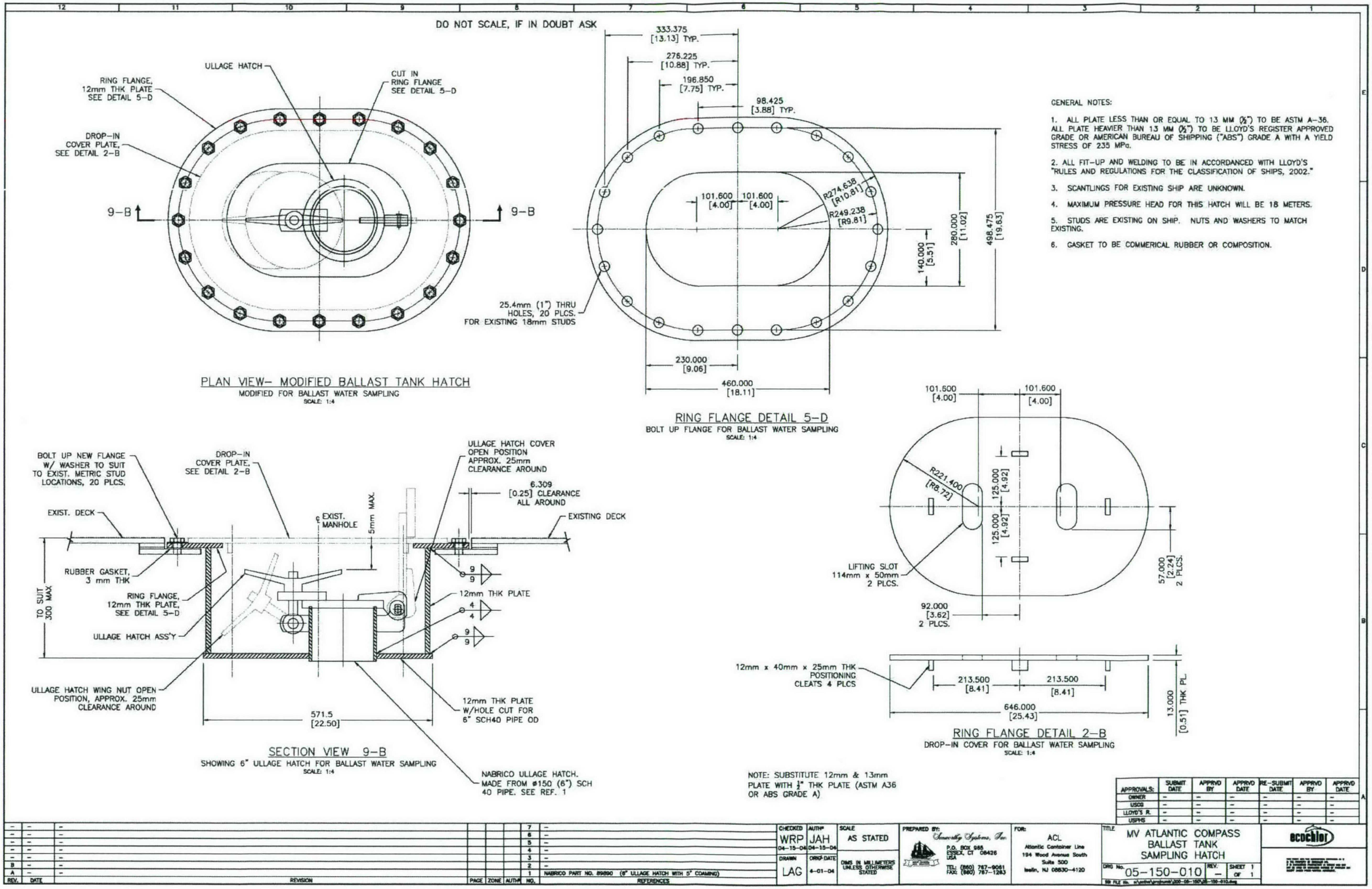

Figure 23. Type B sampling ullage cover in manhole cover.

In the spring of 2004, the author's company installed ullage covers into a modified ballast tank bolted manhole on a RO/RO ship to provide easy sampling access for a ballast water treatment system demonstration. Figures 24 and 25 are pictures of the modified covers prior to and after installation, respectively. The ullage covers had to be recessed with another steel cover over the ullage opening since the tank top was a RO/RO deck that could have vehicles driving on it. In a non-RO/RO deck installation, it would not be necessary to recess the ullage cover. The estimated cost for the modified covers is $3000. This arrangement was approved by the classification society. The modified covers were designed for a static head of 59 feet of salt water. Ullage covers typically have a clear opening of 6 to 10 inches. Maintenance of the covers requires a periodic greasing of the threaded pin. If the cover is not used often the wing nut may bind and require considerable additional effort to turn. Gaskets need to be replaced occasionally, probably once every five years.

Unlike the Type A hatch, this Type B hatch is safer in that if the tank contents are under an internal static head, the cover can be opened ever so slightly without releasing the cover entirely, in order to check for leakage due to the internal pressure without endangering the crew.

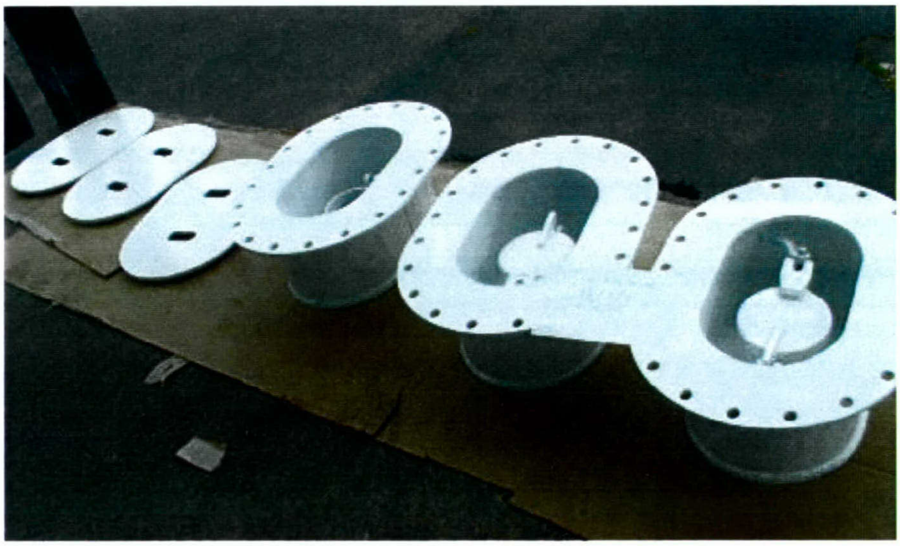

Figure 24. Modified ullage covers prior to installation.

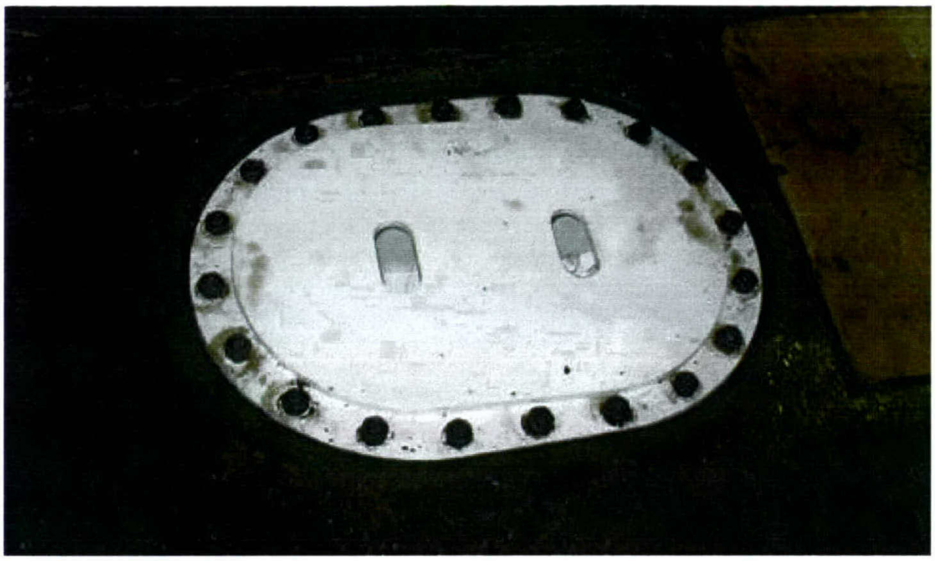

Figure 25. Modified ullage cover after installation.

4.2 Ballast Pump Discharge Piping

Ballast pump discharge lines are often fitted with pressure gauges to assist in determining when the tank is full. The tap into the pump discharge piping can also be used to install a globe valve to enable ballast water to be drawn off for sampling. Figure 26 shows a schematic sketch of the pump discharge piping and sampling valve modifications.

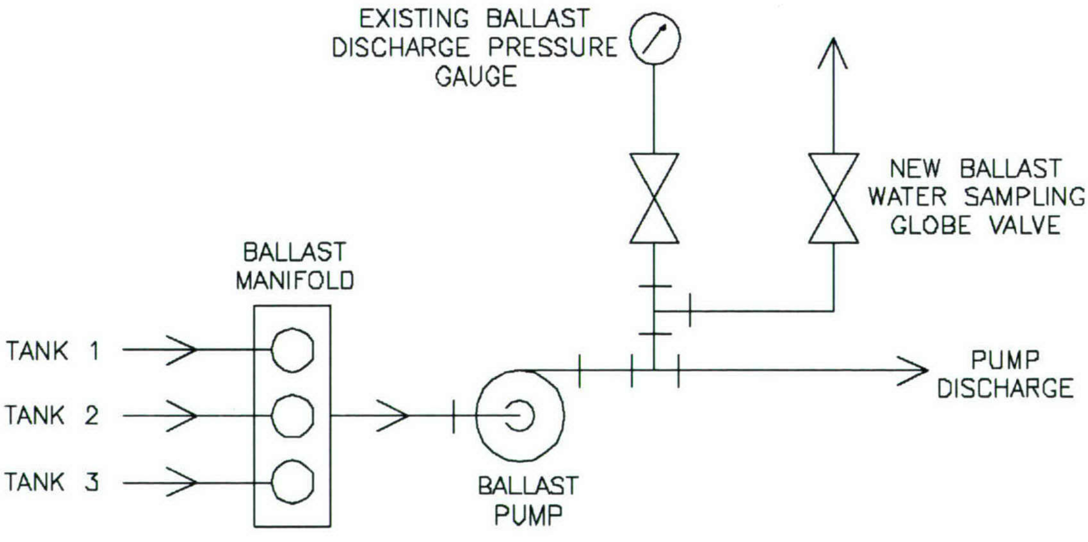

Figure 26. Conceptual ballast pump discharge sampling schematic.

5.0 CONCLUSIONS

1. There are seven major types of ballast-water carrying ships that visit U.S. ports on an annual basis. Ballast tank systems are a large percentage of the tankage onboard the ships. Ballast tank arrangements and accesses within a given class of ships are similar.

2. Ballast tank accesses for compliance sampling must be as user friendly as possible to minimize the survey team's time onboard and disruption to ship operations. Sampling equipment must be simple and portable in order to make the sample collecting process logistically possible.

3. Where top access allows, the best means to accommodate sampling equipment is the installation of quick-acting hatches, or ullage covers in the existing hatches or tank tops.

4. If top access is not available, the best option is to install a sampling valve in the discharge piping as shown in Figure 26.

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