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Ballast Water Treatment, U.S. Great Lakes Bulk Carrier Engineering and Cost Study

Volume I: Present Conditions

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16. Abstract (MAXIMUM 200 WORDS)
The intent of this study is to investigate the design and ballast water management (BWM) practices of US flag vessels operating solely within the Great Lakes; assess the potential for these vessels to install and operate ballast water management systems to kill or remove living organisms; and develop generalized, installation design and cost estimations, including a land-based alternative to shipboard ballast water treatment. "Ballast Water Treatment, U.S. Great Lakes Bulk Carrier Engineering and Cost Study – Volume I: Present Conditions" identifies ballast water practices as related to trading patterns, including an analysis of ballast discharge information with respect to vessel size and type, using information from calendar year 2010. The study selects five vessels that best represent the "full range" of U. S. flag "Laker" trade (including voyage patterns and vessel types). In "Ballast Water Treatment - U.S. Great Lakes Bulk Carrier Engineering and Cost Study – Volume II: Analysis of On-Board Treatment Methods, Alternative Ballast Water Management Practices, and Implementation Costs," we examine the costs to outfit and operate four of the five vessels with installed ballast water treatment systems, and also investigate cost associated with treating ballast water ashore. Importantly, this study does not assess the ability of any ballast water management system or practice to kill or remove organisms in ships' ballast water.

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- Lake Carriers' Association, Rocky River, Ohio
- Van Enkevort Tug & Barge, Inc., Escanaba, Michigan

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EXECUTIVE SUMMARY

This study is an independent assessment from the Coast Guard R&D Center to the Coast Guard Office of Environmental Standards and the Great Lakes National Program Office of the Environmental Protection Agency. The overarching purpose of this R&D Center study is to provide knowledge to assist and inform project sponsors in policy development. The R&D Center does not set Coast Guard policy.

Mitigating and/or preventing the introduction and spread of invasive marine species throughout the Great Lakes system has been an ongoing concern for over 20 years. Multiple studies show that untreated ballast water discharged from seagoing vessels is a significant path for introducing and spreading invasive and/or non-native aquatic species into the region. Other studies theorize that ballast water operations by Lakers[1] and other vessels also tend to spread invasive and non-native species throughout the Great Lakes system. Under the Non-indigenous Aquatic Nuisance Prevention and Control Act of 1990 (NANPCA), and as reauthorized and amended by the National Invasive Species Act of 1996 (NISA), the United States Coast Guard (USCG) is authorized (and actively engaged) in the rule-making process to help prevent the introduction and spread of non-indigenous marine species within the waters of the United States. Recent advances in Ballast Water Treatment (BWT) systems, along with continued international and regional attention on this (worldwide) problem, provide us with potential tools to combat this threat.

The purpose of this volume is to research, document, and understand the variables associated with ballast water transport by United States (U. S.) flag Lakers, including ballast water system design and ballast water management (BWM) practices. Based on this research, a second purpose is to identify five specific vessel/voyage combinations that represent the broad range of vessel/voyage patterns associated with ballast water movement throughout the Great Lakes system. The scope of this work does not include Canadian Lakers or other vessels (bulk carriers, tankers, or barges) that do not trade exclusively on the Great Lakes.

This volume focuses on commodity trade routes and ballast water transport data, which are available through public domain (Lake Carriers' Association website; National Ballast Information Clearinghouse website; USCG vessel database website; Great Lakes and Seaway Shipping website; Great Lakes Information Network website; American Bureau of Shipping (ABS) vessel database (ABS Record) website; and American Steamship Company website) with additional background from two technical reports (McCormick, August 1996; Cangelosi & Mays, May 1996). Detailed vessel information was provided by the vessel owners/operators. Especially helpful to this effort is the information available through the National Ballast Information Clearinghouse (NBIC) website, which provides statistical data on the intake and discharge of ballast water transport throughout the Great Lakes region. Due to the extremely large amount of data available, this research effort focused only on ballast water data from the year 2010 and records associated only with U.S. flag vessels. The analysis provides a clear picture of the magnitude and geographic extent of ballast water transport and the diversity of associated routes, ports, and U. S. flag

[1] "Laker" is the common name for the large and uniquely designed and constructed dry bulk vessels (or carriers) used to transport bulk material commodities throughout the Great Lakes system. U. S. flag lakers usually only transport goods on the four upper Great Lakes and connecting channels, as *most* are limited by their size from transiting the Welland Canal. The primary commodities transported by the Lakers include iron ore pellets, coal, grain, limestone, cement, sand, and salt, and are described in more detail in Section 2 of this volume.

vessels that travel the Great Lakes. Figure 1 through Figure 5 and Table 2 through Table 7 summarize this analysis.

The volume includes a detailed review of Laker trades, and differences among representative vessels – specifically with regard to ballast water systems and ballast water management (BWM) practices. The work selected five vessel/voyage combinations to represent the full range of contemporary U.S. Laker trade. The vessels selected were of various designs and constructed between 1952 and 2000. Four were “typical” Great Lakes self-unloading bulk carriers and the fifth was an articulated tug and barge (ATB.) The trade routes and ballast transport span a range from two ports (one cargo loading and one cargo discharge) to a combination of seven ports (cargo loading and discharge at multiple ports). The vessels and representative routes selected are:

1. Intermediate to Large Capacity 1000’ Laker with a basic route between West Lake Superior (cargo loading) and South Lake Michigan (cargo discharge). This trade route is for iron ore pellets.
2. Large Capacity 1000’ Laker with a basic trade route between West Lake Superior (cargo loading) and South Lake Huron (cargo discharge). This trade route is mainly coal.
3. Older, Small Capacity 700’ – 800’ Laker that operates among South Lake Michigan, Northwest Lake Huron, and West Lake Erie ports. This vessel carries a variety of commodities among multiple ports.
4. Newer, Intermediate Capacity 800’ – 900’ ATB that operates in North and South Lake Michigan, Northwest and South Lake Huron, and West Lake Erie. This vessel carries a variety of commodities among multiple ports.
5. Small Capacity, River Class 600’ – 700’ Laker that operates in North Lake Michigan, Northwest and South Lake Huron, and Lake Erie. This vessel carries a variety of commodities among multiple ports.

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LIST OF ACRONYMS

ABS	American Bureau of Shipping
AR	Arrival region
ATB	Articulated Tug and Barge
BWM	Ballast Water Management
BWT	Ballast Water Treatment
EBDG	Elliott Bay Design Group
ft	Foot
IMO	International Maritime Organization
ITB	Integrated tug and barge
LCA	Lakes Carriers Association
lt	Long ton (2240 pounds)
mt	Metric ton (2205 pounds)
NANPCA	Non-indigenous Aquatic Nuisance Prevention and Control Act [of 1990]
NBIC	National Ballast Information Clearinghouse
NISA	National Invasive Species Act [of 1996]
nt	Net tons (2000 pounds)
RDC	Research & Development Center
SAIC	Science Applications International Corporation
SERC	Smithsonian Environmental Research Center
TDH	Total dynamic head
U.S.	United States
USCG	United States Coast Guard

CONVERSION TABLES

Name of Unit	Symbol	Conversion
Length		
meter	m	
foot	Ft or ‘	= 0.3048 m
Area		
square foot	ft^2	= 0.0929 m^2
Volume		
liter	L	
cubic foot	ft^3	= 0.0283 m^3 = 28.3168 L
gallon	gal	= $3.7854 \cdot 10^{-3}$ m^3 = 3.7854 L = 0.1337 ft^3 = $3.7854 \cdot 10^{-3}$ mt (ρ_{fw} = 62.2 lb/ft^3)
Weight		
kilogram	kg	
long ton	lt	= 1016 kg = 2240 lb
metric ton	mt	= 1000 kg = 2204.6 lb
net tons	nt	= 907.1847 kg = 2,000 pounds
pounds	lb	= 0.4536 kg
Flow Rate		
gallons per minute	gpm	= $6.3090 \cdot 10^{-5}$ m^3/sec = 0.2271 mt/hr
Power		
kilowatt	kW	
Horsepower	hp	0.745 kW

1 INTRODUCTION

The primary goal of this part of the study is to identify and document the broad range of differences among trade routes and vessels, specifically with regard to ballast water systems and ballast water management (BWM) practices of vessels engaged in the United States (U.S.) flag Great Lakes commodities trades. Towards this end, the work identifies five specific vessel/voyage combinations that represent the broad range of vessel/voyage variables associated with transporting ballast water throughout the Great Lakes system.

Section 2 provides a brief perspective on the commodities trades and an overview of the most travelled trade routes of U.S. flag vessels on the Great Lakes. The trade route charts represent a high-level look at the general areas and ports where ballast water is taken into the vessels and where it is discharged.

Section 3 develops and presents an in-depth analysis of the ballast water volumes transported by specific vessels on specific routes. From this analysis, we determine the terminus points of the movement of ballast water, the extent and magnitude of ballast water transport, and the time durations associated with transiting these routes; thus we derive the amount of time ballast water is contained aboard each ship, for each route.

In Section 4, data presented in Sections 2 and 3 are used with defined vessel selection criteria to identify five specific vessel/voyage combinations. Collectively, these five selected vessel/voyage combinations represent the full range of variables associated with contemporary U.S. Laker trade. These variables are grouped into two separate categories:

1. Variables among vessels
2. Variables among trade routes

There are significant differences in the construction, size, propulsion configurations, electrical systems and capabilities, cargo off-loading equipment, and other design aspects of the vessels engaged in trade on the Great Lakes. These differences have definite impacts upon the economic and technical challenges associated with operating and maintaining the vessels, as well as implementing capital improvements onboard the vessels. Similarly, the difference among trade routes – primarily dominated by the different lengths and transit durations of the routes themselves – also has significant influence on the technical efficacy and costs of various Ballast Water Treatment (BWT) technologies and BWM practices.

Section 5 contains written descriptions and graphic representations of the five selected vessel/voyage combinations.

Appendix A through Appendix E consist of the selected five vessels' principal characteristics, drawings, and other technical documentation.

2 TRADE ROUTES

There are a number of specific bulk commodities, along with other general cargos, traded and transported on the Great Lakes system. The greatest tonnage of dry bulk cargo transported on the Great Lakes system is transported by U.S. flag vessels among U.S. ports. This U.S.-to-U.S. port shipping industry trade is a segment of what is commonly referred to as the "Jones Act Trade," and only U.S. flag vessels are allowed to participate in these U.S. coastal trades. Almost all the U.S. flag carriers engaged in this trade belong to the Lakes Carriers Association (LCA). LCA is a marine industry trade organization whose membership includes 17 companies operating over 55 U.S. flag vessels. These vessels range in length from roughly 494 ft to the largest of the Lakers topping out around 1013 ft. In years past, total dry bulk cargo movement by LCA fleet vessels and other U.S. flag Laker operators has exceeded more than 125 million net tons (nt) in a single year. (Note: For purposes of this report and in accordance with LCA's commodities trade information, cargo amounts are provided in net tons (nt).)

The shipping companies that are members of the LCA transported 88.7 million nt of dry bulk commodities in 2010 (Lake Carriers' Association, 2010). The seven major commodities and the net tons transported are listed in Table 1.

Table 1. Commodities trade, year 2010.

Iron Ore Pellets:	42,028,418 nt
Coal (total):	21,539,866 nt
Limestone:	20,410,266 nt
Cement:	2,782,259 nt
Salt:	1,391,239 nt
Sand:	225,593 nt
Grain:	306,872 nt

Figure 1 through Figure 4 *generally* depict the four major commodity trade routes. These routes do not include U.S.-Canada trade, and for the purposes of this work, assume that a vessel does not "back-haul" a cargo en route to a load port (or a nearby port). A full, detailed discussion of Great Lakes trading would include the instances where cargo discharge and load ports are nearby each other. However, when viewed in terms of total ballast water movement, these short trips account for only a small percentage of the total.

The trading routes for the iron ore pellets are shown in Figure 1. The primary trade route for iron is from western Lake Superior, Marquette (Presque Isle), and Escanaba to the lower lakes.

The trade routes for coal are shown in Figure 2. "Western" coal moves from Superior, WI east and south, and from Chicago northward, while "Eastern" coal moves from Lake Erie throughout the lakes.

The trading routes for limestone are shown in Figure 3. The primary trade route for limestone is from the Northern section of Lake Huron and Lake Michigan to the other lakes. There is one location in western Lake Erie that also provides limestone.

The trading routes for cement are shown in Figure 4. There are two U.S. cement plants (Charlevoix and Alpena) that supply all U.S. ports on the lakes.

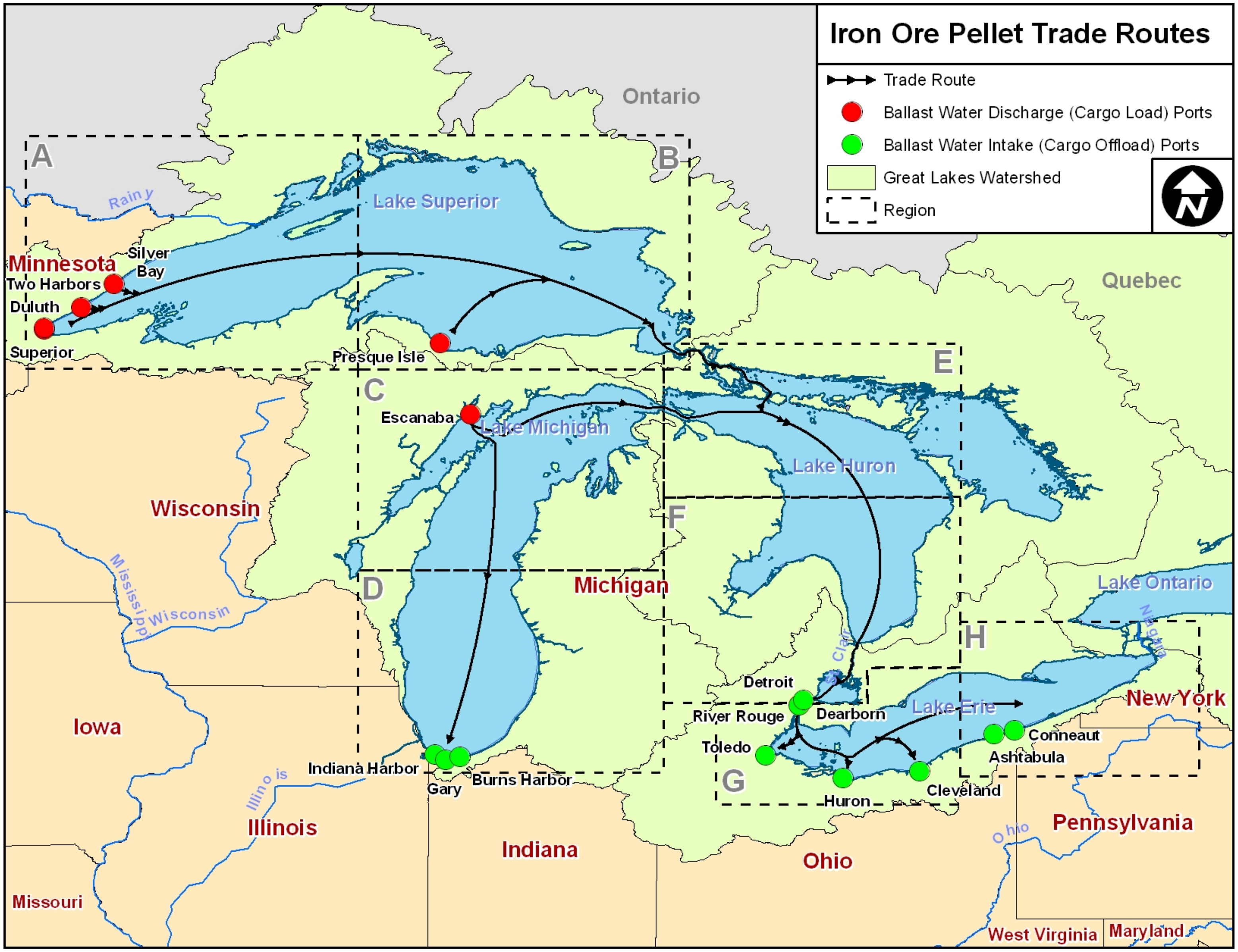

Figure 1. Iron ore pellets trade routes.

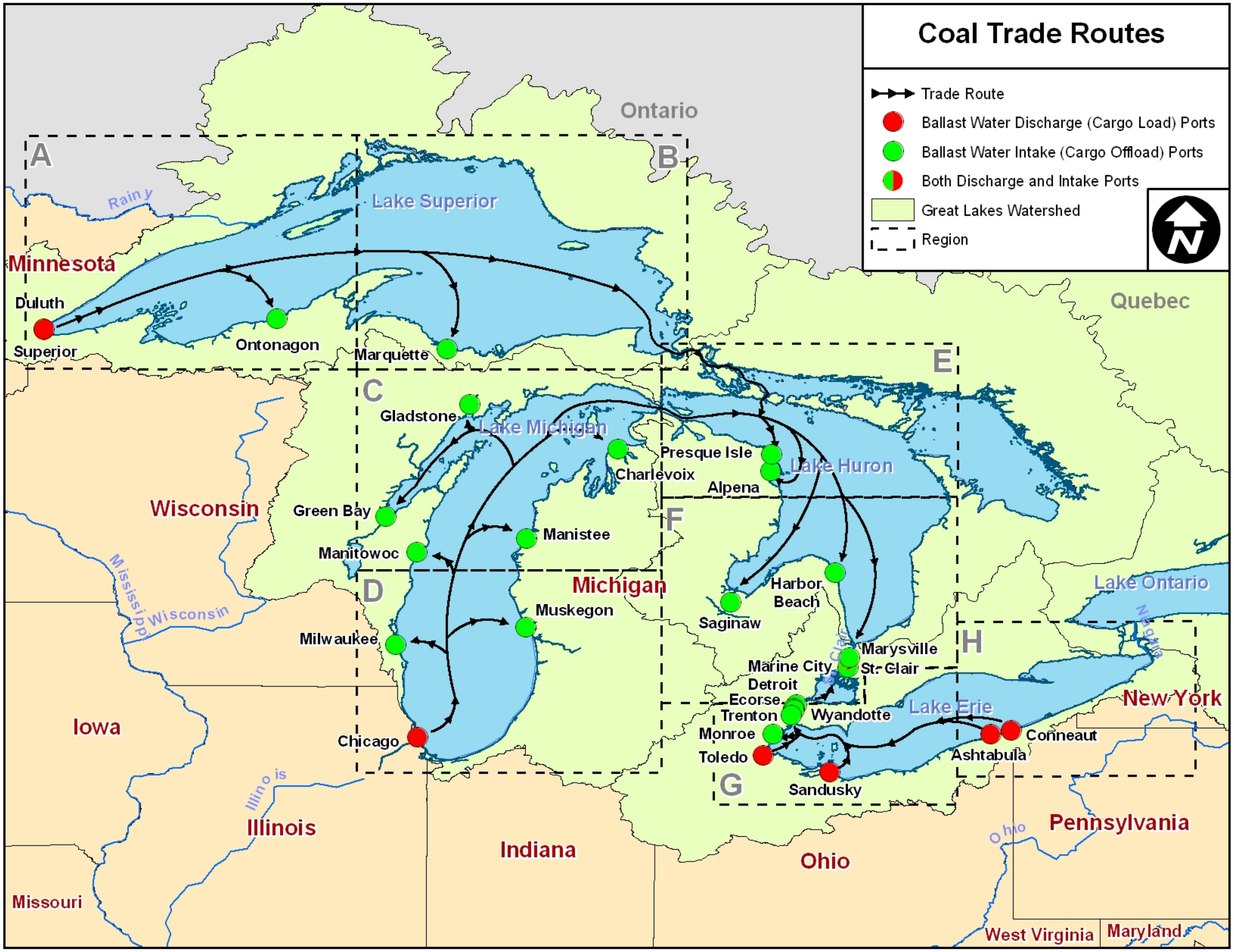

Figure 2. Coal trade routes.

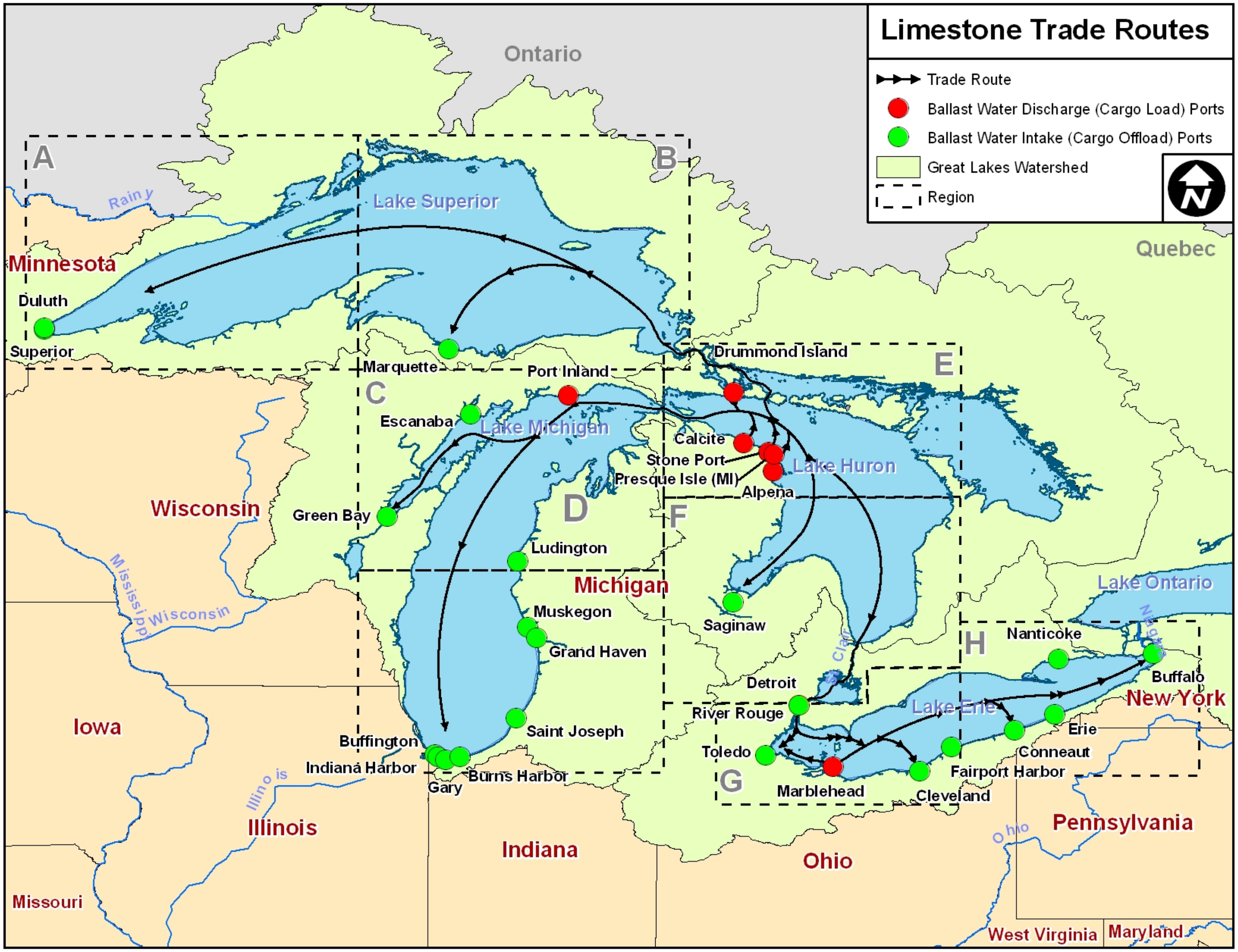

Figure 3. Limestone trade routes.

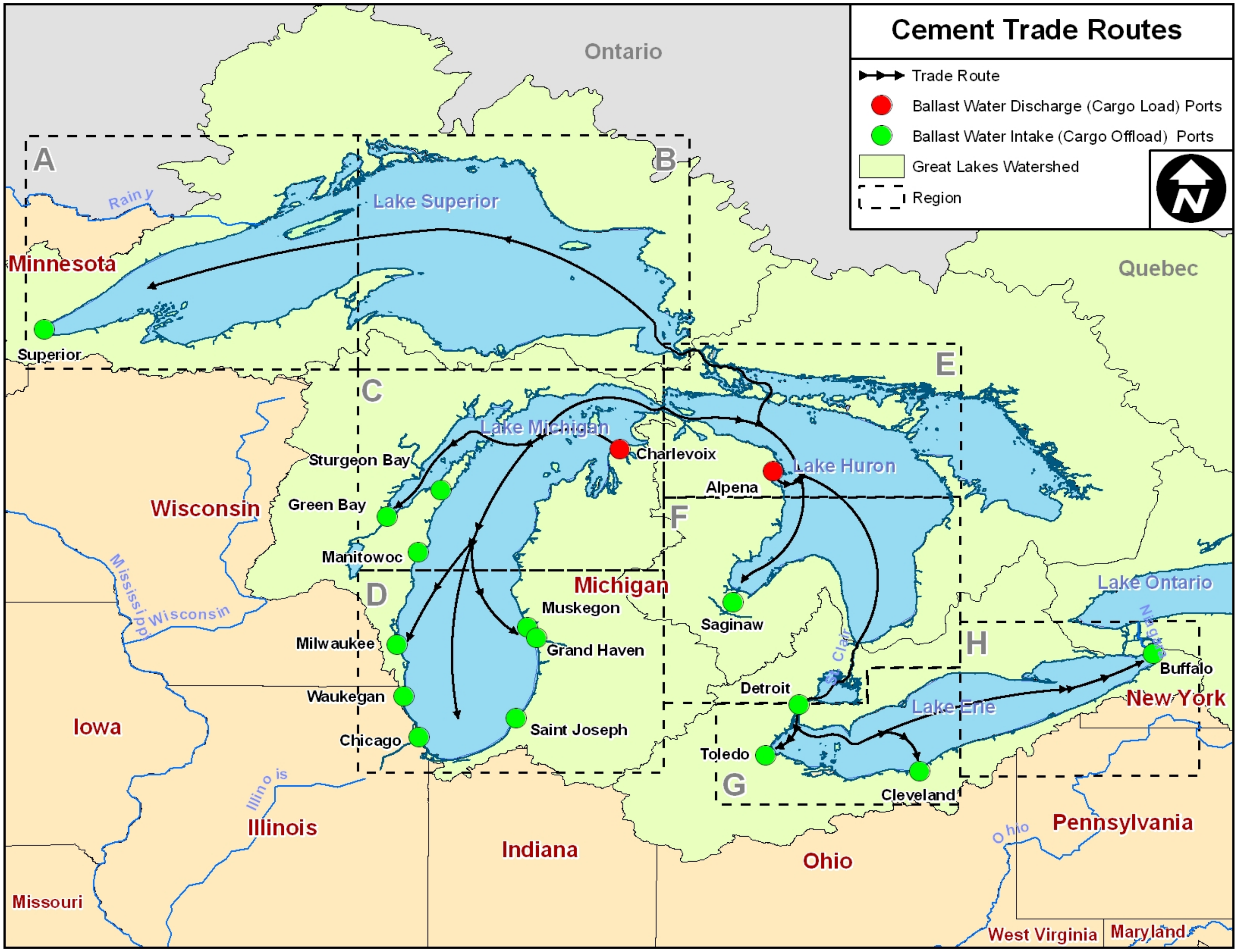

Figure 4. Cement trade routes.

3 BALLAST WATER DATA ANALYSIS

Taking on, transporting, and then discharging ballast water is an integral design and operating feature of practically all commercial ships that operate on the Great Lakes. During cargo unloading operations and/or when empty, ships take on ballast water to maintain draft and stability; submerge the propeller, rudders, and bow thrusters; and maintain or minimize stress loads on the hull. Vessels may only load some of their ballast tanks at the cargo discharge port because transporting ballast water from port to port increases operational costs due to increased fuel consumption. Vessels routinely take on additional ballast en route during transit. This operation is attributable to events such as bad weather, but ballast is sometimes taken on or discharged in multiple locations, for instance if a vessel is either loading at multiple ports, or splitting discharge at multiple ports.

Ultimately, the amount, weight, and distribution of cargo onboard determine ballast loads and their distribution within the vessel. For the largest of the Great Lakes vessels, loading and un-loading operations typically require 8 to 10 hours, and the quantity of ballast water discharged/taken in during these operations ranges between approximately 10 and 15 million gallons (38,000 to 57,000 metric tons (mt)).

The National Ballast Information Clearinghouse (NBIC) is a joint program of the Smithsonian Environmental Research Center (SERC) and the United States Coast Guard (USCG) chartered to collect, analyze, and interpret data on the ballast water management practices of commercial ships that operate in the waters of the United States. The NBIC was established in 1997 at the direction of the 1996 National Invasive Species Act (NISA). A principal aim of the NBIC is to quantify the amounts and origins of ballast water discharged in U.S. coastal systems, and to determine the degree to which such water has undergone open-ocean exchange or alternative treatments designed to reduce the likelihood of ballast-mediated invasions by exotic species.

The purpose of the data analysis in this volume is to develop criteria to cover the *full-range of the U.S. Laker trade* to reflect movement of ballast water. Specifically, the analysis must lead to vessel types and trade routes (vessel/voyage pairs) that represent this "full range." The work uses NBIC data for the year 2010 and U.S. flag vessels to review the transport of ballast water in the Great Lakes system. In 2010, the total ballast water discharge by ALL vessels in U.S. Great Lakes ports was more than 52 million mt. In 2010, U.S. flag vessels discharged approximately 42 million mt of ballast water in U.S. Great Lakes ports (approximately 80% of the total). We extracted records that represented the vast majority of ballast water discharged at U.S. ports. Our analysis accounts for more than 95% of the ballast water discharged by the U.S. fleet. The analysis provides an understanding of the volumes and geographic extent of ballast water transport by U.S. flag Lakers. The information provides comparisons among specific vessels, routes, ports, and regions of the Great Lakes.

This volume divides the Great Lakes into regions to better understand ballast water transport based on major trade routes. The trade patterns take into account, but do not specifically align with voyage characterizations by the Lake Carriers Association (2010) or Rup, Bailey,et al. (2010). The ports for each region are listed in Table 2 and are graphically depicted in Figure 5 below. We included St. Clair River and Saginaw Bay and River ports in the South Huron region, while Detroit River and River Rouge ports appear in the West Erie region.

Table 2. Great Lakes ports by region*.

West Superior Region A	East Superior Region B	North Lake Michigan Region C	South Lake Michigan Region D	Northwest Huron Region E	South Huron Region F	West Erie Region G	East Erie Region H
Ashland, WI	Marquette, MI	Brevort, MI	Buffington, IN	Alpena, MI	Bay City, MI	Cleveland, OH	Ashtabula, OH
Duluth, MN	Munising, MI	Charlevoix, MI	Burns Harbor, IN	Calcite, MI	Carrollton, MI	Dearborn, MI	Buffalo, NY
Hancock, MI	Presque Isle (UP), MI	Escanaba, MI	Calumet, IL	Cedarville, MI	Essexville, MI	Detroit, MI	Conneaut, OH
Ontonagon, MI	Sault Ste. Marie, MI	Frankfort, MI	Chicago, IL	Cheboygan, MI	Harbor Beach, MI	Ecorse, MI	Dunkirk, NY
Silver Bay, MN		Gladstone, MI	Ferrysburg, MI	Drummond Island, MI	Marine City, MI	Fairport Harbor, OH	Erie, PA
Superior, WI		Green Bay, WI	Gary, IN	Mackinac Island, MI	Marysville, MI	Huron, OH	Tonawanda, NY
Taconite Harbor, MN		Ludington, MI	Grand Haven, MI	Port Dolomite, MI	Port Gypsum, MI	Kellys Island, OH	
Two Harbors, MN		Manistee, MI	Holland, MI	Presque Isle, MI	Port Huron, MI	Lorain, OH	
		Manitowoc, WI	Indiana Harbor, IN	Stoneport, MI	Saginaw, MI	Marblehead, OH	
		Marinette, WI	Milwaukee, WI		Saint Clair, MI	Monroe, MI	
		Menominee, MI	Muskegon Harbor, MI		Tawas City, MI	River Rouge, MI	
		Port Inland, MI	Oak Creek, WI		Zilwaukee, MI	Sandusky, OH	
		Sturgeon Bay, WI	Port Washington, WI			Toledo, OH	
		Traverse City, MI	Racine Harbor, WI			Trenton, MI	
			Saint Joseph, MI			Wyandotte, MI	
			South Chicago, IL				
			Waukegan, IL				
			Whiting, IN				

*Note: Multiple names may appear for the same "port," based on NBIC entry or common name.

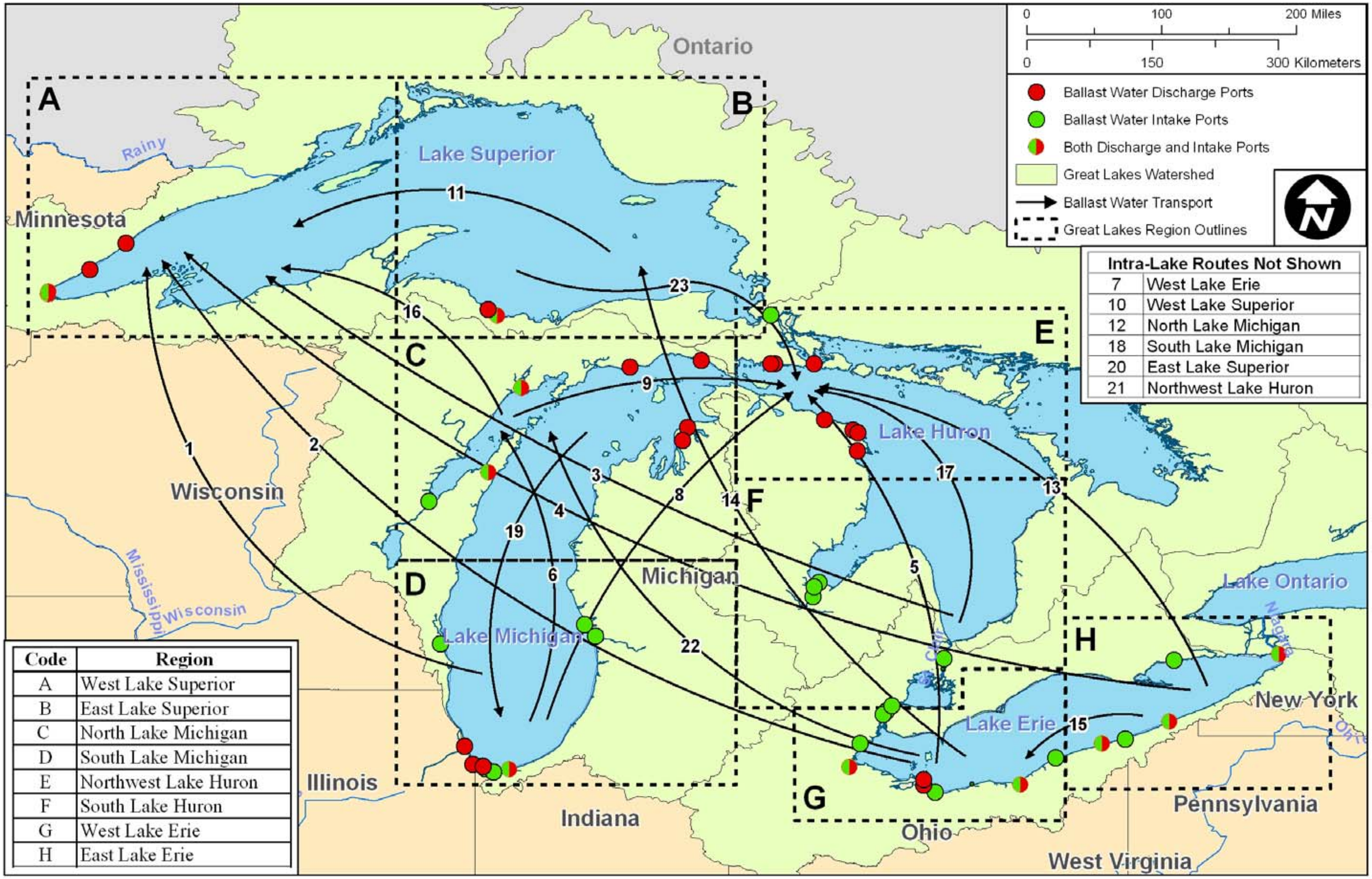

Figure 5. Great Lakes ballast water transport.

Table 3 summarizes the quantity of ballast water transferred among the regions described in Table 2 and Figure 5 by U.S. flag vessels. Ballast water quantities are in metric tons. The top 23 routes are listed, ranked by the quantities of ballast water transported by U.S. flag vessels from their "Departure Region" (ballast uptake) to their Arrival Region (ballast water discharge). The five vessels that transport the most ballast water are listed for each region. The five vessels listed for each region-transit pair (from highest ballast discharge to least ballast discharge) do not account for 100% of the "all U.S. vessel total" shown at the bottom of Table 3. They account for a large majority of those regional transit values and percentages, but other vessels not listed make up some smaller percentage of the listed values. Graphical overviews of the general routes are shown in Figure 5. Each numbered route in Figure 5 corresponds to the rank of the route listed in Table 3.

Table 3 yields two significant pieces of information: (1) In 2010, more than half of the total ballast water discharged by U.S. vessels into the Great Lakes was discharged into western Lake Superior ports by 13 vessels, all but one being 1000-foot, all transiting from lower-lake ports. (2) All sizes of Lakers are responsible for *intra*-regional movement of ballast, even 1000-foot Lakers.

The individual port locations with high ballast water discharge may affect vessel/voyage selection. The ports with the highest ballast water discharge are listed in Table 4. More than 50 percent of the ballast water discharged occurs at Superior and Two Harbors, indicating that transport of iron ore pellets and Western coal, and the subsequent return to loadport in a ballast condition, results in the majority of ballast water transport by U.S. Lakers on the Great Lakes.

Table 3. Ballast discharge volumes by region with top 5 discharging vessels (for each regional transport of ballast water).

Rank	Departure Region	Arrival Region (AR)	Total Annual Coastwise Ballast Transported (mt)		Vessels with Greatest Discharge				
			AR Total Discharge	Percent of Total	1st	2nd	3rd	4th	5th
1	S Lake Michigan	W Superior	7,899,425	18.6%	Edgar B. Speer	Burns Harbor	Stewart J. Cort	Edwin H. Gott	American Spirit
2	West Erie	W Superior	6,739,416	15.9%	Paul R. Tregurtha	American Integrity	Presque Isle	Walter J. McCarthy Jr.	Edwin H. Gott
3	S Huron	W Superior	4,012,489	7.9%	Indiana Harbor	Paul R. Tregurtha	American Century	James R. Barker	American Integrity
4	E Erie	W Superior	3,984,870	9.4%	American Century	Edgar B. Speer	Edwin H. Gott	Roger Blough	Presque Isle
5	West Erie	NW Huron	2,208,294	5.2%	Pathfinder	H. Lee White	John J. Boland	Philip R. Clarke	Sam Laud
6	S Lake Michigan	N Lake Michigan	2,035,119	4.8%	Joseph L. Block	Great Lakes Trader	Wilfred Sykes	St. Marys Challenger	Burns Harbor
7*	West Erie	West Erie	1,990,617	4.7%	Pathfinder	McKee Sons	H. Lee White	Calumet	American Republic
8	S Lake Michigan	NW Huron	1,298,398	3.1%	Cason J. Callaway	Philip R. Clarke	John G. Munson	Arthur M. Anderson	Joseph H. Thompson
9	N Lake Michigan	NW Huron	1,230,925	2.9%	Lewis J. Kuber	John G. Munson	Cason J. Callaway	Philip R. Clarke	Innovation
10*	W Superior	W Superior	1,206,915	2.8%	Philip R. Clarke	John G. Munson	James R. Barker	American Century	American Integrity
11	E Superior	W Superior	1,155,024	2.7%	Mesabi Miner	James R. Barker	Great Lakes Trader	Herbert C. Jackson	Manitowoc
12*	N Lake Michigan	N Lake Michigan	1,101,969	2.6%	Lewis J. Kuber	Joseph L. Block	Wilfred Sykes	St. Marys Challenger	American Mariner
13	E Erie	NW Huron	1,011,571	2.4%	Great Lakes Trader	Joseph H. Thompson	James L Kuber	John G. Munson	American Mariner
14	West Erie	E Superior	903,004	2.1%	Kaye E. Barker	Herbert C. Jackson	Charles M. Beeghly	Lee A. Tregurtha	Pathfinder
15	E Erie	West Erie	843,583	2.0%	John J. Boland	Manistee	James L Kuber	American Mariner	H. Lee White
16	N Lake Michigan	W Superior	831,467	2.0%	American Integrity	Walter J. McCarthy Jr.	St. Clair	John J. Boland	Edwin H. Gott
17	S Huron	NW Huron	904,220	1.4%	Lewis J Kuber	Calumet	Manitowoc	McKee Sons	Joseph H. Thompson
18*	S Lake Michigan	S Lake Michigan	328,406	0.8%	Manitowoc	Cason J. Callaway	Philip R. Clarke	Arthur M. Anderson	Manistee
19	N Lake Michigan	S Lake Michigan	312,291	0.7%	Calumet	Manitowoc	Manistee	McKee Sons	Endeavour
20*	E Superior	E Superior	247,493	0.6%	Manitowoc	Calumet	Kaye E. Barker	Lee A. Tregurtha	Herbert C. Jackson
21*	NW Huron	NW Huron	154,909	0.4%	Calumet	Sam Laud	Manitowoc	Lewis J Kuber	Manistee
22	West Erie	N Lake Michigan	153,486	0.4%	American Spirit	Edwin H. Gott	Mesabi Miner	Herbert C. Jackson	Lewis J Kuber
23	E Superior	NW Huron	145,524	0.3%	McKee Sons	Manitowoc	Pathfinder	Calumet	Alpena
		Total shown:	**40,699,415**	**mt**					
		Total, all U.S. Vsls:	**42,508,108**	**mt**					
		% ballast moved by top 5 vsls:	**95.7%**						

*These are intra-lake routes and not shown in Figure 5

Table 4. Ballast discharge by arrival port.

Rank	Arrival Port	Ballast Discharged (mt)	% of Total
1	Superior	13,264,306	31.5
2	Two Harbors	8,092,120	19.2
3	Silver Bay	2,584,280	6.1
4	Duluth	2,008,944	4.8
5	Calcite	1,926,582	4.6
6	Port Inland	1,805,522	4.3
7	Marquette	1,600,102	3.8
8	Presque Isle	1,414,239	3.4
9	Stoneport	1,325,849	3.2
10	Marblehead	1,111,806	2.6
11	Escanaba	1,071,847	2.5
12	Toledo (USA, OH)	1,003,928	2.4
13	Port Dolomite	908,993	2.2
14	Alpena	876,457	2.1
15	Sandusky	569,505	1.4
16	Chicago	408,728	1.0
17	Drummond Island	397,421	0.9
18	Cleveland	300,483	0.7
19	Charlevoix	280,624	0.7
20	Sturgeon Bay	267,003	0.6
21	Cedarville	249,445	0.6
22	South Chicago	193,193	0.5
23	Ashtabula	166,512	0.4
24	Brevort	90,331	0.2
25	Burns Harbor	62,653	0.1
26	Whiting	48,436	0.1
27	Detroit	24,413	0.1
	Totals (mt):	**42,053,722**	**100.00**

Table 5 lists the location of the ports where ballast water is taken on; it includes Canadian ports which are part of the U.S. flag vessel routes. Fifty percent of the ballast water taken on comes from seven ports, all in the southern portions of the Great Lakes.

Table 5. Ballast intake by departure port.

Rank	Source Port	Country	Ballast Intake (mt)	% of Total
1	Gary	USA	4,534,821	10.8
2	Indiana Harbor	USA	3,742,141	8.9
3	Saint Clair	USA	3,313,204	7.9
4	Monroe	USA	3,119,239	7.4
5	Cleveland	USA	2,662,340	6.3
6	Burns Harbor	USA	2,487,640	5.9
7	Detroit	USA	2,283,156	5.4
8	Conneaut	USA	1,810,050	4.3
9	Nanticoke	Canada	1,794,733	4.3
10	Ashtabula	USA	1,511,532	3.6
11	Ecorse	USA	1,509,867	3.6
12	Marquette	USA	1,091,068	2.6
13	Green Bay	USA	846,869	2.0
14	River Rouge	USA	837,103	2.0
15	Essexville	USA	733,378	1.7
16	Toledo (USA, OH)	USA	709,398	1.7
17	Muskegon	USA	691,327	1.6
18	Duluth	USA	664,908	1.6
19	Milwaukee	USA	663,617	1.6
20	Buffington	USA	461,467	1.1
21	Sault Ste. Marie	Canada	389,307	0.9
22	Superior	USA	387,075	0.9
23	Buffalo	USA	352,368	0.8
24	Erie	USA	304,388	0.7
25	Saginaw	USA	294,644	0.7
26	Huron	USA	283,021	0.7
27	Sturgeon Bay	USA	278,322	0.7
28	Bay City	USA	267,960	0.6
29	Dearborn (USA, MI)	USA	264,638	0.6
30	Escanaba	USA	260,130	0.6
31	Fairport (USA, OH)	USA	249,517	0.6
32	Grand Haven	USA	235,460	0.6
33	Silver Bay	USA	187,074	0.4
34	Manistee	USA	184,763	0.4
35	Alpena	USA	176,459	0.4
36	Lorain	USA	174,275	0.4
37	Marine City	USA	173,683	0.4
38	Chicago	USA	168,725	0.4
39	Saint Joseph	USA	164,517	0.4
40	Taconite Harbor	USA	159,447	0.4
41	Marysville	USA	147,896	0.4
42	Port Inland	USA	121,621	0.3

Table 5. Ballast intake by departure port (continued).

Rank	Source Port	Country	Ballast Intake (mt)	% of Total
43	Windsor	Canada	114,332	0.3
44	Waukegan	USA	103,813	0.2
45	Harbor Beach	USA	92,478	0.2
46	Presque Isle	USA	83,813	0.2
47	Charlevoix	USA	77,855	0.2
48	Holland	USA	68,324	0.2
49	Kingsville	Canada	64,779	0.2
50	Manitowoc	USA	60,749	0.1
51	Whitefish Falls, Ontario	Canada	58,640	0.1
52	Wyandotte	USA	53,482	0.1
53	Port Dolomite	USA	47,956	0.1
54	Thorold	Canada	47,760	0.1
55	Sault Ste. Marie	USA	47,671	0.1
56	Sarnia	Canada	40,130	0.1
57	Munising	USA	34,583	0.1
58	Ferrysburg	USA	32,093	0.1
59	Trenton (USA, MI)	USA	30,507	0.1
60	Hamilton (Canada)	Canada	25,955	0.1
61	Meldrum Bay	Canada	25,769	0.1
62	South Chicago	USA	25,230	0.1
63	Menominee	USA	24,853	0.1
64	Heron Bay	Canada	23,742	0.1
65	Milwaukee	USA	19,985	<0.1
66	Montreal	Canada	19,949	<0.1
67	Gladstone (USA, MI)	USA	17,386	<0.1
68	Fairport Harbor	USA	16,983	<0.1
69	Toronto	Canada	16,641	<0.1
70	Ludington	USA	16,322	<0.1
71	Cedarville	USA	11,131	<0.1
72	Sandusky	USA	11,127	<0.1
73	Calumet	USA	10,789	<0.1
74	Carrollton	USA	10,499	<0.1
75	Whitefish River	Canada	7,742	<0.1
76	Prescott	Canada	5,547	<0.1
77	Port Colborne	Canada	5,547	<0.1
78	Fisher Harbor (Canada)	Canada	5,547	<0.1
79	Marblehead	USA	304	<0.1
80	Tracy	Canada	268	<0.1
81	Whiting	USA	268	<0.1
82	Rochester (USA, NY)	USA	25	<0.1
	Ballast Water Total (mt):		**42,053,722**	**100.0**

Figure 6 shows the results of further analysis of ballast uptake and discharge records. Figure 6 shows ballast water hold time for the percentage of ballast discharged, for the fleet as a whole, as well as for five, representative-type vessels.

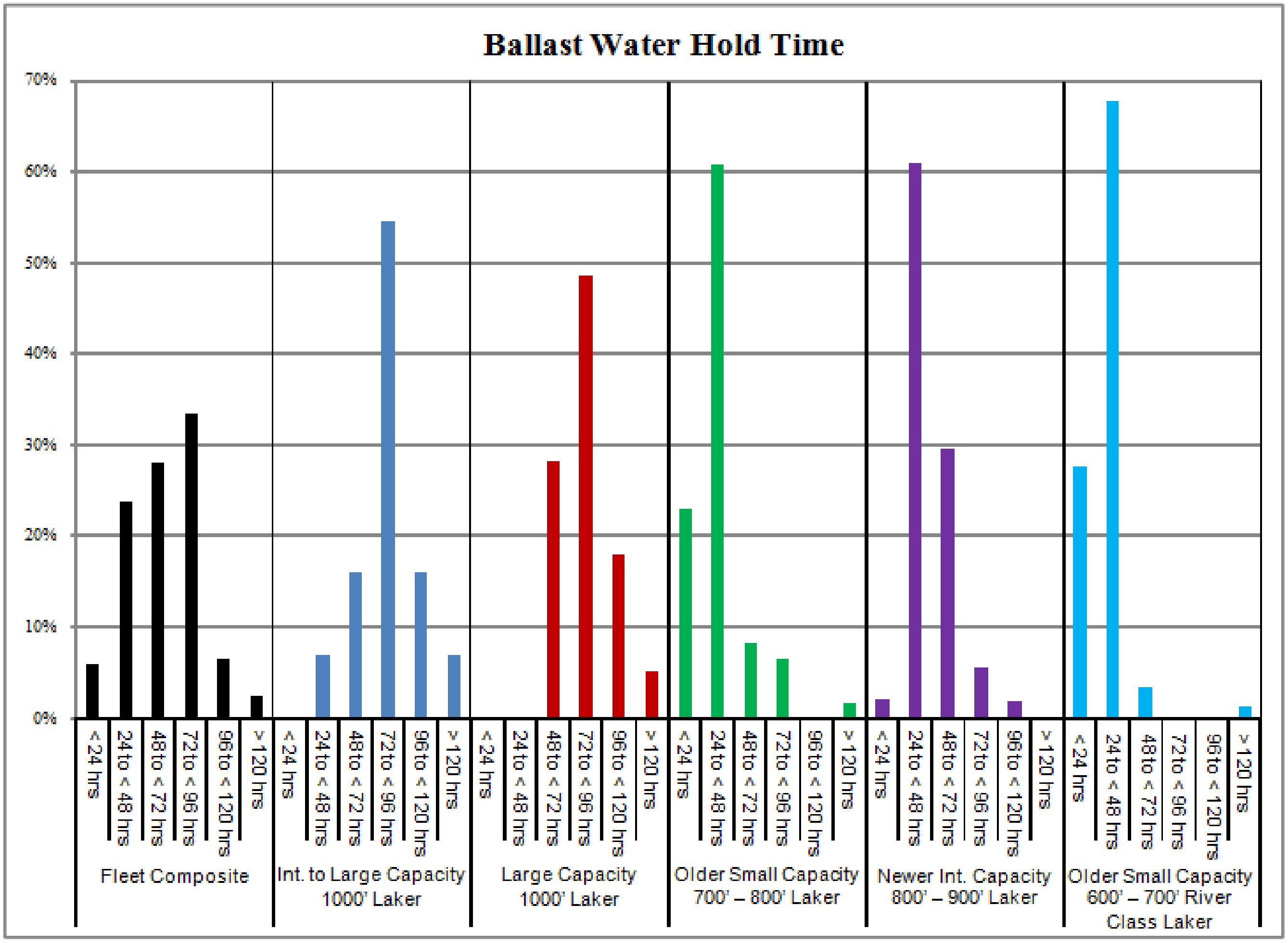

Figure 6. Ballast water hold time.

The results show that discharges of the bulk of ballast water transported throughout the Great Lakes occurs between 24 hours and 96 hours after uptake. In 2010, only 6 percent of the ballast water discharged by the Laker fleet, as a whole, occurred less than 24 hours after uptake. Though the two representative-type 1000-foot vessels selected for this ballast water hold-time analysis did not indicate transits in ballast of less than 24 hours, Table 3 shows that 1000-foot vessels do make transits of less than 24 hours (W. Superior port to W. Superior port). This statistic generally indicates that BWT systems that allow safe discharge of treated ballast in 24 hours or less will have relatively low impact on current operations.

The results also show that there are considerable operational differences between vessels. For example, a BWT system which requires retention longer than 24 hours might be acceptable for installation on the "Large Capacity 1000' Laker" that usually makes only long runs, whereas systems that require even short hold times might have an operational effect (i.e., delay) on vessels which routinely make shorter runs, such as the "Small Capacity, River Class 600' – 700' Laker." Ultimately, the requirement will depend on a vessel's specific operational profile. For the purposes of this engineering and cost study, in Volume II, only those BWT systems thought to allow discharge of ballast water within 24 hours of uptake are considered.

Early project-cost considerations limited the marine engineering efforts to picking only two systems, yielding a "one type fits all" approach.

Table 6 lists the top 25 vessels by amount of ballast water transported in 2010. Combined, these 25 U.S. flag vessels transported approximately 77 percent of the ballast water moved by U. S. vessels throughout the Great Lakes system. These 25 vessels represent a reasonably large cross-section of different vessel types, classes, sizes, and ballast system configurations and capabilities.

Table 6 includes additional information such as: general vessel type, International Maritime Organization (IMO) number, ballast system capacity, year and shipyard of build, cargo capacity, principal dimensions, ownership, and trade. This data was compiled from a variety of sources including public domain internet sites, the American Bureau of Shipping (ABS) Record Vessel Database, and the USCG Vessel Information Database, National Ballast Information Clearinghouse website; McCormick, 1996; Cangelosi & Mays, 1996; Lake Carriers' Association website; Great Lakes and Seaway Shipping website; and the Great Lakes Information Network website.

Table 7 summarizes the total number of trips for a vessel by basic route, including intra and inter-region. This table shows the breadth of routes traveled by the various vessels. The shaded rows in Table 7 contain data from routes that are not included in the top 25 basic routes identified in Table 3.

Table 6. Vessel information for the top 25 vessels by volume of ballast water discharged for 2010.

Rank	Vessel Name	Vessel Type	IMO Number	Total Coastwise Discharge (mt)	Ballast Capacity (mt)	Shipyard	Year Built	Capacity[1] (long ton (lt))	Dimensions (ft)			Owner/ Operator	Trade
									L	B	D		
1	Edgar B. Speer	Bulker	7625952	2,270,929	54,905	American Ship Bldg Co.	1980	73,700	1004.0	105.0	56.0	Great Lakes Fleet, Inc.	Iron Ore Pellets
2	James R. Barker	Bulker	7390260	1,874,938	44,308	American Ship Bldg Co.	1976	63,300	1004.0	105.0	50.0	Interlake Steamship Co.	Iron Ore Pellets, Coal
3	Paul R. Tregurtha	Bulker	7729057	1,803,112	51,816	Lorain, Ohio	1981	68,000	1013.5	105.0	56.0	Interlake Steamship Co.	Iron Ore Pellets, Coal
4	Edwin H. Gott	Bulker	7606061	1,796,276	62,294	Bay Shipbuilding Corp	1979	74,100	1004.0	105.0	52.0	Great Lakes Fleet, Inc.	Iron Ore Pellets
5	Mesabi Miner	Bulker	7390272	1,780,563	44,389	American Ship Bldg. Corp.	1977	63,300	1004.0	105.0	50.0	Interlake Steamship Co.	Iron Ore Pellets, Coal
6	American Integrity	Bulker	7514696	1,659,621	62,143	Bay Shipbuilding Corp	1978	80,900	1000.0	105.0	56.0	American Steamship Co.	Iron Ore Pellets, Coal
7	Indiana Harbor	Bulker	7514701	1,653,444	62,143	Bay Shipbuilding Corp	1979	80,900	1000.0	105.0	56.0	American Steamship Co.	Iron Ore Pellets, Coal
8	Presque Isle	ITB[2]	7303877	1,642,212	55,964	Halter Marine (Tug), Erie Marine (Barge)	1973	57,500	1000.0	104.6	46.5	GLF Great Lakes Corp	Iron Ore Pellets, Coal
9	Burns Harbor	Bulker	7514713	1,624,552	62,143	Bay Shipbuilding Corp	1980	80,900	1000.0	105.0	56.0	American Steamship Co.	Iron Ore Pellets
10	American Century	Bulker	7923196	1,623,218	62,123	Bay Shipbuilding Corp	1981	80,900	1000.0	105.0	56.0	American Steamship Co.	Iron Ore Pellets
11	Walter J. McCarthy Jr.	Bulker	7514684	1,502,599	62,143	Bay Shipbuilding Corp	1977	80,900	1000.0	105.0	56.0	American Steamship Co.	Coal
12	Great Lakes Trader	ATB[2]	8635966	1,247,716	24,113	Halter Marine	2000	34,157	844.8	78.0	45.0	Van Enkevort Tug & Barge	Iron Ore Pellets, Coal, Limestone
13	American Spirit	Bulker	7423392	1,245,946	34,569	American Ship Building Co.	1978	62,400	1004.0	105.0	50.0	American Steamship Co.	Iron Ore Pellets
14	Roger Blough	Bulker	7222138	1,136,012	35,637	American Ship Building Co.	1971	43,900	858.0	105.0	41.5	Great Lakes Fleet, Inc.	Iron Ore Pellets
15	Joseph L. Block	Bulker	7502320	1,050,473	21,578	Bay Shipbuilding	1976	37,200	728.0	78.0	45.0	Indiana. Harbor Steamship Co.	Iron Ore Pellets, Coal, Limestone
16	H. Lee White	Bulker	7366362	1,023,398	22,031	Bay Shipbuilding Corp	1974	35,400	704.0	78.0	45.0	American Steamship Co.	Iron Ore Pellets, Coal, Limestone, Grain
17	Calumet	Bulker	7329314	970,186	11,318	American Ship Building Co.	1973	19,650	630.0	68.0	36.9	Grand River Navigation	Iron Ore Pellets, Coal, Limestone
18	Pathfinder	ATB	5166768	914,638	10,988	Great Lakes Engineering	1952	26,700	700.0	70.0	36.0	The Interlake Steamship Co.	Iron Ore Pellets, Coal, Limestone

Table 6. Vessel information for the top 25 vessels by volume of ballast water discharged for 2010 (Continued).

Rank	Vessel Name	Vessel Type	IMO Number	Total Coastwise Discharge (mt)	Ballast Capacity (mt)	Shipyard	Year Built	Capacity[1] (long ton (lt))	Dimensions (ft)			Owner/ Operator	Trade
									L	B	D		
19	St. Clair	Bulker	7403990	895,832	24,674	Bay Shipbuilding Corp	1976	44,800	770.0	92.0	52.0	American Steamship Co.	Iron Ore Pellets, Coal, Limestone
20	Stewart J. Cort	Bulker	7105495	894,600	39,590	Rust Eng. Co Erie Marine Division	1971	58,000	1000.0	105.0	49.0	Interlake Leasing III	Iron Ore Pellets
21	American Mariner	Bulker	7812567	877,702	23,426	Bay Shipbuilding Corp	1980	37,300	730.0	78.0	45.0	American Steamship Co.	Iron Ore Pellets, Coal, Limestone, Grain
22	Lewis J Kuber	ATB	5336351	818,922	16,546	Bethlehem-Sparrow Point	1952	22,300	617.0	70.0	37.0	Black Creek Shipping Co. Inc.	Iron Ore Pellets, Coal, Limestone
23	John J. Boland	Bulker	7318901	814,205	21,194	Bay Shipbuilding Corp	1973	34,000	667.0	78.0	43.0	American Steamship Co.	Iron Ore Pellets, Coal, Limestone, Grain
24	Philip R. Clarke	Bulker	5277062	762,480	17,245	American Ship Bldg Co.	1952	25,300	767.0	70.0	36.0	Great Lakes Fleet Inc.	Iron Ore Pellets, Coal, Limestone
25	John G. Munson	Bulker	5173670	745,272	11,932	Manitowoc Shipbuilding	1952	25,550	768.3	72.0	36.0	Great Lakes Fleet Inc.	Iron Ore Pellets, Coal, Limestone
	Total:			**25,077,550**									
	Total for U.S. Vessels:			**42,508,108**									
	Percent Captured:			**76.8%**									

[1]Capacity refers to the maximum cargo carrying capacity of the vessel. This is also referred to as "Dead Weight Tonnage".
[2]ITB stands for "integrated tug and barge"; ATB stands for "articulated tug and barge." While similar in concept, the primary difference is the way the "tug" and "barge" connect, and the corresponding vessel characteristics while in a seaway. The tug of an ITB is connected rigidly to the barge and both hulls behave as if they are one large ship. The tug of an ATB on the other hand is allowed to pitch and heave somewhat separately from the barge through pinned connects into the barge hull.

Table 7. Count of region-to-region (and intra-region) trips for the top 25 vessels.

Regional Transits	Total All Vessels	American Century	American Integrity	American Mariner	American Spirit	Burns Harbor	Calumet	Edgar B. Speer	Edwin H. Gott	Great Lakes Trader	H. Lee White	Indiana Harbor	James R. Barker	John G. Munson	John J. Boland	Joseph L. Block	Lewis J Kuber	Mesabi Miner	Pathfinder	Paul R. Tregurtha	Philip R. Clarke	Presque Isle	Roger Blough	St. Clair	Stewart J. Cort	Walter J. McCarthy Jr.
S Lake Michigan To W Superior	116	2	1	1	21	1		1	14			5	4	2	1	1		1			1	12	19	10	18	1
West Erie To W Superior	113	1	2	10	13		1		9	1	1	8	12		3			1		28		21		1		1
E Erie To W Superior	93	21	1	4	2			10	11	1		4	8	1				1				9	13	3		4
West Erie To West Erie	94			3			15				11			6	4		4		50		1					
S Huron To W Superior	48	12	1	1			1					14	2		2			1		12				1		1
West Erie To NW Huron	79			3			2			3	11			9	9		7		21		12	2				
S Lake Michigan To N Lake Michigan	23			2	3	1			1	1	4		1		1	2	2	1						3		1
N Lake Michigan To NW Huron	49			2			7							13	1	1	13		4		8					
SW Huron To NW Huron	50						21										28		1							
W Superior To W Superior	47	2	2	1	2			1		1	3		3	14	1	1		1			14			1		
N Lake Michigan To N Lake Michigan	40			5			6			1	1				3	5	17		1		1					
E Superior To W Superior	16						3			1			11					1								
S Lake Michigan To NW Huron	31			1						1	6			11							12					
E Erie To NW Huron	16			3						1	2			8	1						1					
E Erie To West Erie	28			5			6			2	4			3	7						1					
N Lake Michigan To W Superior	25		7	2	1	1			1	1	2				3					1			1	3	1	1
SW Huron To W Superior	10			1								8														1
N Lake Michigan To S Lake Michigan	14						12				1				1											
S Huron To NW Huron	14						7								1				6							
NW Huron To NW Huron	2						1										1									
S Lake Michigan To S Lake Michigan	9						2				1			2	1						3					
West Erie To E Superior	7														1				6							
E Superior To E Superior	7						7																			
West Erie To E Erie	5						2							2					1							
West Erie To N Lake Michigan	4				1				1								1	1								
E Superior To NW Huron	4						2												2							
NW Huron To N Lake Michigan	4																4									
E Erie To E Erie	3			1			1							1												
S Huron To E Superior	3																	1	2							
S Huron To West Erie	2						1												1							
SW Huron To N Lake Michigan	3						1			1							1									
E Erie To N Lake Michigan	1									1																
N Lake Michigan To E Superior	1										1															
NW Huron To W Superior	2												1							1						
W Superior To E Superior	2										1				1											
E Erie To E Superior	1										1															

Note: green shaded rows indicate routes that are not included in the top 25 basic routes identified in Table 3

Table 7. Count of region-to-region (and intra-region) trips for the top 25 vessels (Continued).

Regional Transits	Total All Vessels	American Century	American Integrity	American Mariner	American Spirit	Burns Harbor	Calumet	Edgar B. Speer	Edwin H. Gott	Great Lakes Trader	H. Lee White	Indiana Harbor	James R. Barker	John G. Munson	John J. Boland	Joseph L. Block	Lewis J Kuber	Mesabi Miner	Pathfinder	Paul R. Tregurtha	Philip R. Clarke	Presque Isle	Roger Blough	St. Clair	Stewart J. Cort	Walter J. McCarthy Jr.
S Huron To N Lake Michigan	1						1																			
S Lake Michigan To E Superior	1														1											
S Lake Michigan To West Erie	1														1											
W Superior To N Lake Michigan	1																									1
W Superior To NW Huron	1			1																						
W Superior To S Lake Michigan	1																								1	
Total regions visited by vsl		**5**	**6**	**7**	**6**	**4**	**8**	**4**	**6**	**8**	**7**	**4**	**7**	**6**	**8**	**4**	**7**	**7**	**6**	**5**	**6**	**5**	**3**	**7**	**3**	**7**

Note: green shaded rows indicate routes that are not included in the top 25 basic routes identified in Table 3

4 VESSEL/VOYAGE SELECTION CRITERIA

The previous two sections of this volume present common trade routes and data representing the recorded movements of ballast water through the Great Lakes region. This section builds on the analysis of the previous two sections, and includes the methodology and processes used, and the range of variables considered, in the selection of five vessel/voyage combinations that best illustrate the *full range of contemporary U.S. Laker trade*. We use and define the term *full range of contemporary U.S. Laker trade* to encompass all the major variables and differences among the Lakers themselves, their individual ballast systems, and the trade routes upon which they travel. The purpose for this broad-based review and perspective is to determine five specific vessel/voyage combinations that represent the full range of technical and economic challenges associated with the installation of BWT systems.

The criteria used to evaluate and select five vessel/voyage combinations include the following:

- **Basic Vessel Differences.** The selected vessels are to be different from one another with respect to overall size and carrying capacity, electrical capacity and configurations, cargo unloading systems, ballast water systems, age, propulsion system, etc.
- **Annual Quantity of Ballast Water Moved.** Although not the single most important criterion, candidate vessels are selected from the list of the top 25 vessels (Table 6) that transport the most ballast water.
- **Geographic Extent and Variability of Ballast Water Movement.** (See Table 7 for details in support of this discussion.) While most of the Lakers have a predominant trade route to which they are assigned, almost all of them also occasionally transport cargoes and ballast water on other routes. Figure 5 presents a good overview of the extent to which ballast water is moved around the Great Lakes. Less obvious is the fact that almost all the vessels trading commodities on the Great Lakes are required to travel both long- and short-duration trips. Some vessels predominately operate inside a single lake or region, on relatively short duration trips (6 to 12 hours), yet are also called upon to make longer distance and duration trips (48 to 72 hours). This variability in mission profile is critically important to the five-vessel selection process.
- **Range of Technical Challenges (with regard to installation of BWT systems).** The technical challenges involved with capital improvement projects aboard the Lakers are directly tied to the differences among the vessels. The areas of the vessel that should be considered for the different locations in which a BWT system can be installed include the engine room or existing machinery spaces, ballast tanks or cargo holds, or the deck of the vessel.

  In some vessels, existing ballast tanks or cargo holds would need to be reduced in size, as that would be the only way to reasonably make space available for installation of large pieces of new equipment or systems. Modifications of this type would have significant schedule and economic impact on vessel owners/operators. Conversely, other vessels (particularly new designs and/or repowers and/or conversions of old Lakers into ATB hulls) have been designed or modified before proposed rules were developed, and may not have adequate room for new equipment installation requirements.

  Differences between vessels' ballast system arrangements and configurations are another specific technical challenge that must be accounted for in characterizing the U.S. Laker trade. Some Lakers have a traditional single or double longitudinal ballast pipe header system with pumps aft in the engine room, and two to four sea chests all tied together. The ballast systems of other Lakers are less conventional: no longitudinal ballast pipe header system, with individual ballast pumps, and individual sea chests for each ballast tank.

Still a third vessel difference representing significant technical challenges and economic impact on some Lakers (and only relatively minor challenges/impacts on others) is electrical capacity. Some Lakers are built with adequate excess (spare) electrical generating capacity; others have little excess electrical power. The vessels with inadequate spare electrical capacity available to run large pieces of new capital equipment will require new generators, and all the modifications associated with installation of new generating equipment (installation space, fuel lines, exhaust lines, foundations, new switchboards and distribution panels, etc.).

- **Economic Factors.** In 2011, the average age of the Laker fleet vessels identified in Table 6 is 37 years. The newest vessel in this group is 11 years old. Vessels typical of the Laker fleet are usually designed and constructed for a 45-50 year service life. While not at the extreme ends of their useful lives, the fleet as a whole is at or past the point where either new tonnage or major life extension projects may soon be needed. Some of the older vessels in the fleet have already undergone mid-life extension or major upgrade modification projects. Vessels tend to be scrapped as they age and become inefficient. These vessels may be replaced with new tonnage. These two basic capital investment options (mid-life extension or scrap and replace) have minor influence on the selection of these five vessels.
- **Availability of Vessel Drawings and Technical Information.** The general availability of vessel drawings and other technical documentation has a minor influence upon the five vessels selected.

4.1 Vessel Selection

To avoid potential issues with confidentiality, proprietary information, and any possible influence on business decisions, we have purposefully not identified the actual vessels selected for this study. The particulars and characteristics of specific vessels are used in the detailed development of this volume's appendices, and actual routes run by these vessels are listed in Table 8 below. Identifying summary titles are assigned to each of the vessels selected in order to avoid using the actual vessel names, and to more broadly represent the general class of vessels from which these five vessels are selected. For purposes of this study, definitions for the words and phrases used in Table 8 and elsewhere in this report are defined as follows.

- **Small Capacity.** The term capacity refers to the overall bulk commodity carrying capacity of the vessel, which is also proportional to the ballast water carrying capacity. For purposes of this study, "small capacity" refers to every vessel with a total carrying capacity of less than 30,000 lt.
- **Intermediate Capacity.** Between 30,000 and 55,000 lt carrying capacity.
- **Intermediate to Large Capacity.** Between 55,000 and 70,000 lt carrying capacity.
- **Large Capacity.** Carrying capacity greater than 70,000 lt.
- **1000-foot Laker.** General overall length of the largest class of Laker. These vessels were generally built in the 10-year span between 1971 and 1981.
- **Older.** Vessel built prior to 1970. (Some the of the existing Laker fleet dates to the 1950's.)
- **Newer.** Vessel built or extensively modified after 1980.
- **River Class.** These vessels are among the smallest of the Lakers, with lengths, beams, and drafts that allow them to navigate into rivers and small ports where the 1000-foot Lakers cannot operate.

In addition to the vessel selection criteria summarized and discussed above, the project reviewed all the trade route and ballast water movement data and analyses summarized in Table 2 through Table ,7 and in Miller (1979). We also conducted interviews with another naval architecture/marine engineering firm (Bay Engineering Incorporated, interviews) that has been involved with the original designs and recent life extension modifications of many of these vessels. Coupled to this were interviews with vessel owners and operations managers, and the project team's own expertise in the design, installation, and operation of vessel ballasting systems.

4.2 Voyage Selection

The variables associated with differences in the commodity trade routes are most easily understood in terms of the different lengths of the routes and typical cargo load times, both of which have a direct bearing on the amount of time ballast water remains in the vessel. Short duration, intra-lake routes can be as short as 6 hours, while each leg of the longest inter-lake trade route voyages (Eastern Lake Erie to Western Lake Superior) can take over 4 days. Loading times vary considerably for different vessels at different ports. The shortest times being in the range of 6-10 hours, while loading of certain commodities (grain for example) at certain ports can take 4 days or more. The most significant variable associated with the different commodity trade routes is the fact that the majority of the Lakers are not dedicated to only one specific route, or to one specific commodity. Most of the Lakers are designed to transport two or three of the primary commodities (defined in Section 2) and most also are engaged in different trade routes, of different durations, involving different water temperatures and water quality (sediments, organic matter content, etc.).

5 VESSEL/VOYAGE SELECTIONS AND DESCRIPTIONS

The five vessel/voyage combinations identified in Table 8 are selected based on which of the top 25 ballast water transport routes (Figure 5), married to the top 25 vessels (Table 6), most fully represents and captures the full range of contemporary U.S. Laker trade variables discussed previously. The shaded port-pairs are trips during the voyage example periods that are outside the generalized primary route.

Table 8. Vessel/voyage selections.

Vessel	Primary Route	Example of Actual Vessel Itinerary/ Voyage Description	
		Take on Ballast	**Discharge Ballast**
Intermediate to Large Capacity 1000' Laker	W. Lake Superior to S. Lake Michigan (see Figure 7)Figure 7	Indiana Harbor	Two Harbors
		Indiana Harbor	Two Harbors
		Indiana Harbor	Two Harbors
		Gary	Escanaba
		Indiana Harbor	Superior
Large Capacity 1000' Laker	W. Lake Superior to S. Lake Huron (see Figure 8)	St. Clair	Superior
		Monroe	Two Harbors
		Indiana Harbor	Superior
		Gary	Superior
		Essexville	Superior
		St. Clair	Superior
Older, Small Capacity 700' – 800' Laker	N.W. Lake Huron to S. Lake Michigan (see Figure 9)	River Rouge	Presque Isle
		Buffington	Calcite
		Buffington	Calcite
		Buffington	Stoneport
Newer, Intermediate Capacity 800' –900' Laker	N.W. Lake Huron to E. Lake Erie (see Figure 10)	Ashtabula	Presque Isle
		Buffington	Port Inland
		Ashtabula	Calcite
		Essexville	Escanaba
		Ashtabula	Calcite
Small Capacity, River Class 600' – 700' Laker	W. Lake Erie to W. Lake Erie (see Figure 11)	Marblehead	Cleveland
		Cleveland	Sandusky
		Green Bay	Presque Isle
		Saginaw	Presque Isle
		Toledo	Marblehead

The five vessel/voyage selections are graphically presented in Figure 7 through Figure 11, and represent actual voyage segments during 2010 of the specific ships selected in this study.

6 CONCLUSIONS

The vessels that operate on the Great Lakes transport a large variety of bulk commodities: iron ore pellets, coal, limestone, cement, stone, salt, sand, and grain. The total trade is 88.7 million net tons. Some vessels generally transport one commodity, while others transport various commodities. Vessels transporting a single commodity load and unload at the same ports on a routine basis. The vessels transporting multiple commodities frequently change routes. The different commodities and routes help determine how much ballast water travels from and to particular locations.

The selection of the five vessels represents the broad range of types of vessels and voyage types. The selection of the vessels included consideration of basic vessel differences (size, cargo capacity, ballast system, etc.), trade routes and quantity of ballast water transported, technical challenges, economic factors, and vessel age. The five vessels chosen are:

The Intermediate to Large Capacity 1000' Laker transports iron ore pellets or coal. The primary trading route selected here is iron ore pellets from Western Lake Superior to South Lake Michigan or Lake Erie. The ballast water transported is almost always discharged in Western Lake Superior. The details of the vessel design are in Appendix A.

The Large Capacity 1000' Laker carries iron ore pellets or coal. The trading route varies from Western Lake Superior to both South Lake Michigan and Lake Huron. The vessel transports ballast water from the two lower lakes to Western Lake Superior. The details of the vessel design are in Appendix B.

Figure 7. Intermediate to large capacity 1000' Laker trade route.

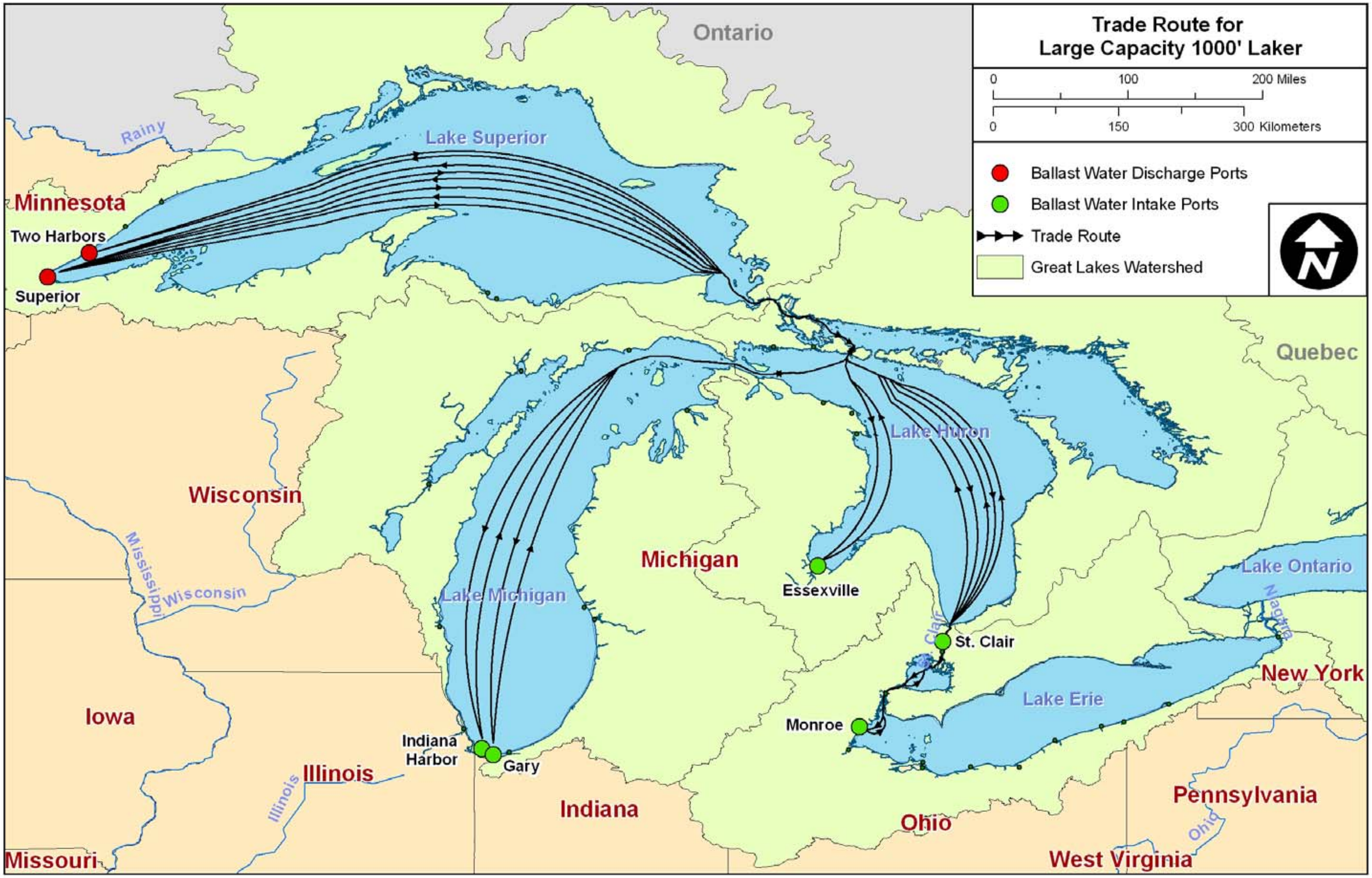

Figure 8. Large capacity 1000' Laker trade route.

Figure 9. Older, small capacity 700' – 800' Laker trade route.

Figure 10. Newer, intermediate capacity 800' − 900' Laker trade route.

Figure 11. Small capacity, river class 600' – 700' Laker trade route.

The Older, Small Capacity 700' – 800' Laker is designed to transport three commodities: iron ore pellets, coal, and limestone. The trading route varies from South Lake Michigan to both North Lake Huron and West Lake Erie. The principal ballast water discharge is in Northwest Lake Huron, with intake in both East Lake Erie and Southern Lake Michigan. The details of the vessel design are in Appendix C.

The Newer, Intermediate Capacity 800' – 900' Laker is designed to transport three commodities: iron ore pellets, coal, and limestone. This selection is an ATB, which as of 2010, was the last major vessel built for Great Lakes service. The trading routes vary from North Lake Michigan and Northwest Lake Huron to Southern Lake Michigan, South Huron, and West Lake Erie. The ballast is discharged in Northern Lake Michigan and Northwest Lake Huron. The details of the vessel design are in Appendix D.

The Small Capacity River Class 600' – 700' Laker is designed to transport three commodities: iron ore pellets, coal, and limestone. This vessel has the most varied trading route and ballast water transport. The trading routes vary from Northwest Huron and West Erie to Northern Lake Michigan, South Lake Huron, and Western Lake Erie. The short routes in West Lake Erie results in little transport of ballast water. The longer routes transport ballast water to West Lake Erie and Northwest Lake Huron from Northern Lake Michigan, Southern Lake Huron, and Western Lake Erie. The details of the vessel design are in Appendix E.

Due to varying degrees of information availability, some of the appendices include vessel information in more detail than others.

The second part of this report "Ballast Water Treatment - U.S. Great Lakes Bulk Carrier Engineering and Cost Study, Volume II – Analysis of On-Board Treatment Methods, Alternative Ballast Water Management Practices and Implementation Costs" will use four of the five vessels identified in this volume for further investigation. The additional work includes engineering and cost estimates to install BWT systems on the vessels and will also investigate alternative ballast water management systems, i.e, treatment ashore. (Note: Project funding did not allow engineering studies on all five vessels.)

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APPENDIX A INTERMEDIATE TO LARGE CAPACITY 1000' LAKER

A.1 Intermediate to Large Capacity 1000' Laker: Vessel Construction

Table A-1 lists the Intermediate to Large Capacity 1000’ Laker principal characteristics. The vessel is built from ABS high strength steel AH36 or equal for plating and framing. The structure is designed for a scantling draft of 28.0’, with a section modulus capable of a loaded draft of 28.89’. The general structural arrangement of the vessel is longitudinally framed with transverse web frames spaced, in general, at 4.0’. The bow section of the vessel has radial cant frames back to the collision bulkhead with a cylindrical bow shape and the stern shape is similar to a barge rake.

Table A-1. Intermediate to large capacity 1000' Laker: principal characteristics.

Length at Waterline	1,000.0’
Beam Molded	105.0’
Draft	28’
Depth, Molded, Main Deck	50.0’
Camber of Main Deck, Straight Line	0.5’ in 52.5’
Lightship	13,389 lt
Gross Tonnage	34,568
Net Tonnage (Registered)	29,412
Number of Cargo Holds	14
Cargo Type	Iron Ore Pellets
Deadweight Tonnage	62,400 lt (63,401 mt)
Number of Ballast Tanks	20
Ballast Tank Capacity	34,569
Power Plant	16,000 hp (Diesel)
Year Built	1978
Shipyard	American Ship Building Co.

A.2 Intermediate to Large Capacity 1000' Laker: Vessel Arrangement

The vessel is arranged with a deckhouse aft, with accommodations and propulsion (Figure A-1 and Figure A-2). A self-unloading system is fitted at the aft end of the cargo block and embedded into the machinery space below the main deck and into the deckhouse above the main deck; it consists of a loop-type elevating conveyor and boom conveyor (Figure A-3). The pilothouse is aft, over the accommodation house, and the vessel has a small lookout house forward. The machinery space is 19 frames long at 3.0’ each, which equals 57.0,’ and the hull extends another 41.0’ aft of the machinery space. The cargo block is divided into seven cargo holds, six forward holds with a length of 120.0’ each, with 144.0’ for hold seven. The cargo holds are comprised of 35-degree transverse slopes feeding gravity-type cargo gates, where the cargo flows onto a conveyor belt (one port and one starboard, that carry the cargo aft) dropping onto a single transverse belt, feeding the loop conveyor and the boom conveyor. The main deck has hatches with covers that are removed and stacked by a hatch cover crane that allows the vessel to be loaded at a timely rate of some 10,000 tons per hour.

A.3 Intermediate to Large Capacity 1000' Laker: Ballast System

The installed ballast system is capable of counter-acting the loading rate of the shore facility to keep the vessel in close vertical tolerance to the loading facility. The ballast system is comprised of nine electric motor-driven pumps on each side of the vessel for a total of 18. Each pump is rated at 3,600 gpm (820 mt per hour) with a combined capacity of 64,800 gpm (14,720 mt per hour). The ballast piping system on this 1000’ vessel is comprised of a suction/discharge pump located in the unloading tunnel on the tank top, at each tank, port and starboard of the vessel (Figure A-4). The discharge pipe is 12” diameter pipe, and the suction pipe is a 10” pipe. One 6” branch pipe line from # 1, port ballast system services the forepeak tank. Each ballast tank is fitted with a 10” fill line and remotely-controlled, powered valve located in the unloading tunnel, and a suction box which is located close to the vessel bottom for optimum performance.

A.4 Intermediate to Large Capacity 1000' Laker: Ballast Water Management

The vessel is ballasted to maintain safe and efficient operations is discussed in Section 3. Table A-2 provides the tank capacities.

Table A-2. Intermediate to large capacity 1000' Laker: ballast tank capacities (estimated).

Tank	Tank Length (ft)	Weight (mt)	Cubic Feet
Forepeak	40.0	1,742	61,527
No. 1 Port	96.0	2,464	87,028
No. 1 Starboard	96.0	2,464	87,028
No. 2 Port	96.0	2,464	87,028
No. 2 Starboard	96.0	2,464	87,028
No. 3 Port	96.0	2,464	87,028
No. 3 Starboard	96.0	2,464	87,028
No. 4 Port	96.0	2,464	87,028
No. 4 Starboard	96.0	2,464	87,028
No. 5 Port	96.0	2,464	87,028
No. 5 Starboard	96.0	2,464	87,028
No. 6 Port	96.0	2,464	87,028
No. 6 Starboard	96.0	2,464	87,028
No. 7 Port	96.0	2,464	87,028
No. 7 Starboard	96.0	2,464	87,028
No. 8 Port	96.0	2,464	87,028
No. 8 Starboard	96.0	2,464	87,028
No. 9 Port	96.0	2,464	87,028
No. 9 Starboard	96.0	2,464	87,028
After peak Centerline	52.0	680	24,017
Totals		**46,774.0**	**1,652,050**

A.5 Intermediate to Large Capacity 1000' Laker: Ballast Water Management

Table A-3 and Table A-4 respectively, provide estimated ballast pumping capacities and operational ballast conditions.

Table A-3. Intermediate to large capacity 1000' Laker: ballast pumping capacities.

Pumps	Gallons/Hour	mt/Hour	Hours to Empty
3,600 gpm Ballast-one tank	216,000	820	3.0
Stripping	n/a	n/a	n/a
Total Vessel Capacity (18 pumps)	**3,888,000**	**14,760**	**3.0/5.1***

*Note: If the forepeak tank is drained completely in conjunction with the 1-Port Water Ballast tank, the 3,600 gpm pump would require over 5 hours to discharge the combined estimated capacity of 4200 mt. Also, the study has not conducted a full electrical load analysis to determine whether the vessel's electrical service capacity would allow all 18 pumps to operate simultaneously at full load. (Loading all cargo holds simultaneously is not normal vessel loading procedures.)

Table A-4. Intermediate to large capacity 1000' Laker: operational ballast conditions (sample).

Condition	Tanks w/Water	Total mt	Pump Rate (0.8)	Hours	Draft	
					Forward (ft)	Aft (ft)
Limited information available						
Summer	1-9 P/S	28,625	11,808	1.7**	n/a	n/a

**Note: Ballast discharge time based on multiple ballast tanks with 1,723 mt, individual discharge (per water ballast tank) rate as 0.8 * 820 mt/hr

Figure A-1. Intermediate to large capacity 1000' Laker: photo.

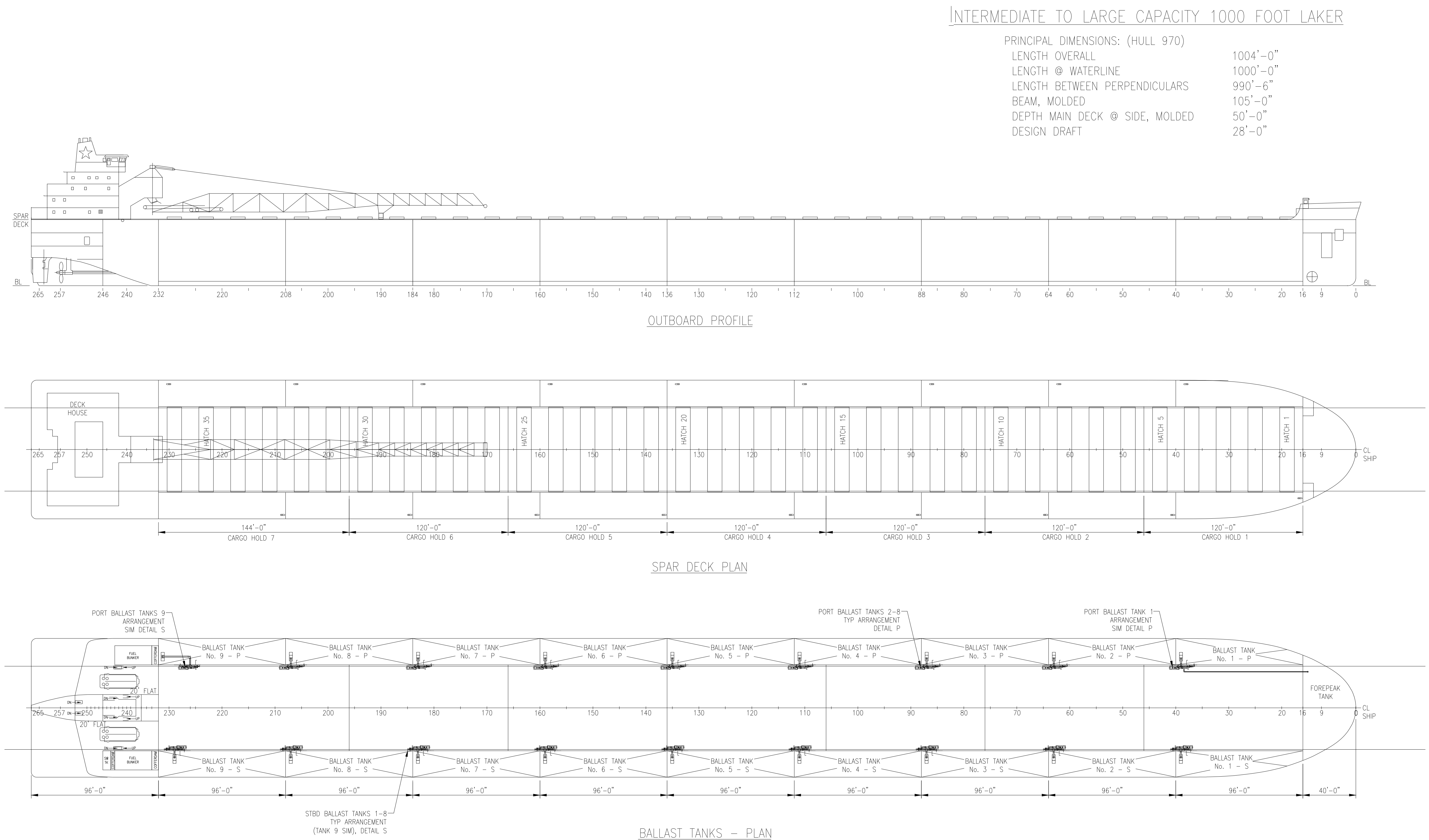

Figure A-2. Intermediate to large capacity 1000' Laker: general arrangement.

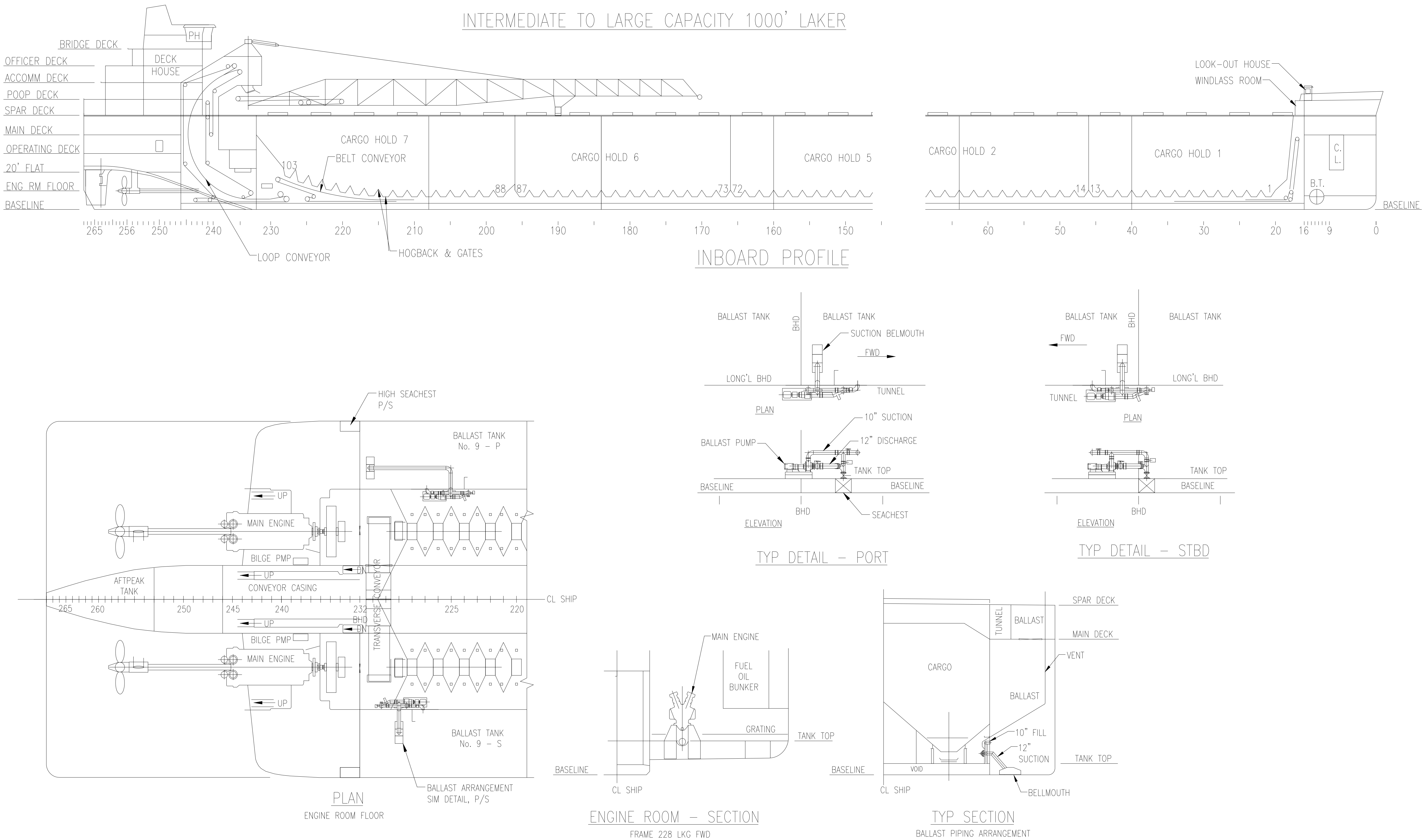

Figure A-3. Intermediate to large capacity 1000' Laker: engine room arrangement.

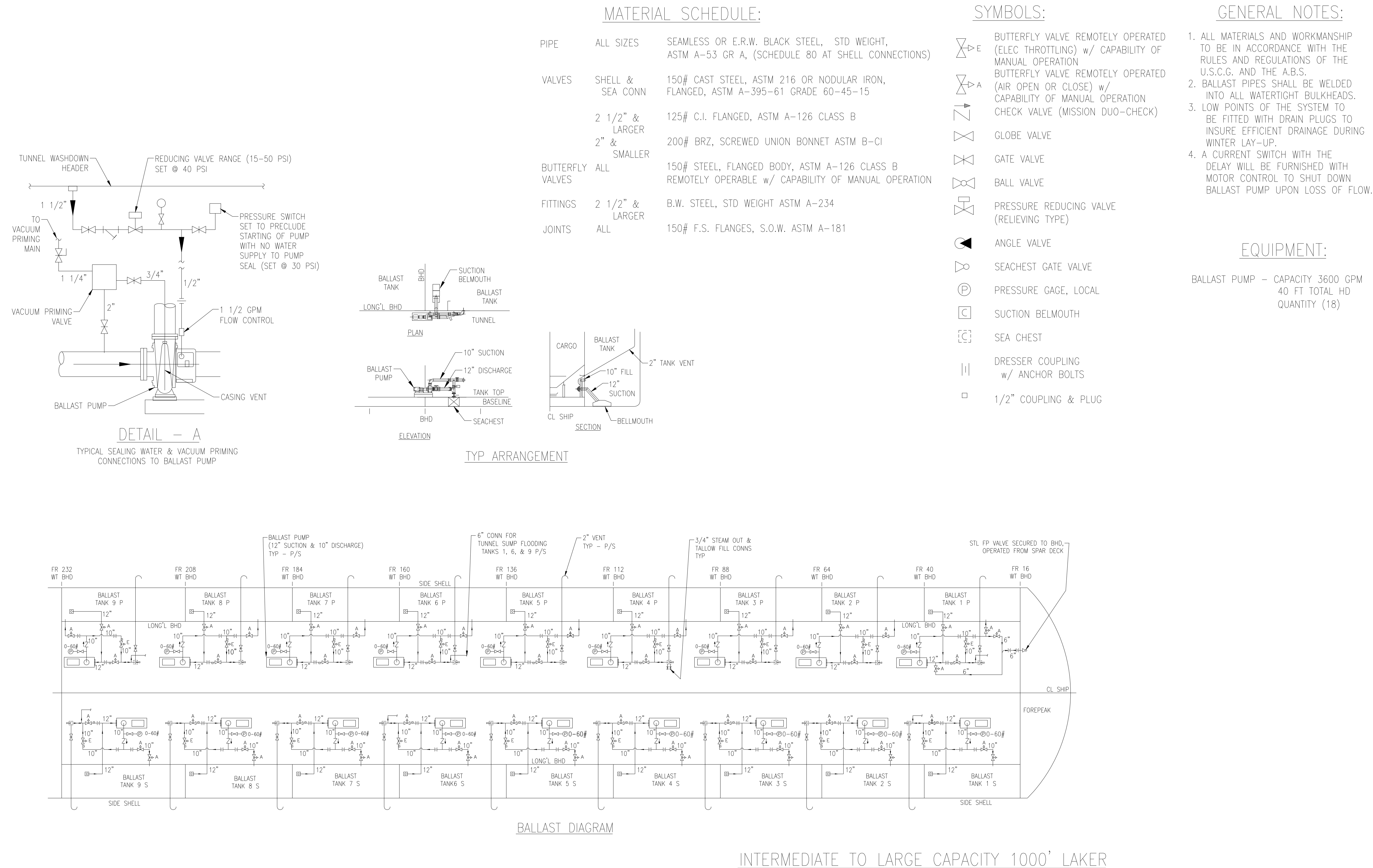

Figure A-4. Intermediate to large capacity 1000' Laker: ballast diagram.

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APPENDIX B LARGE CAPACITY 1000' LAKER

B.1 Large Capacity 1000' Laker: Vessel Construction

Table B-1 lists the Large Capacity 1000' Laker principal characteristics. The vessel is built from ABS high strength steel AH36 or equal for plating and framing. The structure is designed for a scantling draft of 38.0', with a section modulus capable of a loaded draft of 34.0'. The general structural arrangement of the vessel is longitudinally framed with transverse web frames spaced, in general, at 8.0'. The bow section of the vessel has radial cant frames back to the collision bulkhead with a cylindrical bow shape and the stern shape is similar to a barge rake.

Table B-1. Large capacity 1000' Laker: principal characteristics.

Length at Waterline	1,000.0'
Beam Molded	105.0'
Draft	34.0'
Depth, Molded, Main Deck	60.0'
Camber of Main Deck, Straight Line	1.09' in 52.5'
Lightship	13,389 lt
Gross Tonnage	35,923
Net Tonnage (Registered)	33,534
Number of Cargo Holds	7
Cargo Type	Iron Ore Pellets, Coal
Deadweight Tonnage	89,641 lt (91,079 mt)
Number of Ballast Tanks	18
Ballast Tank Capacity	62,150 mt
Power Plant	16,000 hp (Diesel)
Year Built	1979
Shipyard	Bay Shipbuilding Company

B.2 Large Capacity 1000' Laker: Vessel Arrangement

The vessel is arranged with a deckhouse aft, with accommodations and propulsion (Figure B-1 and Figure B-2). A self-unloading system is fitted at the aft end of the cargo block and embedded into the engine room space (Figure B-3) below the main deck and into the deckhouse above the main deck, and consists of a loop-type elevating conveyor and boom conveyor. The pilothouse is located aft, over the accommodation house, and the vessel has a small lookout house forward. The machinery space is seven frames long at 8.0' each, which equals 56.0', and the hull extends another 64.0' aft of the machinery space. The cargo block is divided into seven cargo holds which vary in length from 144.0' midship to 104.0' for hold seven. The cargo holds are comprised of 35-degree transverse slopes feeding gravity-type cargo gates, where the cargo flows onto a single conveyor belt feeding the loop conveyor and the boom conveyor. The main deck has hatches with covers that are removed and stacked by a hatch cover crane that allows the vessel to be loaded at a timely rate of some 10,000 tons per hour.

B.3 Large Capacity 1000' Laker: Ballast System

The installed ballast system is capable of counter-acting the loading rate of the shore facility to keep the vessel in close vertical tolerance to the loading facility. Table B-2 provides the capacity of the ballast tanks. The ballast system is comprised of two large electric motor-driven pumps on each side for a total of four. Figure B-4 shows the arrangement of the ballast system. Each ballast pump is rated at 13,000 gpm (2950 mt per hour). The combined capacity of the four pumps is 52,000 gpm (11,810 mt per hour). The ballast piping system on this 1000' vessel is a single header leading down each side of the vessel and located in the ballast tanks with branch lines to each tank. The main header is a 30" diameter pipe for the most of the length that tapers to a 16" diameter at the forward extreme and the forepeak tank. Each ballast tank is fitted with a 14" diameter branch line and remotely controlled powered valve located in the unloading tunnel, and a suction box which is located close to the vessel bottom for optimum performance.

Table B-2. Large capacity 1000' Laker: ballast tank capacities.

Tank	Tank Length (ft)	Weight (mt)	Cubic Feet
Forepeak	32.0	1,756.2	62,020
No. 1 Port	128.0	3,759.2	132,750
No. 1 Starboard	128.0	3,759.2	132,750
No. 2 Port	120.0	4,071.4	143,780
No. 2 Starboard	120.0	4,071.4	143,780
No. 3 Port	144.0	4,886.5	172,570
No. 3 Starboard	144.0	4,886.5	172,570
No. 4 Port	144.0	4,886.5	172,570
No. 4 Starboard	144.0	4,886.5	172,570
No. 5 Port	144.0	4,886.5	172,570
No. 5 Starboard	144.0	4,886.5	172,570
No. 6 Port	120.0	4,071.4	143,780
No. 6 Starboard	120.0	4,071.4	143,780
No. 7 Port	48.0	1,595.6	56,350
No. 7 Starboard	48.0	1,595.6	56,350
No. 8 Port	120.0	1,647.5	56,350
No. 8 Starboard	120.0	1,647.5	56,350
After peak Centerline	120.0	796.8	28,140
Totals		**62,162.2**	**2,195,260**

The vessel has a stripping system on each side of the vessel. The pump capacity for each stripping system is 3,000 gpm (680 mt per hour) through a 12" diameter pipe on each side. The total ballast discharge rate for this vessel is 58,000 gpm (13,170 mt per hour) with all six pumps at maximum capacity (Table B-3).

Table B-3. Large capacity 1000' Laker: ballast pumping capacities.

Pumps	Gallons/Hour	mt/Hour	Hours to Empty
13,000 gpm (4) Ballast	3,120,000	11,800	5.3
3,000 gpm (2) Stripping	360,000	1400	44.4
Total Capacity	**3,480,000**	**13,200**	**4.7**

B.4 Large Capacity 1000' Laker: Ballast Water Management

The vessel is ballasted to maintain safe and efficient operations as discussed in Section 3. Table B-2 lists the ballast tanks and capacity, while Table B-4 provides several different ballast conditions. The maximum pump capacity is reduced by 20 percent to account for changes in discharge head.

Table B-4. Large capacity 1000' Laker: operational ballast conditions (samples).

Condition	Tanks w/Water	Total mt	Pump Rate (0.8)	Hours	Draft	
					Forward (ft)	Aft (ft)
River Ballast	1,2,3,4,5,6,7, & 8	33,179	9,440 mt/hr	3.53	13.0	21.5
No. 4 Ballast	1,2,3,4,5,6,7, & 8	48,014	9,440 mt/hr	5.16	22.0	23.0
No. 8 Ballast	1,2,3,4,5,6,7, & 8	36,842	9,440 mt/hr	3.92	14.0	23.0
No. 12 Ballast	3,4,5,6,7, & 8	18,825	9,440 mt/hr	2.00	1.0	23.0
Full Ballast	ALL	62,163	9,440 mt/hr	6.62	27.7	27.8

B.5 Large Capacity 1000' Laker: Estimated Electrical Power Requirements

The summary of electrical load is used to size and select the generators to safely operate the vessel. The calculation is unique to vessel design and operation. This electrical load summary is divided into winter and summer, these being distinct load requirements for this vessel (i.e. winter requiring heating, while summer requires air conditioning systems), and are shown in Table B-5. The vessel has different electrical load requirements depending on the operating condition (i.e., docking, loading, etc.). Because not all equipment operates 100 percent of the time, various load factors were assigned to individual electrical systems that make up those listed in the summary table. The load factor is based on design requirement, specification, and engineering experience. For this vessel, the load factors for the ballast pumps range between 0.80 and 1.00, meaning that during loading and unloading ballast pumps are in operation 80-100% of the time.

Table B-5. Large capacity 1000' Laker: summary of estimated electrical load.

Load Group	At Sea		Docking		Loading		Unloading	
	Load Factor	Load (kW)	Load Factor	Load (kW)	Load Factor	Load (kW)	Load Factor	Load (kW)
Propulsion		97.68		104.08		3.6		4.8
Ballast System						392.0		392.0
Ship Service Auxiliary		40.62		39.7		64.7		39.9
Electric Heating System		111.0		111.0		111.0		133.0
Ventilation System		72.2		72.2		72.2		72.2
Deck Equipment				40.0		16.0		16.0
Bow Thruster Auxiliary		0.75		3.6		0.75		0.75
Conveyor System Auxiliary								57.2
Communication & Navigation		3.8		3.5		0.5		0.5
Lighting		70.5		70.5		70.5		70.5
Stern Thruster Auxiliary				8.0				
Galley		14.04		14.04		14.04		14.04
TOTAL		**410.6**		**466.6**		**745.3**		**800.9**
Propulsion		97.68		104.08		3.6		4.8
Ballast System						392.0		392.0
Ship Service Auxiliary		105.42		104.5		129.5		104.7
Electric Heating System								
Ventilation System		72.2		72.2		72.2		72.2
Deck Equipment				40.0		16.0		16.0
Bow Thruster Auxiliary		0.75		3.6		0.75		0.75
Conveyor System Auxiliary								57.2
Communication & Navigation		3.8		3.5		0.5		0.5
Lighting		70.5		70.5		70.5		70.5
Stern Thruster Auxiliary				8.0				
Galley		14.04		14.04		14.04		14.04
TOTAL		**364.4**		**420.4**		**699.1**		**732.7**

Figure B-1. Large capacity 1000' Laker: photo.

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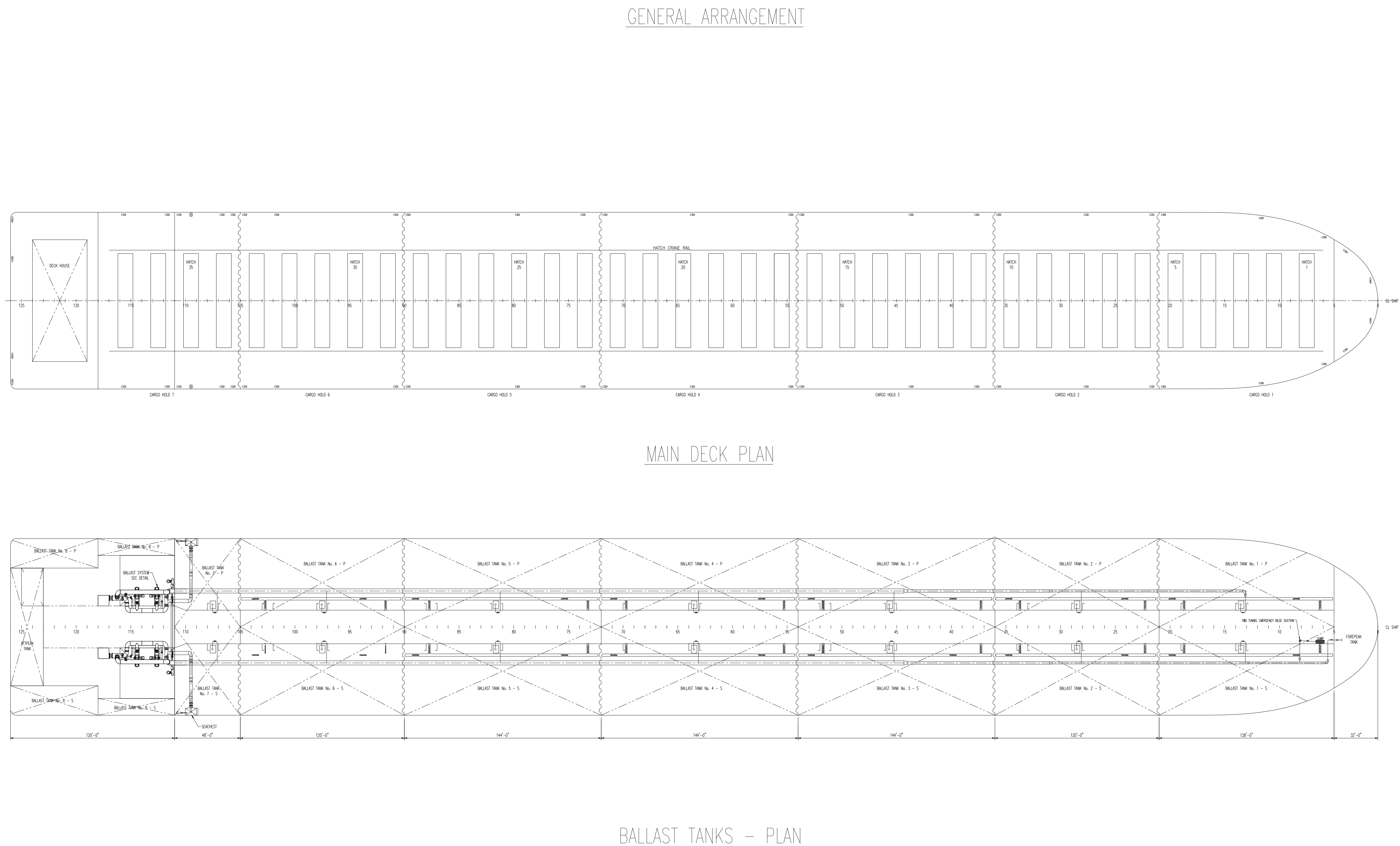

Figure B-2. Large capacity 1000' Laker: general arrangement.

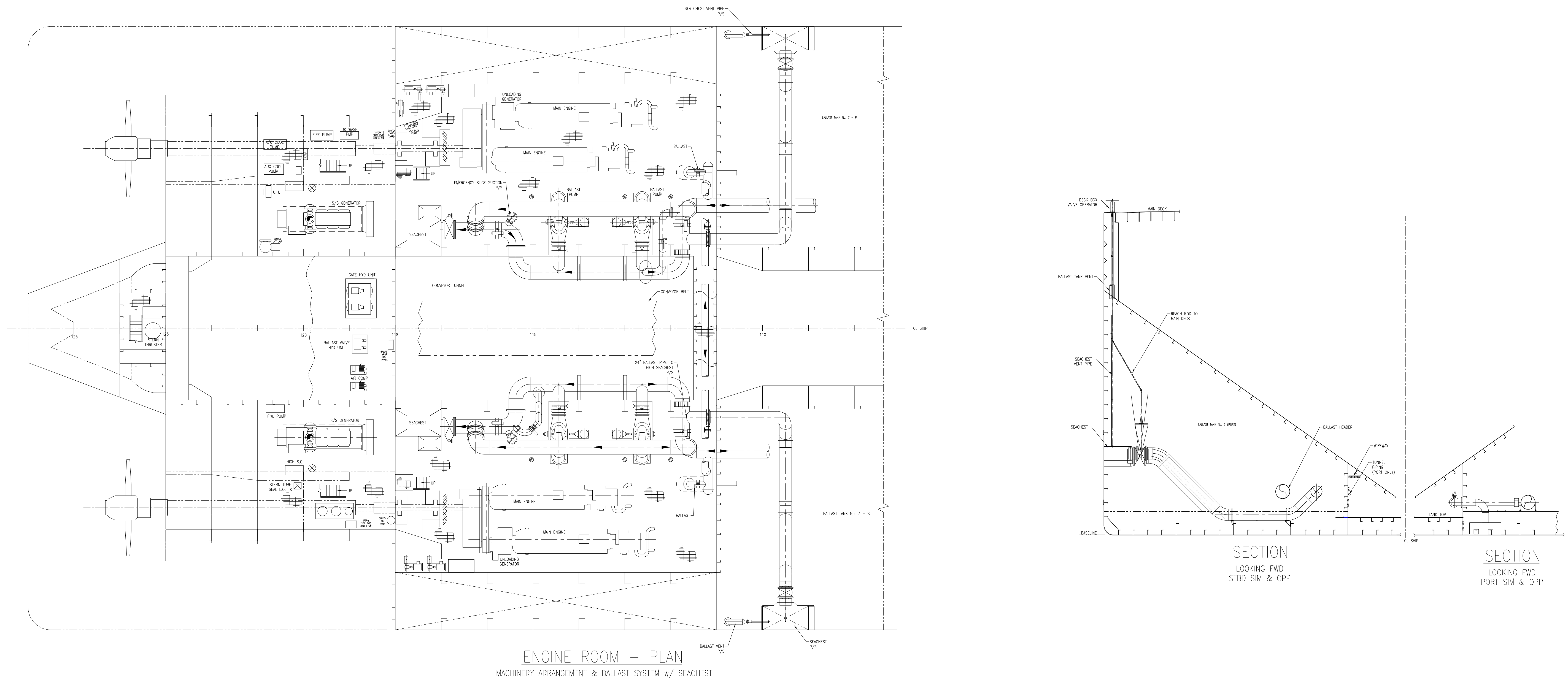

Figure B-3. Large capacity 1000' Laker: engine room arrangement.

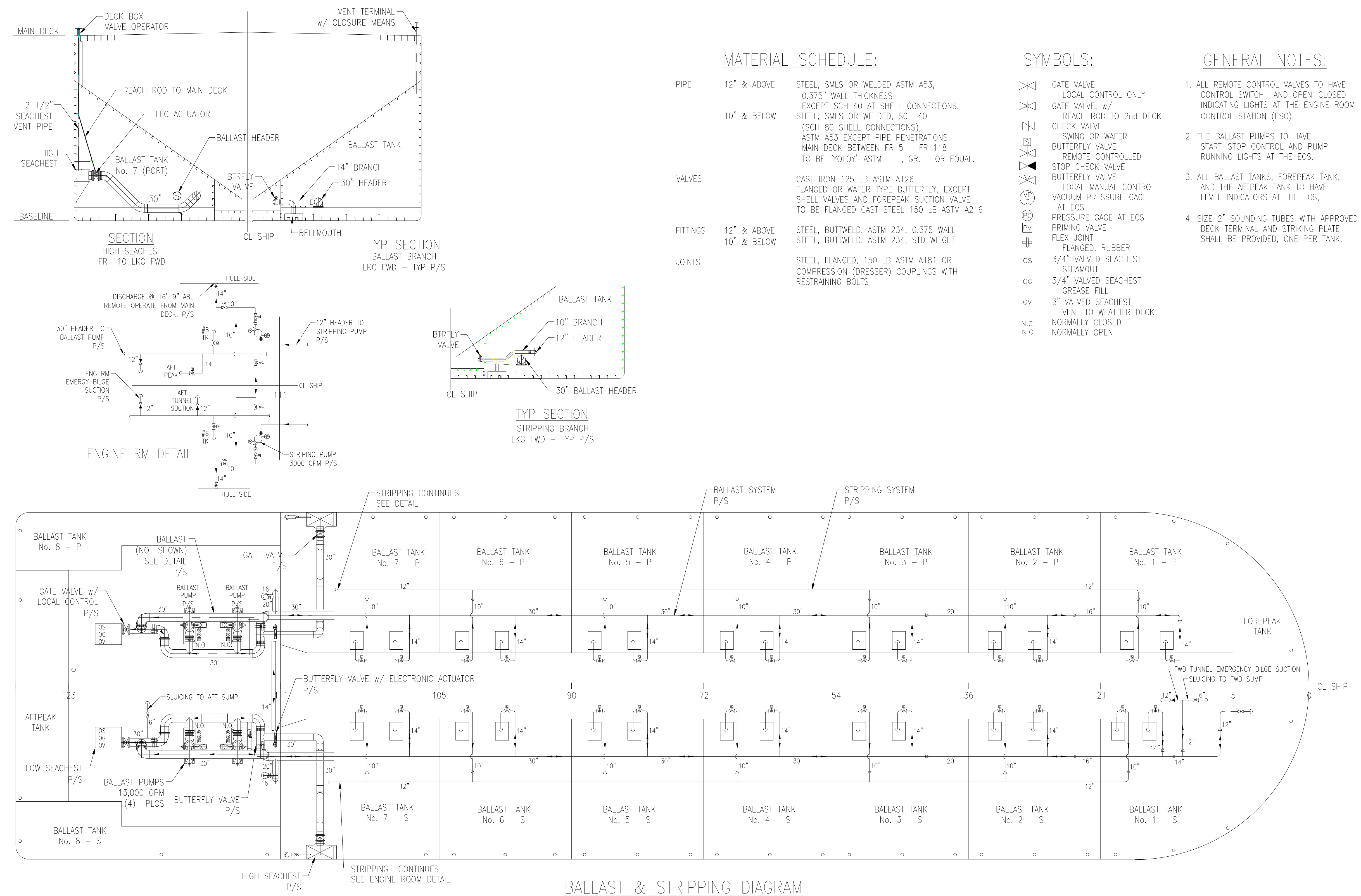

Figure B-4. Large capacity 1000' Laker: ballast water diagram.

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APPENDIX C OLDER, SMALL CAPACITY 700' – 800' LAKER

C.1 Older, Small Capacity 700' - 800' Laker: Vessel Construction

Table C-1 lists the older, small capacity 700' - 800' 1000’ Laker principal characteristics. The vessel is built from ABS ordinary strength steel or equal for plating and framing. The structure is designed for a midsummer draft of 27.04’. The general structural arrangement of the vessel is transversely framed with transverse web frames spaced, in general, at 3.0’. The bow section of the vessel has a semi-ship shape bow, with the collision bulkhead located at frame 16, and the stern shape is a ship shape “wine glass”, with a centerline skeg, and stern frame supporting the rudder lower bearing. This ship has camber on the spar deck, with sheer forward and aft. The vessel was lengthened by 102.0’ in 1976.

Table C-1. Older, small capacity 700' - 800' Laker: principal characteristics.

Length at Waterline	742.0’ after 102.0’ lengthening
Beam Molded	72.0’
Draft	27.0’
Depth, Molded, Main Deck	36.0’
Camber of Main Deck, Straight Line	1.5’ in ½ beam
Lightship	9,150 lt
Gross Tonnage	15,179
Net Tonnage (Registered)	11,330
Number of Cargo Holds	14
Cargo Type	Iron Ore Pellets, Coal, Limestone
Deadweight Tonnage	25,601 lt (26,011 mt)
Number of Ballast Tanks	18
Ballast Tank Capacity	62, 150 mt
Power Plant	7,700 hp (Steam)
Year Built	1952/1976 lengthened
Shipyard	Manitowoc Shipbuilding, Inc./Fraser Shipyard

C.2 Older, Small Capacity 700' - 800' Laker: Vessel Arrangement

The vessel is arranged with a deckhouse forward and aft, with accommodations forward, and with accommodations and propulsion located aft (Figure C-1 and Figure C-2). A self-unloading inclined belt system is fitted at the forward end of the cargo block, with a top side “A” frame through the spar deck, where the cargo then transfers to the cargo boom conveyor. Forward, the pilothouse is located over the accommodations. Aft, the engine room space (Figure C-3) is 102.0’ long over 34 frames of 3’ spacing, and the hull extends another 39.0’ aft of the machinery space. The cargo block is divided into seven cargo holds which vary in length from 90.0’ for hold one, 72.0’ for holds two, three, and six, 96.0’ for hold four, 78.0’ for hold five, and 75.0’ for hold seven, for a total length of 555.0’. The cargo holds are comprised of 35-degree transverse slopes feeding gravity type cargo gates, where the cargo flows onto conveyor belts, one port, one starboard, rising forward and feeding an inclined belt on the centerline via a transverse loading chute feeding the inclined conveyor and the boom conveyor. The spar deck has hatches with covers that are removed and stacked by a hatch cover crane that allows the vessel to be loaded at a timely rate of some 5,600 tons per hour.

C.3 Older, Small Capacity 700' - 800' Laker: Ballast System

The installed ballast system is capable of counter-acting the loading rate of the shore facility to keep the vessel in close vertical tolerance to the loading facility. Table C-2 (Fraser Shipyards, Inc, 1975a; Fraser Shipyards, Inc., 1975b) provides the capacity of the ballast tanks. The ballast system is comprised of one electric motor driven pump on each side (total of two (Figure C-4)). The combined capacity is 21,000 gpm (4,770 mt per hour). Each ballast pump is a 150 hp motor-driven, rated at 10,500 gpm (2,380 mt per hour) with 40' total dynamic head. The ballast system on this vessel is augmented by one smaller electric motor driven pump on each side of the vessel (total of two). Each smaller ballast pump has a capacity of 2,000 gpm (450 mt per hour). The combined capacity of the two systems is 25,000 gpm (5,680 mt per hour)(see Table C-3). The ballast system on this 768.25' vessel is a manifold and single line per tank type, with the single lines leading down each side of the vessel through the ballast tanks in a raft of pipes. The line for ballast tanks 1-8 P/S is a 10" diameter pipe, with a 6" diameter branch line for the forepeak tank. Each ballast tank suction line is fitted with a suction box located close to the vessel bottom.

Table C-2. Older, small capacity 700' - 800' Laker: ballast tank capacities.

Tank	Tank Length (ft)	Weight (mt)	Cubic Feet
Forepeak	24.0	253.0	8,930
No. 1 Port	66.0	497.9	17,580
No. 1 Starboard	66.0	497.9	17,580
No. 2 Port	72.0	672.6	23,750
No. 2 Starboard	72.0	672.6	23,750
No. 3 Port	72.0	649.3	22,930
No. 3 Starboard	72.0	649.3	22,930
No. 4 Port	72.0	649.3	22,930
No. 4 Starboard	72.0	649.3	22,930
No. 5 Port	96.0	865.7	30,570
No. 5 Starboard	96.0	865.7	30,570
No. 6 Port	78.0	703.1	24,830
No. 6 Starboard	78.0	703.1	24,830
No. 7 Port	72.0	649.3	22,930
No. 7 Starboard	72.0	649.3	22,930
No. 8 Port	75.0	653.3	23,070
No. 8 Starboard	75.0	653.3	23,070
Trim Tank Port	36.0	241.8	8,540
Trim Tank Starboard	36.0	241.8	8,540
No. 9 Port	69.0	170.7	6,030
No. 9 Starboard	69.0	170.7	6,030
Afterpeak	36.0	174.0	6,140
TOTALS		**11,933.0**	**421,390**

Table C-3. Older, small capacity 700' - 800' Laker: ballast pumping capacities.

Pumps	Gallons/Hour	mt/Hour	Hours to Empty
21,000 gpm Main Ballast (2)	1,260,000	4,770	2.5
4,000 gpm Auxiliary (2)	240,000	900	13.3
TOTAL CAPACITY	**1,500,000**	**5,670**	**2.1**

C.4 Older, Small Capacity 700' - 800' Laker: Ballast Water Management

The vessel is ballasted to maintain safe and efficient operations as discussed in Section 3. Table C-2 shows a listing of the ballast tanks. Table C-4 provides several different ballast conditions. The maximum pump capacity is reduced by 20 percent to account for changes in discharge head.

Table C-4. Older, small capacity 700' - 800' Laker: operational ballast conditions.

Condition, Tanks w/Water	Tanks	Total mt	Pump Rate (0.8)	Hours	Draft Forward (ft)	Draft Aft (ft)
Light Ballast	4,5,6,7,8,9 & Aftpeak	7556	3,816 mt/hr	2.0	6.3	18.4
Medium Ballast	3,4,5,6,7,8,9 & Aftpeak	8,855	3,816 mt/hr	2.3	9.0	19.5
Heavy Ballast	2, 3, 4, 5, 6, 7, 8, 9, Trim Tank & Aftpeak	10,684	3,816 mt/hr	2.9	19.5	19.9

C.5 Older, Small Capacity 700' - 800' Laker: Electrical Power Requirements

The summary of electrical load is used to size and select the generators to safely operate the vessel. The calculation is unique to vessel design and operation. The vessel has different electrical load requirement depending the operating condition (i.e., docking, loading, etc.); see Table C-5. Since not all equipment operates 100% of the time, a load factor is assigned. The load factor is based on design requirement, specification, and engineering experience. For this vessel the load factors during loading are 1.00 for one ballast pump and 0.80 for the other. The difference between the load factors would be a result of pump size and cargo loading rate.

C.6 References

Fraser Shipyards, Inc. (1975a). Tank capacity curves. Drawing MAN 415-S29-1-21, Rev 0.
Fraser Shipyards, Inc. (1975b). Capacity plan. Drawing MAN 415 S29-1-23.

Table C-5. Older, small capacity 700' - 800' Laker: summary electrical of load.

Load Group	Rated (hp)	Motor Input (kW)	At Sea		Maneuvering		Loading		Unloading	
			Load Factor	Load (kW)	Load Factor	Load (kW)	Load Factor	Load (kW)	Load Factor	Load (kW)
Ballast System		248.00		0.00		0.00		180.00		180.00
Ship Service Auxiliary		608.90		162.91		152.38		171.47		251.43
Heating		1.00		0.08		0.08		0.08		0.08
Ventilation System		86.80		76.40		74.00		64.40		59.60
Deck Equipment		257.60		0.00		0.00		73.20		67.28
Bow Thruster Auxiliary		804.00		0.00		804.00		0.00		0.00
Conveyor System Auxiliary		1095.20		0.00		0.00		0.00		1062.94
Propulsion		163.00		16.00		64.00		0.00		0.00
Lighting		96.00		67.20		67.20		59.52		67.20
Machine Shop		35.20		0.60		0.48		0.00		0.48
Galley		82.40		24.20		21.80		21.80		21.80
Misc		6.60		1.20		0.00		0.00		0.00
Total		**3484.70**		**348.59**		**1183.94**		**570.47**		**1710.81**

Figure C-1. Older, small capacity 700' - 800' Laker: photo.

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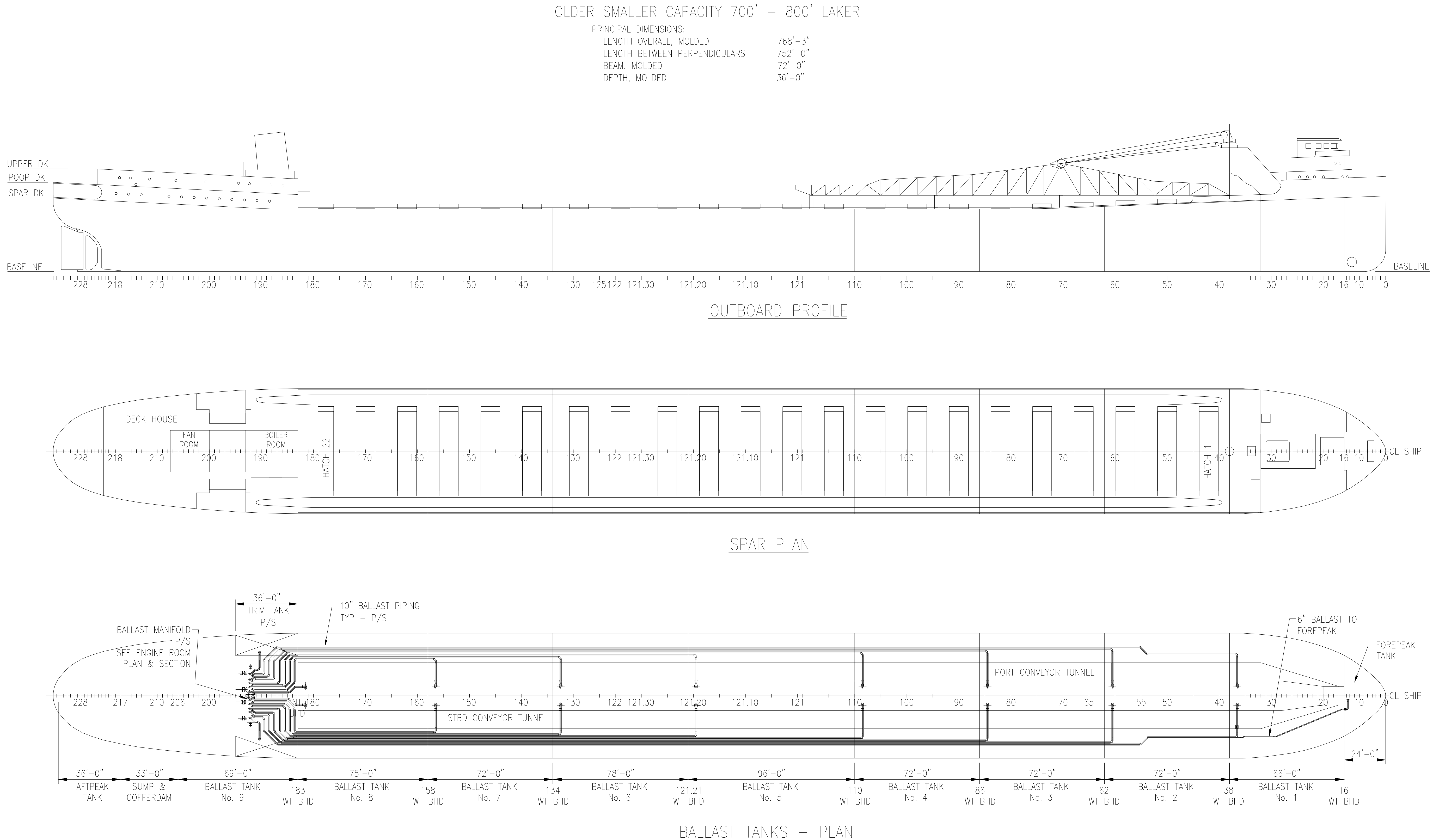

Figure C-2. Older, small capacity 700' - 800' Laker: general arrangement.

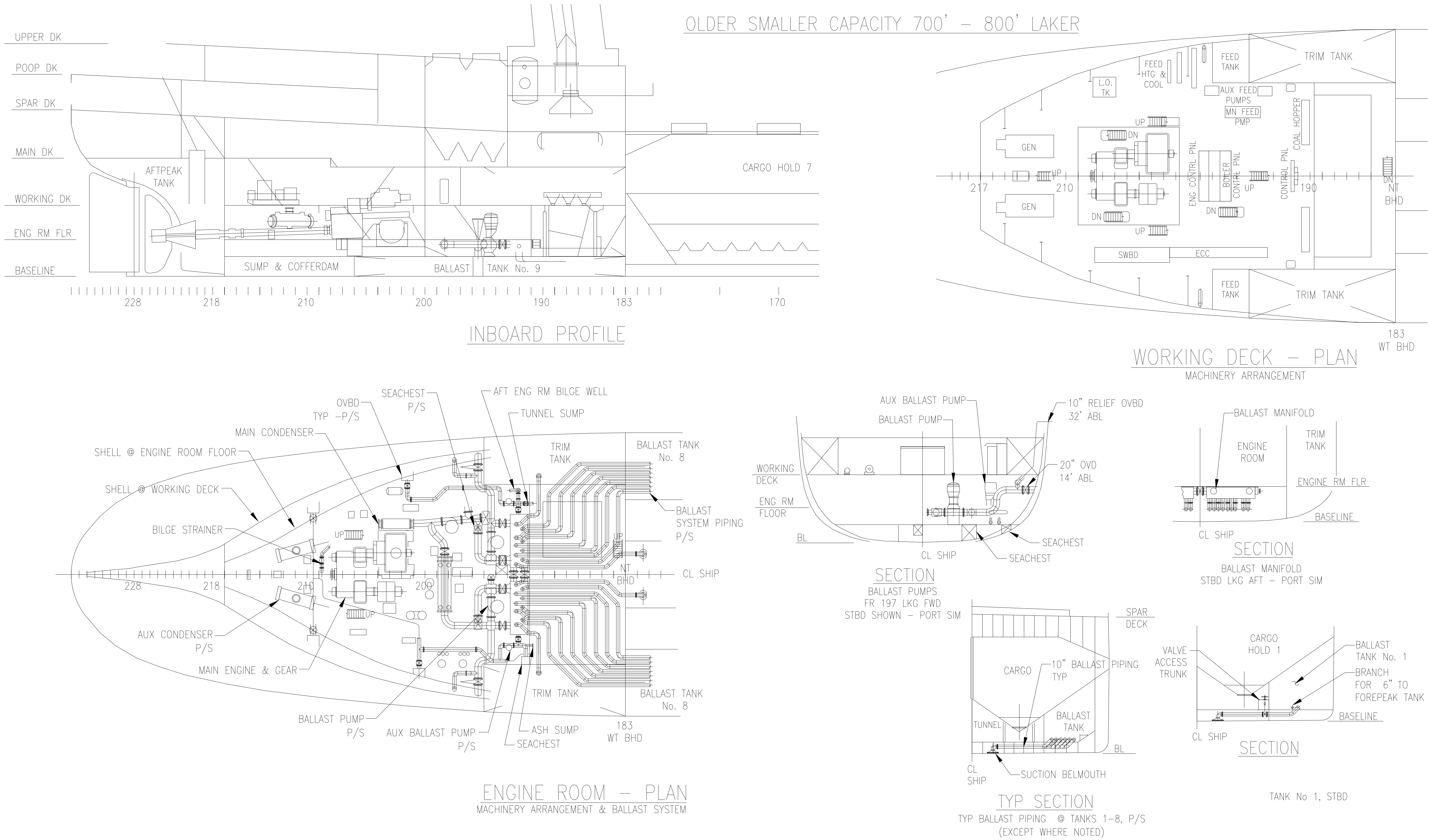

Figure C-3. Older, small capacity 700' - 800' Laker: engine room arrangement.

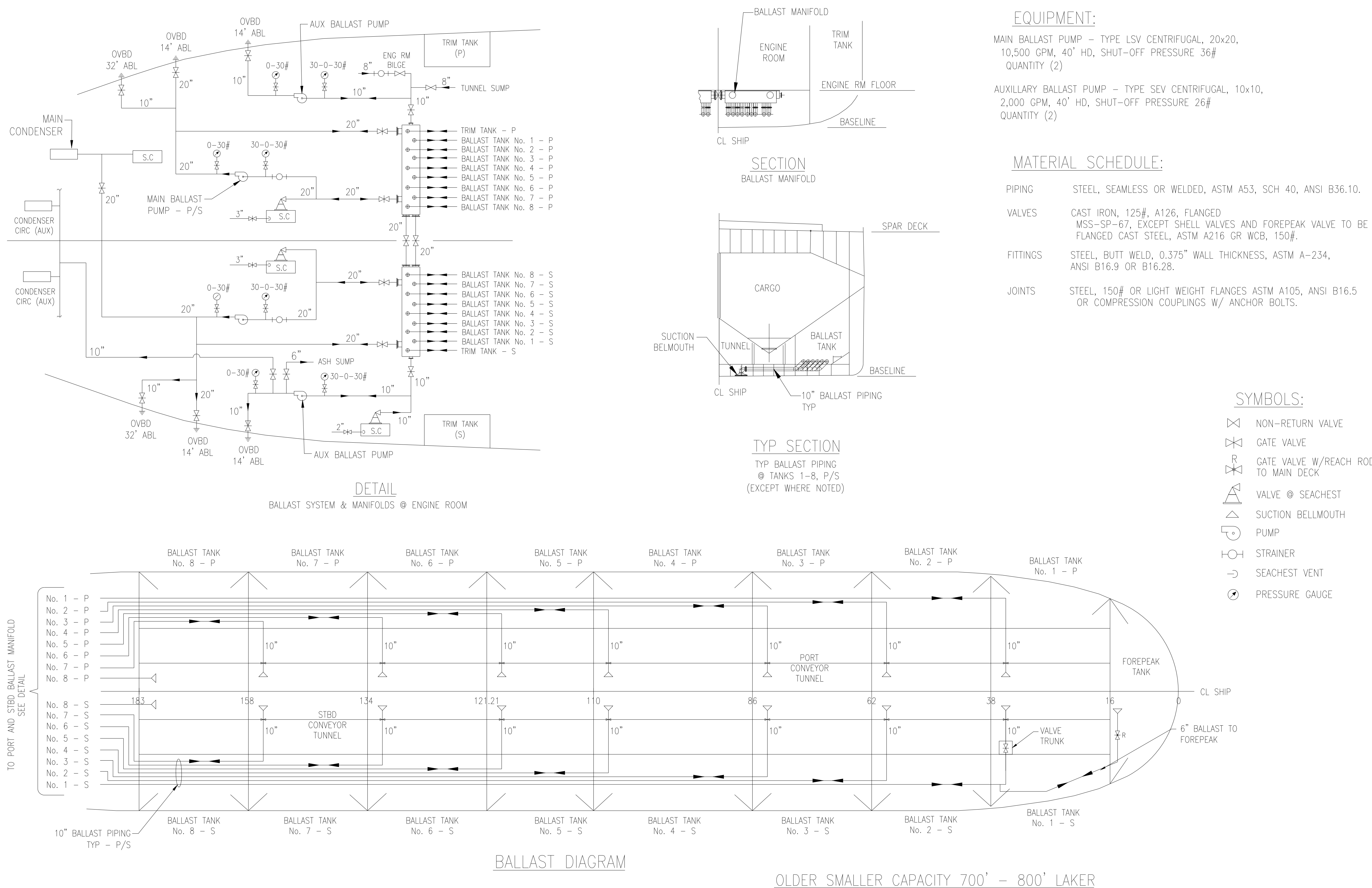

Figure C-4. Older, small capacity 700' - 800' Laker: ballast diagram.

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APPENDIX D NEWER, INTERMEDIATE CAPACITY 800' – 900' LAKER

D.1 Newer, Intermediate Capacity 800' – 900' Laker: Vessel Construction

Table D-1 lists the newer, intermediate capacity 800' - 900' Laker principal characteristics. The vessel is built from ABS high-strength steel AH36 or equal for plating and framing. The structure is designed for a scantling draft of 30.0’, with a section modulus capable of a loaded draft of 27.5’. The general structural arrangement of the vessel is longitudinally framed with transverse web frames spaced, in general, at 8.0’. The bow section of the vessel has radial cant frames back to the collision bulkhead with a cylindrical bow shape and the stern shape is a barge rake, with a tunnel leading into the tug notch for reduced transom drag. The stern has a deep notch cut into it to fit a 135.33’ twin screw pusher tug, with 10,500 horsepower.

Table D-1. Newer, intermediate capacity 800' – 900' Laker: principal characteristics.

Length at Waterline	740.0’ (without tugboat)
Beam Molded	78.0
Draft	27.5’
Depth, Molded, Main Deck	45.0’
Camber of Main Deck, Straight Line	-
Lightship	6235.16 lt
Gross Tonnage	15,823
Net Tonnage (Registered)	15,823
Number of Cargo Holds	7
Cargo Type	Iron Ore Pellets, Coal, Limestone
Deadweight Tonnage	39,600 lt (40,235 mt)
Number of Ballast Tanks	17
Ballast Tank Capacity	24,121 mt
Power Plant	-
Year Built	2000
Shipyard	Halter Marine

D.2 Newer, Intermediate Capacity 800' – 900' Laker: Vessel Arrangement

The vessel is an ATB. The barge is 740’ long and the tug is 135’ long. The barge is arranged with a deckhouse aft that is the main support for the 265’ unloading boom conveyor with a loop-type elevating conveyor that feeds it (Figure D-1 and Figure D-2). The self-unloading system is fitted at the aft end of the cargo block and embedded into the machinery space below the main deck and is enclosed by the deckhouse above the main deck. The barge has a small deckhouse forward which houses the anchor windlass, and has a lookout house on top for improved visibility. The aft machinery space is five frames long at 8.0’ each, for 40.0’, and the hull extends another 40.0’ aft of the machinery space. The cargo block is divided into seven cargo holds which vary in length from 120.0’ midship to 72.0’ for hold seven. The cargo holds are comprised of 35-degree transverse slopes feeding gravity-type cargo gates, where the cargo flows onto a single, centerline conveyor belt feeding the loop conveyor and the boom conveyor. The main deck has hatches with covers that are removed and stacked by a hatch cover crane that allows the vessel to be loaded at a timely rate of some 6,098 mt per hour.

D.3 Newer, Intermediate Capacity 800' – 900' Laker: Ballast System

The installed ballast system is capable of counter-acting the loading rate of the shore facility to keep the vessel in close vertical tolerance to the loading facility. Table D-2 provides the ballast tank capacities. The ballast system is comprised of one hydraulic motor-driven 14,000 gpm (3,180 mt per hour) pump on each side of the vessel with a combined capacity of 28,000 gpm (6,360 mt per hour) (see Table D-3), arranged as shown in Figure D-3 (shown at the end of this appendix). The ballast pumps are each driven by a 225 hp hydraulic motor turning at 600 rpm, direct coupled to the pump shafts. The ballast piping system on this 740' vessel is a single header leading down each side of the vessel and located in the ballast tanks with branch lines to each tank (Figure D-4). The main header is a 24" diameter pipe for the most of the length that tapers to a 12" diameter at the forward extreme, and the forepeak tank. Each ballast tank is fitted with a 12" diameter branch line and has a remotely controlled powered valve located in the unloading tunnel, and a suction box which is located close to the vessel bottom for optimum performance. The vessel also has a stripping system comprised of 14 submersible pumps, one in each tank, with a pumping capacity of 400 gpm (90 mt per hour) each through a 4" diameter pipe tied in to the 12" tank branch lines. The total ballast discharge rate for this vessel is 33,600 gpm (7,620 mt per hour) maximum, with all 16 pumps at maximum capacity.

Table D-2. Newer, intermediate capacity 800' – 900' Laker: ballast tank capacities.

Tank	Tank Length (ft)	Weight (mt)	Cubic Feet
Forepeak	28.0	828.2	29,250
No. 1 Port	80.0	1,244.6	43,950
No. 1 Starboard	80.0	1,244.6	43,950
No. 2 Port	72.0	1,301.4	45,960
No. 2 Starboard	72.0	1,301.4	45,960
No. 3 Port	96.0	1,735.8	61,300
No. 3 Starboard	96.0	1,735.8	61,300
No. 4 Port	120.0	2,169.7	76,620
No. 4 Starboard	120.0	2,169.7	76,620
No. 5 Port	96.0	1,735.8	61,300
No. 5 Starboard	96.0	1,735.8	61,300
No. 6 Port	96.0	1,735.8	61,300
No. 6 Starboard	96.0	1,735.8	61,300
No. 7 Port	72.0	1,370.7	48,410
No. 7 Starboard	72.0	1,370.7	48,410
Machinery Space CL	VOID	0.0	0.0
Aft Ballast Port	24.0	352.7	12,460
Aft Ballast Starboard	24.0	352.7	12,460
After Peak Port	VOID	0.0	0.0
After Peak Starboard	VOID	0.0	0.0
TOTALS	**632.0**	**24,121.2**	**851,850**

Table D-3. Newer, intermediate capacity 800' – 900' Laker: ballast pumping capacities.

Pumps	Gallons/Hour	mt/Hour	Hours to Empty Ballast Tanks
14,000 gpm (2) Ballast	1,680,000	6,360	3.8
400 gpm (14) Stripping	336,000	1,260	19.1
TOTAL CAPACITY	**2,016,000**	**7,620**	**3.2**

D.4 Newer, Intermediate Capacity 800' – 900' Laker: Ballast Water Management

The vessel is ballasted to maintain safe and efficient operations as discussed in Section 3. Table D-2 shows a listing of the ballast tanks. Since this vessel is actually two vessels (tug and barge), the combination has the added required for ballasting during the connection of the tug to the barge. The minimum ballast condition for the barge during the connection is the River Ballast (Table D-4) condition of 17,415 mt. This results in a draft of 16.2 feet. Excerpts from the Guidance Manual for Loading (Bay Engineering, 2011) are listed in Table D-4. The maximum pump capacity is reduced by 20 percent to account for changes in discharge head.

Table D-4. Newer, intermediate capacity 800' – 900' Laker: operational ballast conditions. (Bay Engineering, 2011)

Condition	Tanks w/Water	Total mt	Pump Rate (0.8)	Hours to Empty	Draft (ft)	
					Forward	Aft
Light Ballast (Towing)	1[R], 2, 3[R], 4, 5[R], 6, & 7[R]	10,541	5,088 mt/hr	2.1	10.28	13.17
River Ballast	1, 3, 4, 5, 6, & 7	17,415	5,088 mt/hr	3.4	14.03	18.3
Medium Ballast	1, 2(50% full), 3, 4, 5(75% full), 6, & 7	20,427	5,088 mt/hr	4.0	16.89	19.33
Medium/Heavy Ballast	1, 2(75% full), 3, 4, 5, 6, & 7	21,946	5,088 mt/hr	4.3	18.34	19.83
Heavy Ballast	1, 2, 3, 4, 5, 6, 7, & aftpeak	22,302	5,088 mt/hr	4.4	18.68	21.24
Full Ballast	ALL	24,121	5,088 mt/hr	4.7		

[R]Tank has a residual (approximately 1%) amount of water.

D.5 Newer, Intermediate Capacity 800' – 900' Laker: Electrical Power Requirements

The summary of electrical load is used to size and select the generators to safely operate the vessel. The calculation is unique to vessel design and operation. The electrical summary loads for this vessel include the tugboat and the barge; see Table D-5. Since the tug provides power to the barge during between ports, the barge loads are included in the tug electrical summary loads in transit. These barge loads during transit are used to size the generators on the tugboat. The generators on the barge are principally used during unloading, loading, and docking. These operations are not part of the tugboat operations and the generators are sized for these conditions.

D.6 References

Bay Engineering. (2011). Guidance manual for loading. Drawing 801-03 Rev B.

Table D-5. Newer, intermediate capacity 800' - 900' Laker: summary of electrical load.

			Auxiliary	Rated (hp)	Motor/ Input (kW)	Tug: At Sea (loads are tug-supplied power)				Barge Generator						Remarks
						Summer		Winter		Unloading		Loading		Docking		
						Load Factor	Load (kW)	Load Factor	Load (kW)	Load Factor	Load (kW)	Load Factor	Load (kW)	Load Factor	Load (kW)	
			UNLOADING MCC													
		D4	Charger, Battery, Navigation Lights		0.5	.20	0.1	.20	0.1							
		D4	Charger, Battery, Gen Set & Hyd		0.5	.20	0.1	.20	0.1							
		D4	Charger, Battery, Dual, Diesel Hyd Eng		0.5	.20	0.1	.20	0.1	.20	0.1	.20	0.1	.20	0.1	
		D4	Charger, Battery, Dual, Diesel Hyd Eng		0.5	.20	0.1	.20	0.3	.20	0.1	.20	0.1	.20	0.1	
		D4	Charger, Battery, Dual, Diesel Hyd Eng		0.5	.20	0.1	.20	0.1	.20	0.1	.20	0.1	.20	0.1	
		T4	Compressor, Air (S), No. 1	5	4.1	.30	1.2	.40	1.6	.50	2.1	.50	2.1	.10	0.4	
		T14	Compressor, Air (S), No. 2	15	12.3					.50	6.2	.50	6.2	.10	1.2	
		T14	Fan, Supply, Upper Machy Room, (P)	15	12.3					.90	11.1	.50	6.2	.50	6.2	Variable speed, half speed winter
		T14	Fan, Supply, Upper Machy Room, (S)	15	12.3					.90	11.1	.50	6.2	.50	6.2	Variable speed, half speed winter
		T75	Heating, Upper Machy, Void		90.0			.48	43.2		0.0					
		T75	Heating, Lower Machy Aft & Tunnel		60.0			.48	28.8	.80	48.0					
		T9	Heater, Unit, Actuator Room		15.0			.40	6.0	.80	12.0					
		T4	Heater, Hydraulic Oil, Storage Tanks, (S)		8.0	.40	3.2	.55	4.4							
		T4	Heater, Hydraulic Oil, Storage Tanks, (P)		8.0	.40	3.2	.55	4.4							
		T4	Heater, J W Gen		4.0	.35	1.4	.50	2.0							
		T4	Heater, J W Pump, Eng (P)		3.0	.35	1.1	.50	1.5							
		T4	Heater, J W Pump, Eng (P)		3.0	.35	1.1	.50	1.5							
		T4	Heater, J W Pump, Eng (P)		3.0	.35	1.1	.50	1.5							
		T4	Heater, J W Pump, Eng (P)		3.0	.35	1.1	.50	1.5							
		T4	Heater, J W Pump, Eng (S)		3.0	.35	1.1	.50	1.5							
		T4	Heater, J W Pump, Eng (S)		3.0	.35	1.1	.50	1.5							
		T4	Heater, J W Pump, Eng (S)		3.0	.35	1.1	.50	1.5							
		T4	Heating, Radiant, Control booth (P)		1.0					.24	0.2	.24	0.2	.24	0.2	
		T4	Heating, Radiant, Control booth (S)		1.0					.24	0.2	.24	0.2	.24	0.2	
			Sheet 1 Total kW		**252**		**17**		**102**		**91**		**21**		**15**	

Table D-5. Newer, intermediate capacity 800' - 900' Laker: summary of electrical load (Continued).

			Auxiliary	Rated (hp)	Motor/ Input (kW)	Tug: At Sea (loads are tug-supplied power)				Barge Generator						Remarks
						Summer		Winter		Unloading		Loading		Docking		
						Load Factor	Load (kW)	Load Factor	Load (kW)	Load Factor	Load (kW)	Load Factor	Load (kW)	Load Factor	Load (kW)	
		T50	Panel, Lighting, L2, Aft		7.5	.10	0.8	.10	0.8	.90	6.8	.90	6.8	.90	6.8	
		T14	Panel, Lighting, L3, Fwd \ Deck		4.0	.10	0.4	.10	0.4	.90	3.6	.90	3.6	.90	3.6	
		T23	Panel, Lighting, L4, Aft Boom all-lts		5.5	.09	0.5	.09	0.5	.50	2.8	.50	2.8	.50	2.8	
		T23	Panel, Lighting, L5, Tunnel		4.0	.09	0.4	.09	0.4	1.00	4.0	1.00	4.0	1.00	4.0	
		T23	Panel, Lighting, L6, Signal Lts, Tunnel		7.5					.90	6.8	.90	6.8	.90	6.8	
	7,	T4	Pump, Anti-Freeze	1.5	1.2	.10	0.1	.20	0.2							
	3,	T4	Pump, Bilge, Aft, (P)	5	4.1	.10	0.4	.10	0.4	.10	0.4	.10	0.4	.10	0.4	
	3,	T4	Pump, Bilge, Aft, (S)	5	4.1	.10	0.4	.10	0.4	.10	0.4	.10	0.4	.10	0.4	
		T23	Panel, Lighting, L7, Cargo Hold		13.0					.90	11.7	.90	11.7	.60	7.8	
	13,	T23	Pump, Cooling, Raw water, #3	25	20.5					.90	18.5	.20	4.1	.40	8.2	
	13,	T23	Pump, Cooling, Raw water, #2	25	20.5					.90	18.5	.20	4.1	.40	8.2	
	7,	T4	Pump, Cooling, Raw water, Gen, #1	3	2.5					.90	2.2	.90	2.2	.90	2.2	
	14,	T23	Pump, Dredge, (P), Aft Fr 80	30	24.6					.50	12.3					
	14,	T23	Pump, Dredge, (S), Fwd Fr 5	30	24.6					.50	12.3					
	10,	T23	Boom Swing Hyd Unit	20	16.4					.40	6.6	.40	6.6			
	24,	T23	Hyd Standby Mooring & Boarding Ladder	25	20.5					.30	6.2			.30	6.2	
		T23	Panel, Lighting, L8/L9, Deck & Anchor Lts		1.7	.20	0.3	.20	0.3	.60	1.0	.60	1.0	.60	1.0	
	17,	T4	Pump, Stripping, #, 1	8	6.6							.80	5.2			
	17,	T4	Pump, Stripping, #, 2	8	6.6											
	18,	T4	Pump, Stripping, #, 3	8	6.6							.80	5.2			
	18,	T4	Pump, Stripping, #, 4	8	6.6											
	19,	T4	Pump, Stripping, #, 5	8	6.6											
	19,	T4	Pump, Stripping, #, 6	8	6.6							.80	5.2			
	20,	T4	Pump, Stripping, #, 7	8	6.6											
	20,	T4	Pump, Stripping, #, 8	8	6.6											
	21,	T4	Pump, Stripping, #, 9	8	6.6							.80	5.2			
	21,	T4	Pump, Stripping, #, 10	8	6.6											
	22,	T4	Pump, Stripping, #, 11	8	6.6											
	22,	T4	Pump, Stripping, #, 12	8	6.6							.80	5.2			
	23,	T4	Pump, Stripping, #, 13	8	6.6											
	23,	T4	Pump, Stripping, #, 14	8	6.6							.80	5.2			
		T23	Panel, Lighting, L8/L9, Deck & Anchor Lts		2.8	.10	0.3	.10	0.3	.60	1.7	.60	1.7	.60	1.7	
			Sheet 2 Total kW		**277**		**3**		**3**		**114**		**81**		**58**	

Table D-5. Newer, intermediate capacity 800' - 900' Laker: summary of electrical load (Continued).

			Auxiliary	Rated (hp)	Motor/ Input (kW)	Tug: At Sea (loads are tug-supplied power)				Barge Generator						Remarks
						Summer		Winter		Unloading		Loading		Docking		
						Load Factor	Load (kW)	Load Factor	Load (kW)	Load Factor	Load (kW)	Load Factor	Load (kW)	Load Factor	Load (kW)	
L1-	1,	D9	Ballast & Stripping (P/S)Console Valve Control		1.0					.20	0.2	.20	0.2	.20	0	
L1-	2,	D4	Ballast Tank Gauge System		0.8	.10	0.08	.10	0.1							
L1-	3,	D4	Vibrator system, (S) Panel		0.1					.30	0.0					
L1-	3A,	D4	Vibrator System, (P) Panel		0.1					.30	0.0					
L1-	5,	D4	Space Heater, Gen		0.6	.10	0.06	.55	0.3							
P401-	16,	T4	Pump, Transfer, Waste Oil, (dirty oil) #1	3	2.5					.20	0.5	.20	0.5			
P402-	16,	T4	Pump, Transfer, Waste Oil, (dirty oil) #2	3	2.5						0.0		0.0			
P402-	8,	T4	Pump, Vacuum Priming, (P), #1	5	4.1						0.0	.40	1.6	.50	2.1	
P404-	1,	T4	Heater, Fwd Machy Room		5.0											
P405-	1,	T4	Heater, De-Icing		5.0			.45	2.3							
P401-	2,	T50	Pump, General Service	50	41.0					.20	8.2	.20	8.2			
P402-	2,	T50	Pump, Washdown Service	50	41.0					.20	8.2	.20	8.2	.50	20.5	
P405,	2,	T14	Pump, Process, De-Icing	15	12.3			.45	5.5					.45	5.5	
P405-	3,	T4	Pump, Feed, De-Icing	5	4.1			.45	1.8							
P407,		T23	Receptacle, Main Deck, Aft		0.8					.10	0.1	.10	0.1			
P404-	2,	T4	Heater, Fwd Machy Room		5.0			.55	2.8							
P408,		T23	Receptacles, Upper Machy Room, P/S		3.0					.05	0.2	.05	0.2			
L1-	6,	D4	Gate Seal Control & Alarm		0.2	.30	0.06	.30	0.1							
L1-	7,	D4	Boom Topping & Slew Control		0.6					.70	0.4					
L1-	12,	D9	Receptacle, 2nd Deck, (S), Control Room		1.0					.40	0.4	.40	0.4	.40	0.4	
L1-	13,	D9	Receptacle, 2nd Deck, (P), Control Room		1.0					.40	0.4	.40	0.4	.40	0.4	
L1-	14,	D4	Trim Indicator		0.1					.70	0.1	.70	0.1			
P401-	15,	T4	Separator, Oil/Water, (S)	1	0.8					.05	0.04	.05	0.04			
L1-	17,	D4	Lights, Actuator Room		0.6	.20	0.12	.20	0.1	.90	0.5	.90	0.5	.90	0.5	
L1-	18,	D4	Engine Power Control, (P)		0.5					.90	0.5					
L1-	21,	D4	Engine Power Control, (S)		0.5					.90	0.5			.50	0.3	
P404-	3,	T4	Pump, Case Drain Unit	5	4.1	.20	0.82	.20	0.8							
L1-	8,	D9	Winch, Mooring Controls (6)		0.5			.30	0.2	.60	0.3	.60	0.3	.60	0.3	
P404-	4,	T4	Bowthruster, Hyd	5	4.1									.70	2.9	
			Sheet 3 Total kW		**141**				**14**		**20**		**21**		**33**	

Table D-5. Newer, intermediate capacity 800' - 900' Laker: summary of electrical load (Continued).

			Auxiliary	Rated (hp)	Motor/ Input (kW)	Tug: At Sea (loads are tug-supplied power)				Barge Generator						Remarks
						Summer		Winter		Unloading		Loading		Docking		
						Load Factor	Load (kW)	Load Factor	Load (kW)	Load Factor	Load (kW)	Load Factor	Load (kW)	Load Factor	Load (kW)	
L1-	1,	D9	Ballast & Stripping (P/S)Console Valve Control		1.0					.20	0.2	.20	0.2	.20	0	
L1-	2,	D4	Ballast Tank Gauge System		0.8	.10	0.08	.10	0.1							
L1-	3,	D4	Vibrator system, (S) Panel		0.1					.30	0.0					
L1-	3A,	D4	Vibrator System, (P) Panel		0.1					.30	0.0					
L1-	5,	D4	Space Heater, Gen		0.6	.10	0.06	.55	0.3							
P401-	16,	T4	Pump, Transfer, Waste Oil, (dirty oil) #1	3	2.5					.20	0.5	.20	0.5			
P402-	16,	T4	Pump, Transfer, Waste Oil, (dirty oil) #2	3	2.5						0.0		0.0			
P402-	8,	T4	Pump, Vacuum Priming, (P), #1	5	4.1						0.0	.40	1.6	.50	2.1	
P404-	1,	T4	Heater, Fwd Machy Room		5.0											
P405-	1,	T4	Heater, De-Icing		5.0			.45	2.3							
P401-	2,	T50	Pump, General Service	50	41.0					.20	8.2	.20	8.2			
P402-	2,	T50	Pump, Washdown Service	50	41.0					.20	8.2	.20	8.2	.50	20.5	
P405,	2,	T14	Pump, Process, De-Icing	15	12.3			.45	5.5					.45	5.5	
P405-	3,	T4	Pump, Feed, De-Icing	5	4.1			.45	1.8							
P407,		T23	Receptacle, Main Deck, Aft		0.8					.10	0.1	.10	0.1			
P404-	2,	T4	Heater, Fwd Machy Room		5.0			.55	2.8							
P408,		T23	Receptacles, Upper Machy Room, P/S		3.0					.05	0.2	.05	0.2			
L1-	6,	D4	Gate Seal Control & Alarm		0.2	.30	0.06	.30	0.1							
L1-	7,	D4	Boom Topping & Slew Control		0.6					.70	0.4					
L1-	12,	D9	Receptacle, 2nd Deck, (S), Control Room		1.0					.40	0.4	.40	0.4	.40	0.4	
L1-	13,	D9	Receptacle, 2nd Deck, (P), Control Room		1.0					.40	0.4	.40	0.4	.40	0.4	
L1-	14,	D4	Trim Indicator		0.1					.70	0.1	.70	0.1			
P401-	15,	T4	Separator, Oil/Water, (S)	1	0.8					.05	0.04	.05	0.04			
L1-	17,	D4	Lights, Actuator Room		0.6	.20	0.12	.20	0.1	.90	0.5	.90	0.5	.90	0.5	
L1-	18,	D4	Engine Power Control, (P)		0.5					.90	0.5					
L1-	21,	D4	Engine Power Control, (S)		0.5					.90	0.5			.50	0.3	
P404-	3,	T4	Pump, Case Drain Unit	5	4.1	.20	0.82	.20	0.8							
L1-	8,	D9	Winch, Mooring Controls (6)		0.5			.30	0.2	.60	0.3	.60	0.3	.60	0.3	
P404-	4,	T4	Bowthruster, Hyd	5	4.1									.70	2.9	
			Sheet 4 Total kW		**141**				**14**		**20**		**21**		**33**	
			Sheet 1 Total kW		**252**		**17**		**102**		**91**		**21**		**15**	
			Sheet 2 Total kW		**277**		**3**		**3**		**114**		**81**		**58**	
			Sheet 3 Total kW		**141**				**14**		**20**		**21**		**33**	
			Sheet 4 Total kW		**141**				**14**		**20**		**21**		**33**	
			Total		**669.37**		**20.17**		**118.91**		**225.19**		**122.40**		**105.82**	

Figure D-1. Newer, intermediate capacity 800' – 900' Laker: photo.

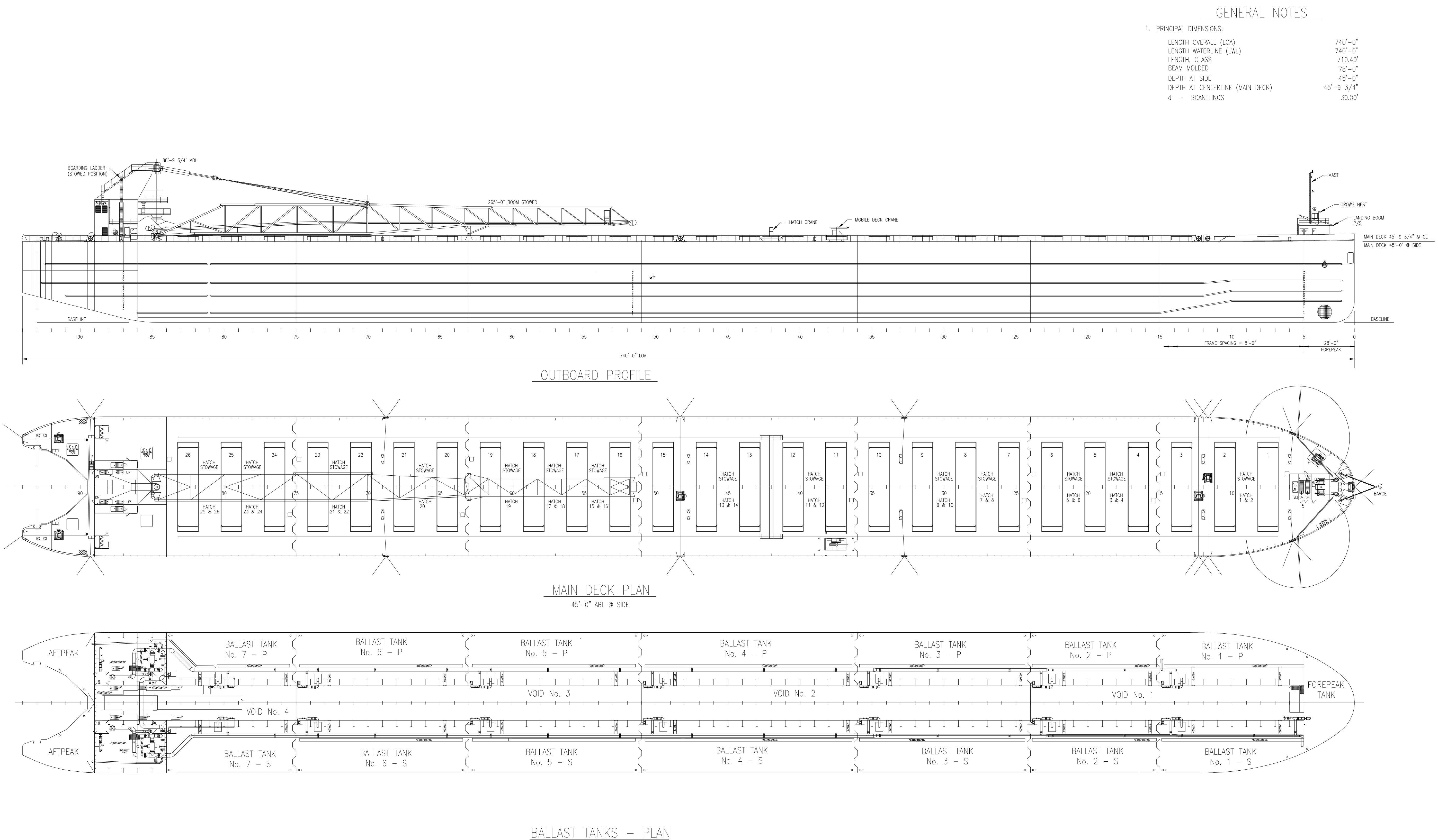

Figure D-2. Newer, intermediate capacity 800' – 900' Laker: general arrangement.

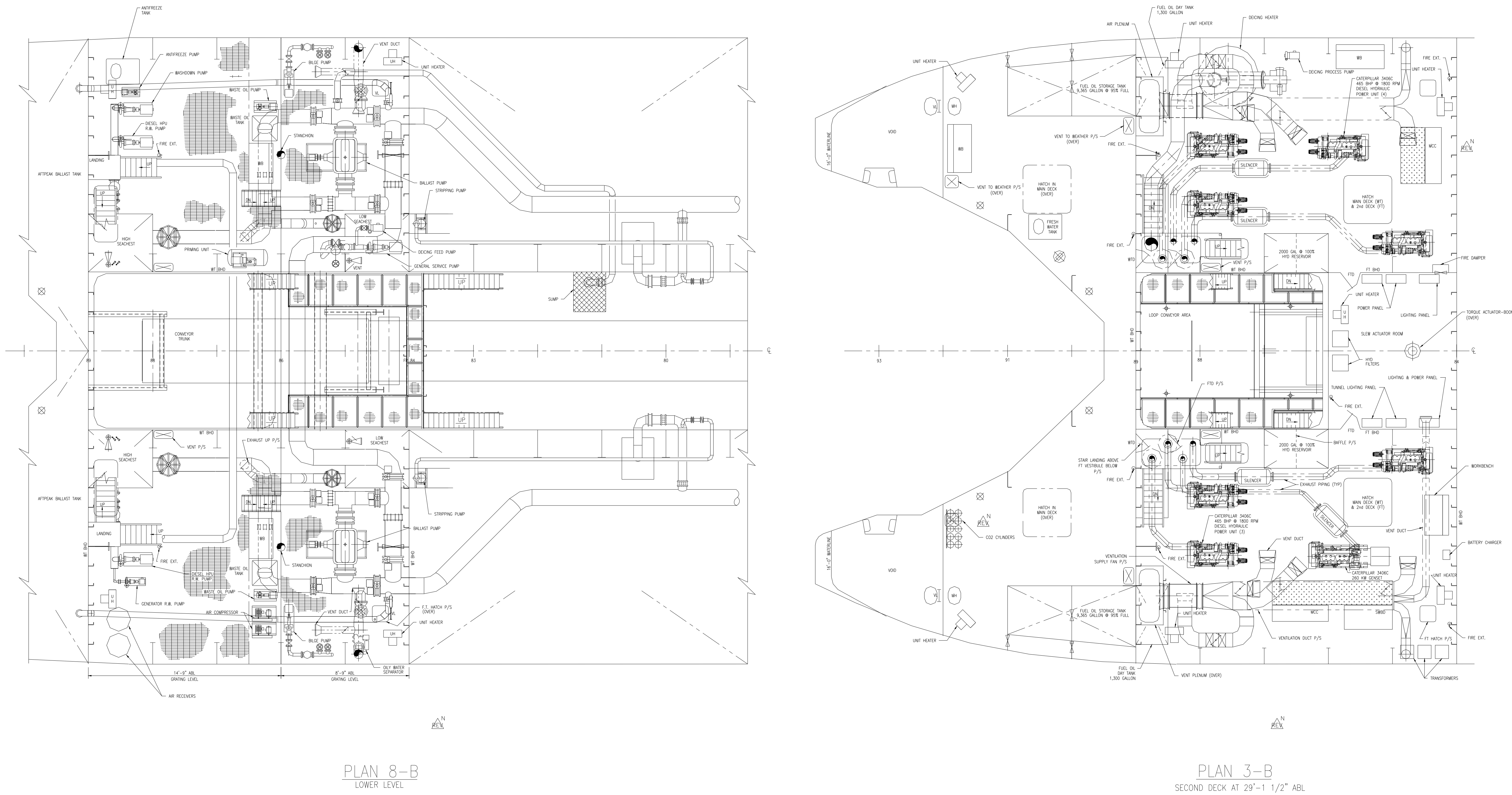

Figure D-3. Newer, intermediate capacity 800' – 900' Laker: engine room arrangement.

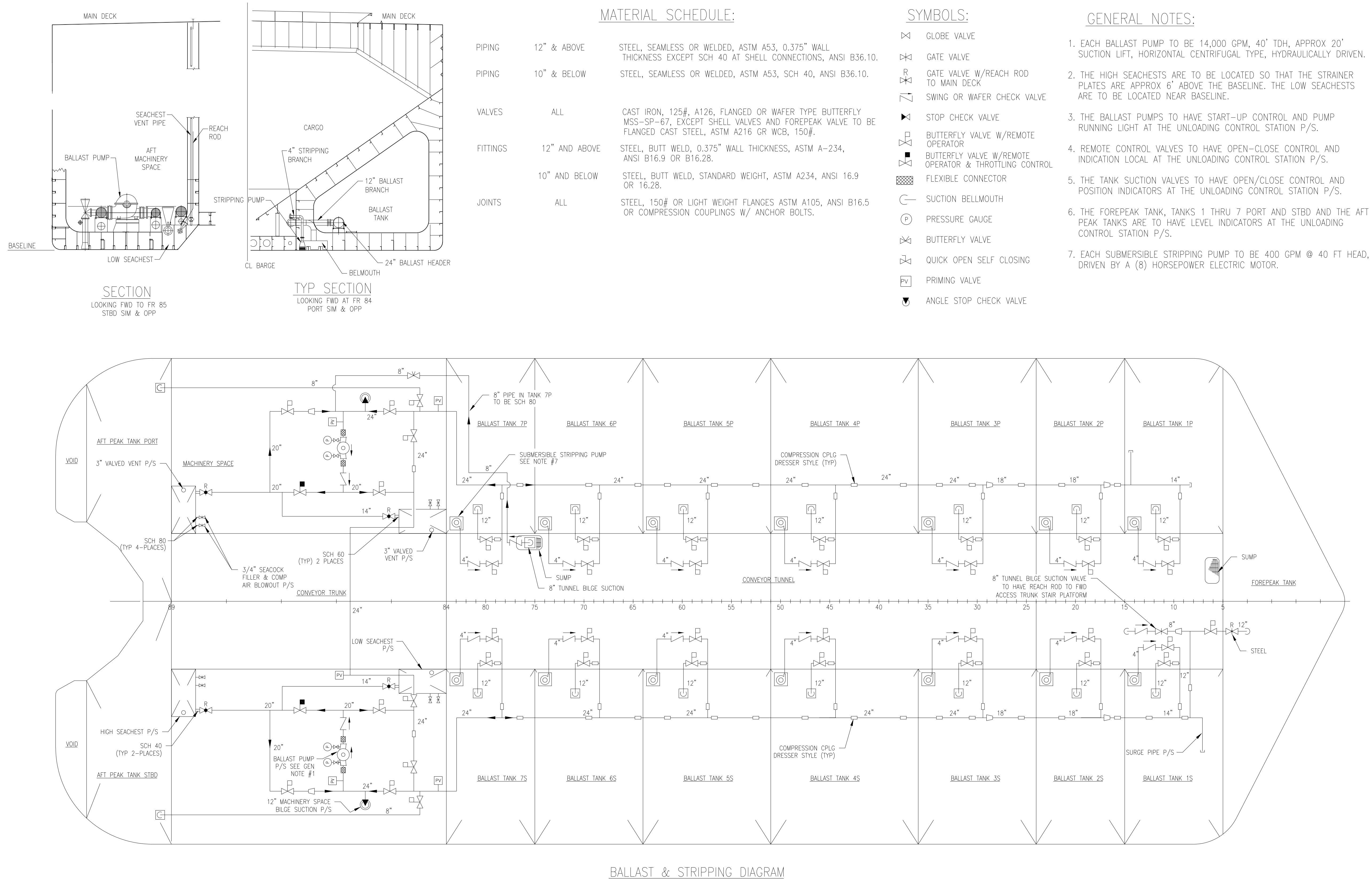

Figure D-4. Newer, intermediate capacity 800' – 900' Laker: ballast water diagram.

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APPENDIX E SMALL CAPACITY, RIVER CLASS 600' – 700' LAKER

Small Capacity, River Class 600' – 700' Laker: Vessel Construction

Table E-1 lists the small capacity, river class 600' – 700' Laker principal characteristics. The vessel is built from ABS high strength steel or equal for plating and framing. The structure is designed for a midsummer draft of 25.41'. The general structural arrangement of the vessel is transversely framed with transverse web frames spaced, in general, at 6.0', with partial intermediate frames. The bow section of the vessel has a semi-ship shape bow, with the collision bulkhead located at frame 12, and the stern shape is a ship shape "wine glass", with a centerline skeg, and stern frame supporting the rudder lower bearing. This ship has no camber or sheer on the spar deck. The vessel was modified by removing the upper side tank bulkheads above the cargo slopes in 1977. The result of the modification allowed the vessel to carry more cargo by enlarging the cargo volume.

Table E-1. Small capacity, river class 600' – 700' Laker: principal characteristics.

Length at Waterline	610.0'
Beam Molded	68.0'
Draft	27.5'
Depth, Molded, Main Deck	36,9'
Camber of Main Deck, Straight Line	n/a
Lightship	5,530.0 lt
Gross Tonnage	9,639
Net Tonnage (Registered)	5,700
Number of Cargo Holds	4
Cargo Type	Iron Ore Pellets, Coal, Limestone
Deadweight Tonnage	19,786 lt
Number of Ballast Tanks	17
Ballast Tank Capacity	12,009.1 mt t
Power Plant	5,600 hp (Diesel)
Year Built	1973
Shipyard	American Shipbuilding Co.

Small Capacity, River Class 600' – 700' Laker: Arrangement

The vessel is arranged with a deckhouse with accommodations aft, propulsion plant aft, and a forecastle house forward (Figure E-1 and Figure E-2). A self-unloading inclined belt system is fitted at the aft end of the cargo block, with a topside "A" frame on top of the deckhouse for unloading boom support. The engine room space (Figure E-3) is 102.0' long, over 34 frames of 3' spacing, and the hull extends another 39.0' aft of the machinery space. The cargo block is divided into four cargo holds which vary in length from 108.0' for hold one, 120.0' for holds two and three, and 90.0' for hold four, for a total length of 438.0'. The cargo holds are comprised of 35-degree transverse slopes feeding gravity-type cargo gates, where the cargo flows onto a conveyor belt on centerline, rising aft and feeding an inclined belt off centerline via a transverse loading chute feeding another inclined conveyor leading forward to the boom conveyor. The spar deck has hatches with covers removed and stacked by a hatch cover crane that allows the vessel to be loaded at a rate of some 5,000 tons per hour.

Small Capacity, River Class 600' – 700' Laker: Ballast System

The installed ballast system is capable of counter-acting the loading rate of the shore facility to keep the vessel in close vertical tolerance to the loading facility. Table E-2 provides the capacity of the ballast tanks. The ballast system is comprised of one ballast pump on each side of the vessel (total of two), (Figure E-4) with a combined capacity of 17,000 gpm (3,860 mt per hour). Each pump is rated 8,500 gpm (1,930 mt per hour). The main ballast pumps are centrifugal pumps driven by 120 hp electric motors. The ballast system is augmented with an auxiliary electric-motor-driven centrifugal pump on each side of the vessel, rated at 1,500 gpm (340 mt per hour), combined capacity of 3,000 gpm (680 mt per hour). The combined pumping capacity of the two systems is 20,000 gpm (4,500 mt per hour) (Table E-3). The ballast system on this vessel is a single header leading down each side of the vessel located in a tunnel space inboard of the ballast tanks, with branch lines to each tank. The main header is a 20" diameter pipe for the most of the length that tapers to a 10" diameter at the forward extreme, and the forepeak tank line is 8" diameter. Each ballast tank is fitted with a 10" diameter branch line and has a remotely controlled hydraulic-powered valve located in the ballast tank, and a suction box which is located close to the vessel bottom for optimum performance.

Table E-2. Small capacity, river class 600' – 700' Laker: ballast tank capacities.

Tank	Tank Length (ft)	Weight (mt)	Cubic Feet
Forepeak	24.0	483.8	17,100
No. 1 Port	66.0	599.6	21,200
No. 1 Starboard	66.0	599.6	21,200
No. 2 Port	60.0	758.2	26,800
No. 2 Starboard	60.0	758.2	26,800
No. 3 Port	60.0	758.2	26,800
No. 3 Starboard	60.0	758.2	26,800
No. 4 Port	60.0	758.2	26,800
No. 4 Starboard	60.0	758.2	26,800
No. 5 Port	60.0	758.2	26,800
No. 5 Starboard	60.0	758.2	26,800
No. 6 Port	60.0	758.2	26,800
No. 6 Starboard	60.0	758.2	26,800
No. 7 Port	45.0	624.0	22,000
No. 7 Starboard	45.0	624.0	22,000
No. 8 Port	45.0	658.6	23,300
No. 8 Starboard	45.0	658.6	23,300
Afterpeak	28.0	178.9	6,300
TOTALS		**12,009.1**	**424,400**

Table E-3. Small capacity, river class 600' – 700' Laker: ballast pumping capacities.

Pumps	Gallons/Hour	mt/Hour	Hours to Empty
17,000 gpm (2) Ballast	1,020,000	3,860	3.1
3,000 gpm Auxiliary	180,000	680	17.7
TOTAL CAPACITY	**1,200,000**	**4540**	**2.6**

Small Capacity, River Class 600' – 700' Laker: Ballast Water Management

The vessel is ballasted to maintain safe and efficient operations is discussed in Section 3. Table E-2 shows the listing of the ballast tanks. Table E-4 lists excerpts from the Guidance Manual for Loading (R. A. Stern, Inc., 1986). The maximum pump capacity is reduced by 20 percent% to account for changes in discharge head.

Table E-4. Small capacity, river class 600' – 700' Laker: operational ballast conditions.

Condition	Tanks w/Water	Total mt	Pump Rate (0.8)	Hours	Draft	
					Forward (ft)	Aft (ft)
Light Ballast/Thruster Out	5,6,7 & 8	5,598	3,610 mt/hr	1.6	0.92	17.25
Medium Ballast	2,3,4,5,6,7 & 8	10,147	3,610 mt/hr	2.8	3.67	17.58
Deep Ballast	FP, 2, 3, 4, 5, 6, 7 & 8	21,899.	3,610 mt/hr	6.1	16.00	18.58
Full Ballast	FP, 2, 3, 4, 5, 6, 7, 8 & aft peak	22,078	3,610 mt/hr	6.1	17.08	20.00
Propeller Out	1 & 2	2,715	3,610 mt/hr	0.8	9.42	7.92

References

R. A. Stern, Inc. (1986). Guidance manual for loading. Drawing 1608-856-01, Rev 1.

Figure E-1. Small capacity, river class 600' – 700' Laker: photo.

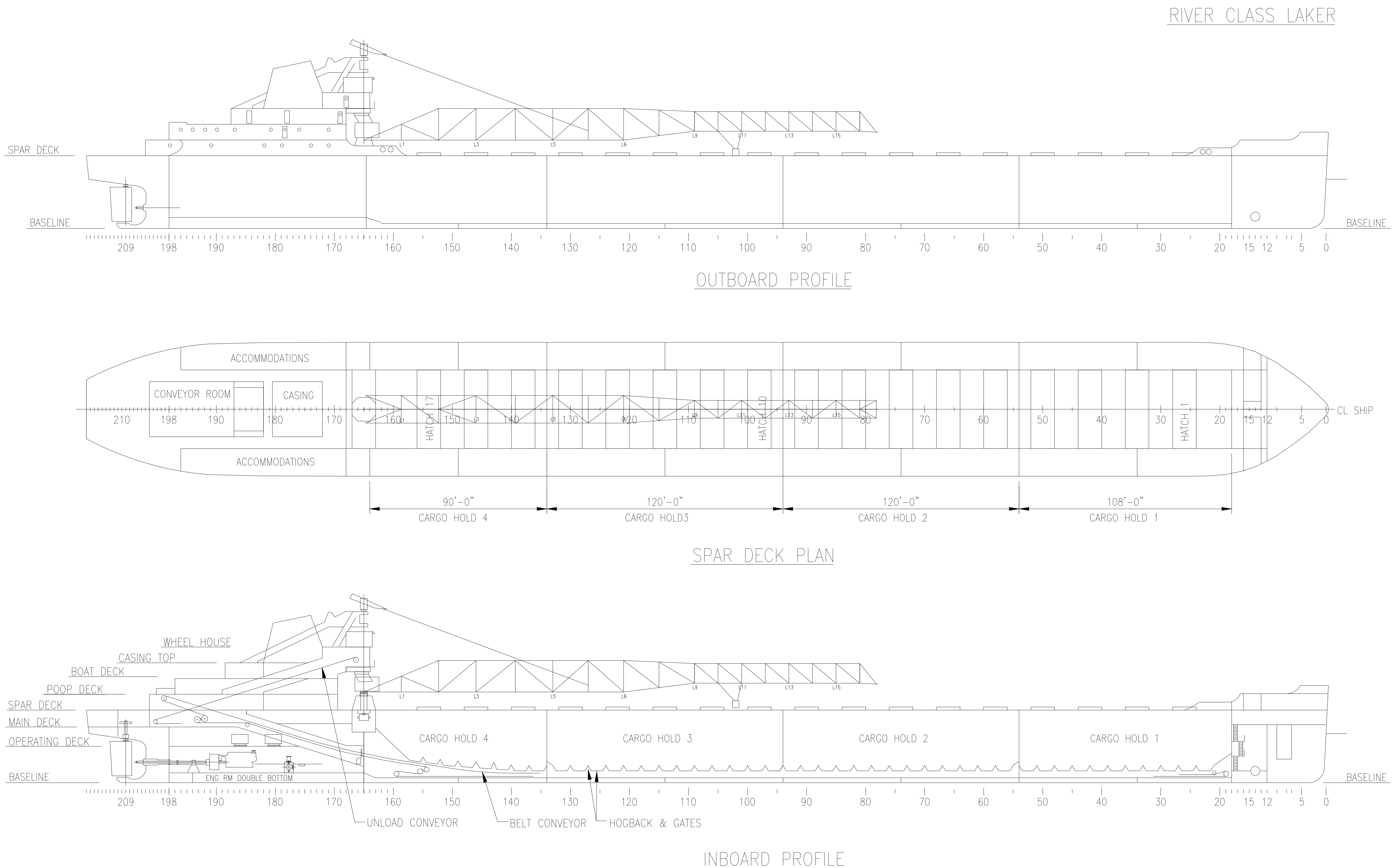

Figure E-2. Small capacity, river class 600' – 700' Laker: general arrangement.

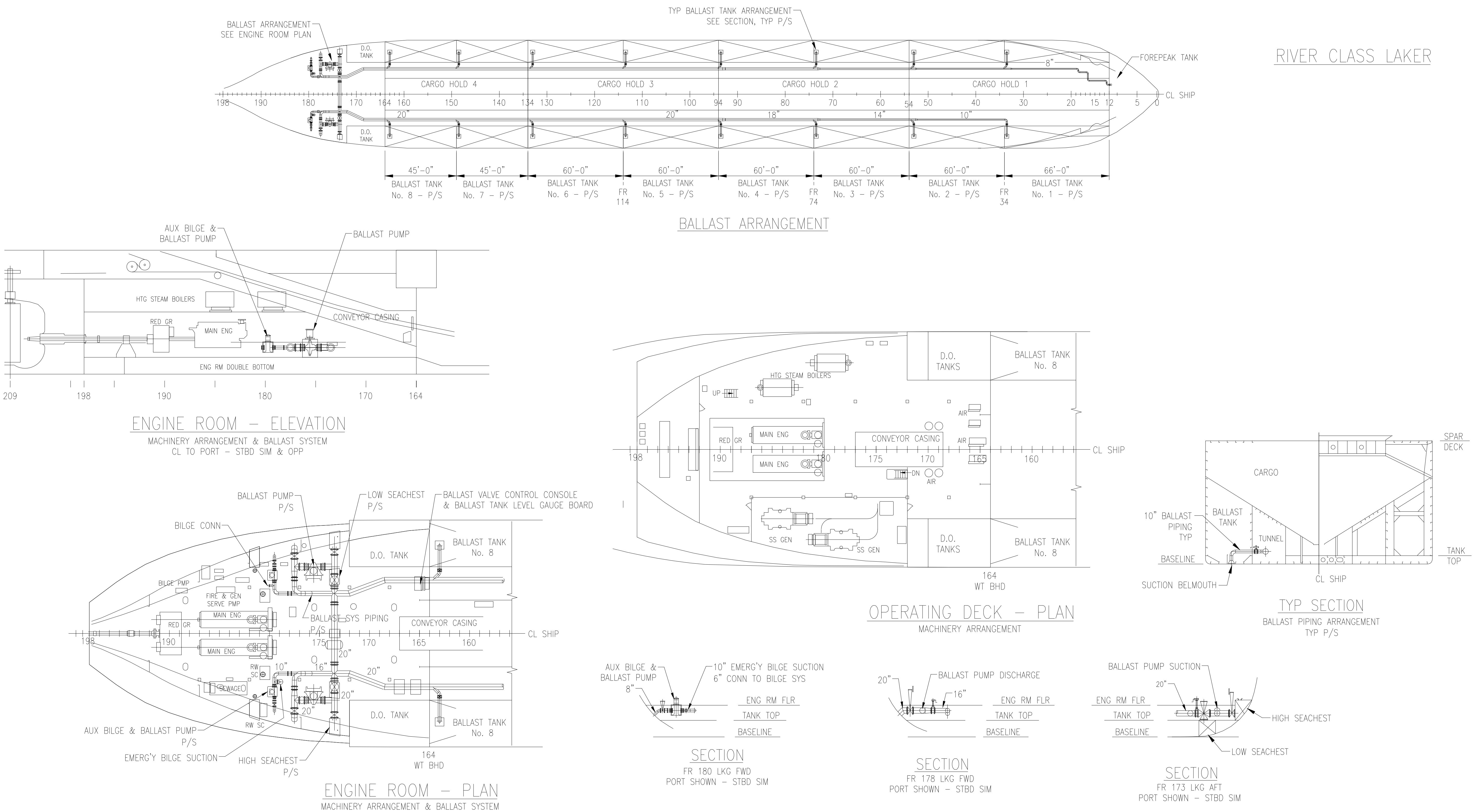

Figure E-3. Small capacity, river class 600' – 700' Laker: engine room arrangement.

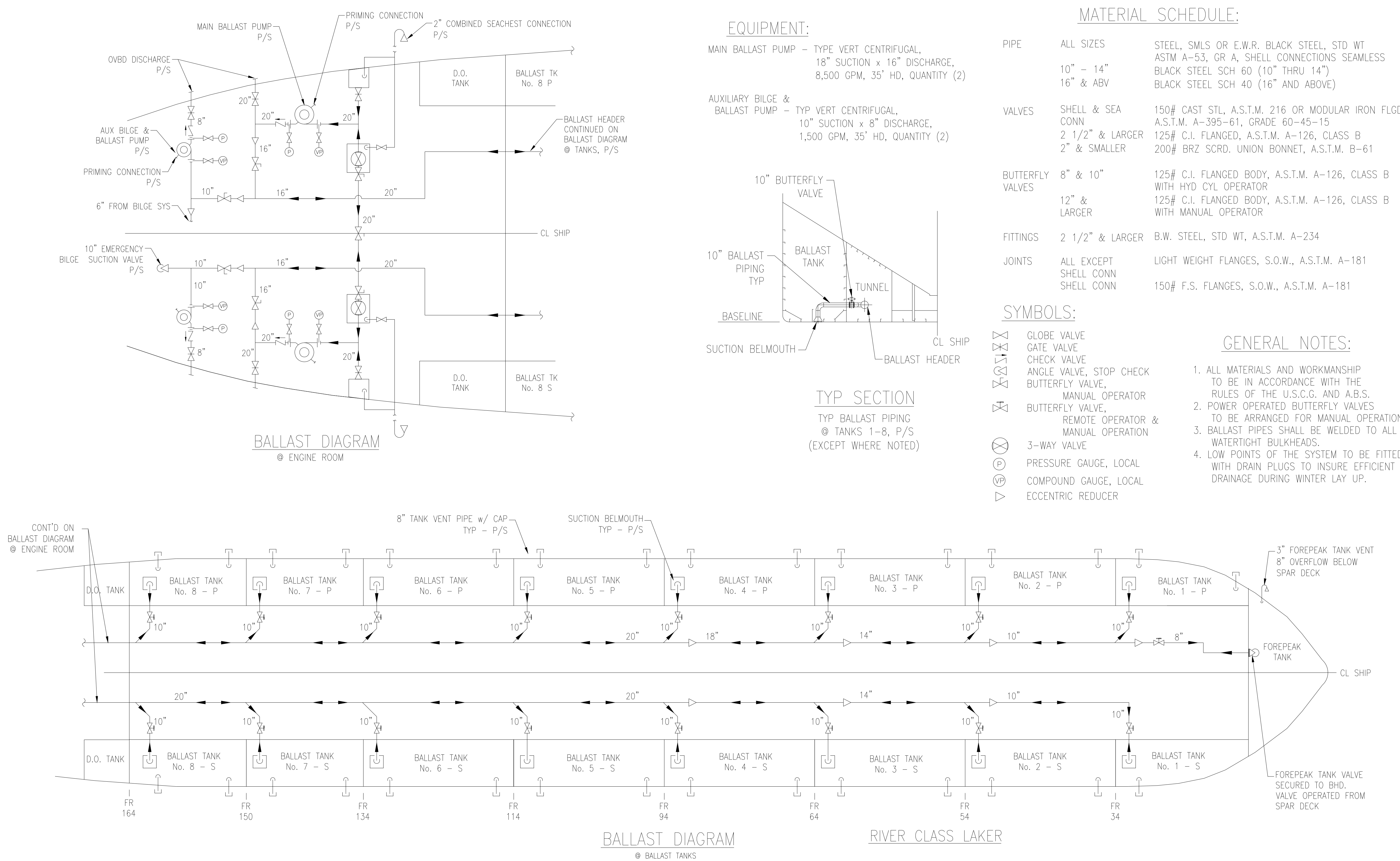

Figure E-4. Small capacity, river class 600' – 700' Laker: ballast diagram.

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