Motor Vessel Mississippi Raw Water Cooling Systems Redesign

Submitted to: Dr. W. J. Danley

The Senior Design Project Committee

Mechanical Engineering and Mechanics Department

Drexel University

Team Number MEM-17

Team Members:

James H. Asbury IV

Julia Ciliberti

Michael Kelley

Submitted in partial fulfillment of the requirements for the Senior Design Project

November 24, 2003

Abstract

The following proposal deals with a re-work of the raw water cooling system onboard a U.S. Army Corps of Engineers vessel and the subsequent proposal to redesign, build and install an improved cooling system.

The current cooling system onboard the M/V MISSISSIPPI receives raw river water from inland waterways and is circulated through the main engines, reduction gears, air conditioning system, the ballast, and fire main systems. Since the ship was built in 1992, the cooling system has experienced frequent clogging by debris and silt from operations on the inland waterways. These cloggings cause system flow degradation, subsequent failure of air conditioning condenser heat exchanger tubes and loss of propulsion.

Our design project team proposes to design a replacement of the current system with a closed loop system cooled by clean treated water. After implementing a cost benefit analysis, we will provide documentation of all engineering analysis related to the successful integration of the new system with the existing affected systems focusing on mechanical, electrical and structural analysis.

During the second term of this project we plan to complete the detailed drawings and analysis of the closed loop systems and test requirements. We will submit the drawings to the United States Coast Guard (USCG) for approval and release to the shipyard for installation. During that time, we also plan to take baseline measurements of all affected systems and compare them with measurements after the installation to ensure successful integration of our design.

Upon completion of testing and evaluation of the device, we will generate a final report that will document our methods of analysis, results obtained and lessons learned. We will then make recommendations for future design improvements, if needed.

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List of Figures

Background

In 1879 the US Congress established the Mississippi River Commission (MRC) to oversee the maintenance of navigable waters and flood control. The MRC is made up of seven presidential appointed members consisting of three Generals in the US Army Corps of Engineers (USACE), one Admiral from National Oceanic & Atmospheric Administration (NOAA) , and three civilians. The MRC commissioned the Steamer MISSISSIPPI I in 1882 as an inspection vessel in order to perform inspections of the Lower Mississippi River from St. Louis, MO to New Orleans, LA. Theses inspections have been performed twice a year and the vessels have been used as a meeting hall in various cities along the Mississippi to hold hearings for interested parties on activities on the river by the Corps of Engineers. Since the first Steamer MISSISSIPPI there have been three others prior to the existing vessel.

In 1991 the Mississippi River Commission commissioned Halter Marine Shipbuilding to build and construct a replacement vessel for the Motor Vessel (M/V) MISSISSIPPI IV. The vessel was designed to be the largest towboat ever built in the United States and was designed and built with a raw (river) water system for supplying water to the main engines, reduction gears, shaft seals, Air-conditioning chiller condensers, and fire main and ballast systems. The engines were designed to utilize a plate heat exchanger (Appendix C Fig. 1) to transfer heat from the engines to the river water, and the raw water system was designed to circulate water through the reduction gear oil coolers and the A/C Chiller condensers (See Figure 1). The main and emergency generators were designed to use an external heat exchanger called a grid or keel cooler, which transfers heat to the river water, by natural convection. The vessel was commissioned and went into operation in 1992 (Figure 2).

Historically all diesel powered inland river boats (towboats, tugs, etc.) use grid coolers or channel bar coolers for all engine cooling systems. Air conditioning systems are typically cooled by either grid coolers or fan-coil units. Inland river boat operators prefer these types of cooling systems to avoid the very problems the Towboat MISSISSIPPI is currently having with its existing systems. Additionally, any raw water systems that these boats use are used primarily for ballast, fire, and flushing water systems.

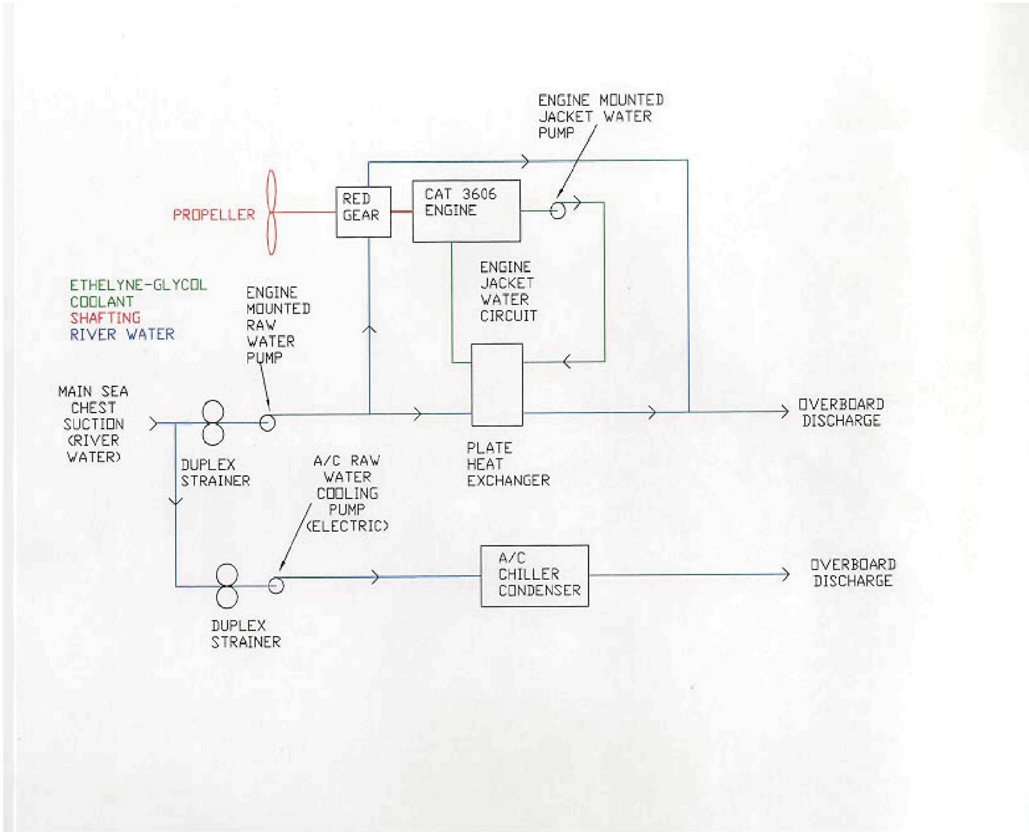

Figure 1. One Line Diagram of Existing Cooling System

Figure 2. Towboat MISSISSIPPI V

Problem Statement

Since the M/V MISSISSIPPI went into operation, it has been experiencing excessive fouling of the main engine duplex strainers (Appendix C, Fig. 2), reduction gear coolers and A/C Chiller condensers. This fouling of the main engine duplex strainers requires the crew to shift and clean each strainer (1 per engine) as often as once every 15 minutes (Reference A), and under the most severe conditions, has caused the engines to overheat and shut down on over temperature alarms. If all engines were to shut down at the same time a loss of propulsion would occur resulting in a loss of steerage of the vessel. This would become a detrimental situation if the vessel were in traffic on the river or if the vessel were navigating under bridges or other structures in the water. Additionally, when the vessel backs down on a tow (goes in reverse), the water around the sea chest suctions becomes aerated from the propeller wash and this causes the engine raw water pumps (Appendix C, Fig. 3) begin to cavitate and become air bound, causing the engines to overheat, and potentially shutdown.

An example of a loss of propulsion would be the Cargo Ship *BRIGHT STAR* accident in 1996 in which the vessel lost propulsion and crashed into the Riverwalk Mall in New Orleans, LA , over 100 people were injured and over $200 million in property damage was incurred (Appendix C, Fig. 4). Another accident that occurred was the towboat collision that occurred in 2001 in which a towboat crashed into a bridge caisson on an Interstate 40 bridge over the Arkansas River (Appendix C, Fig. 5). This accident killed 14 motorists when their cars fell into the river after the bridge collapsed. This accident was a result of the pilot having a heart attack at the controls causing the vessel to go out of control. The same affect might have occurred had the pilot lost propulsion

In 2001 the engineers on the M/V MISSISSIPPI had to replace one of the Air Conditioning Chiller condensers because the tubes had been so eroded by sand and silt that they could no longer plug any more tubes without affecting the heat transfer capacity of the condenser (Appendix C, Fig. 6 &7). It took over a month to have a new condenser delivered and installed, which affected the vessels availability and schedule.

Constraints on the Solution

The design constraints of our project are:

- The cooling systems for the engines, reduction gears and A/C Chiller condensers must be capable of removing 125% of the design heat rejection.
- The new systems must fit within the confines of the vessel.
- Any components of these systems must not affect the aesthetics, appearance, or function of the vessel.
- The engine cooling systems must be of closed loop design.
- The engine cooling systems must be capable of allowing the vessel to operate at 100% power in water temperatures from 32^0F to 90^0F (Ref. B), with a 1-knot speed of advance.
- The electrical requirements for the pump motors must not exceed available electrical power provided by the ships service generators, and the vessel must be capable of operating at 100% on one generator.
- The air conditioning system must be capable of operating in 85^0F water at 0 knots.
- The design must not adversely affect the natural frequency of the vessels hull.
- Maximum inlet Temperature to main engine after-cooler: 122^0F. (Ref. C)
- Maximum inlet temperature to reduction gear oil cooler: 95^0F (Ref. D)
- A/C Chiller Condenser outlet temperature: Maximum 95^0F (Ref. E)

Statement of Work

The project of redesigning, building and testing of the cooling systems onboard the Motor Vessel MISSISSIPPI requires numerous tasks. The tasks will include analysis of the existing system, selection of a system to replace the current system, electrical load analysis, and mechanical component selection, structural analysis, drawing production, and specifications for repair and testing.

The first of the tasks was to analyze the existing system and determine the reasons behind the need to replace the system. A visit to the vessel was completed, discussions with the crew were held and a review of the "as-built" drawings and manufacturer's data sheets was completed. The results of the visit were then used to research possible alternative systems. (Appendix D)

Three alternatives were presented to the vessel's owners and operators. Two of the proposed systems utilized grid coolers (Appendix C, Fig. 8) attached to the side of the hull (Appendix A, Dwgs 436-A205-01 sheets. 1, 2). These types of systems are the standard on U.S. inland waterways.

The third system proposed a box cooler system in which the coolers were an integral part of the vessel's structure (Appendix A, Dwg. 436-A205-01 sheet. 3). Box cooler cooling systems of this nature are common on workboats throughout Europe but this would be a first for a U.S. towboat.

The proposal was reviewed and based on system cost, ease of maintenance and other operational considerations, the box cooler arrangement was selected. The box coolers were ordered and have been shipped to Memphis.

The specific system having been settled upon, the work on the remainder of the system is set to go forward. Work on the project will be performed at the Marine Design Center and NAVSEA Carderrock. Team members will draw on any additional engineering resources at these facilities.

The team will analyze the existing system layout and determine which portions of the existing systems can be reused and which must be removed. A set of rip-out drawings detailing the system removal will be generated for shipyard use.

The new equipment requirements will then be identified including the pumps to be added. The proposed system requires the addition of eight new pumps to the vessel three for the engines, three for the reduction gears and two for the air conditioning units. The pump size will be dictated by the flow requirements of the existing equipment and the amount of pipe being added to each of the systems. The size of the pumps required will then dictate the electrical energy required to run the pumps. An analysis of the vessels existing electrical system will be performed and new electrical system drawings generated to show the power sources for the new pumps.

The size of the required pumps will also drive the mechanical system layout. Pump footprint will dictate pump placement and therefore the required piping runs. General piping layouts will be generated and included in the delivered drawings. The actual layout of the piping will be determined by the pipe fitters in the shipyard for a "best fit" system configuration.

The mechanical and electrical portion of the design being completed the design team will turn its attention to the vessel structure and the physical mounting of the coolers. The ballast tank modifications required to mount the coolers will be laid out in detail and construction drawings penned. The changes required to the actual hull will also be delineated in a similar manner.

The team will develop and submit detailed construction and test procedures. The estimated date of final testing of the completed systems and the vessel is after the senior deign project completion date.

Economic Feasibility

The Memphis District has determined that it is in the best interest of the Motor Vessel MISSISSIPPI to perform the cooling system modifications. The district has further determined that, regardless of cost, the modifications need to be done as soon as possible. The driving force behind these decisions was not a question of economics but rather one of political appearances, were the MISSISSIPPI unable to complete its bi-annual inspection trips due to a system failure, public perception of the vessel would be irreparably damaged.

The only economic question then would be how much would it cost to have the work done at a private shipyard vice a government yard. The U.S. Army Corps of Engineers operates a ship repair yard in Memphis, TN capable of performing the suggested modifications.

Estimates were performed using known rates from private shipyards and the rates from the government owned Ensly shipyard in Memphis Appendix B, Tables 1 & 2. The results were submitted to the Memphis District for final determination. The Memphis District determined, based on the projected savings, to have the work done by their own shipyard.

Project Management and Scheduling

This project to redesign and replace the open loop cooling system on the Towboat MISSISSIPPI was started in July of 2003. This project was started ahead of schedule because the Memphis Engineer District found it had funds to purchase the coolers, and needed to use these funds prior to the end of Fiscal Year 2003 which ended on 31 October 2003. The various options available were reviewed and it was decided that the Box Cooler was the most viable option. Based upon the amount of heat rejection required by the engines, Reduction Gears and A/C Chillers, a particular size of cooler was chosen and ordered.

The following major tasks have been completed on the following dates:

Project Development:	25 Jul 2003
Determine Cooling system design constraints:	25 Jul 2003
Contact Cooler manufacturer for quotes:	30 Jul 2003
Evaluate types of cooling system options:	8 Aug 2003
Order Box Coolers:	15 Aug 2003
Form Senior Design Team:	1 Sep 2003
Submit Pre-proposal:	20 Oct. 2003
Head-loss analysis:	7 Nov 2003
Electrical Load Analysis	20 Nov 2003
Select cooling system components	7 Nov 2003
(2) Site Visits - 23-25 July, 22-24 Oct	
Identify equipment/piping for removal	24 Oct 2003
Complete Rip-out drawing package	14 Nov 2003

The remaining tasks can be found in the Gantt chart in Appendix D.

The detail design and repair and testing specification is scheduled to be completed in 19 March 2004, with construction on the vessel to commence on 26 March with the dry-docking of the M/V MISSISSIPPI at the USACE Ensley Repair Yard in Memphis, TN. The construction and testing of the new systems is scheduled to be completed on 28 May 2004.

The following is the task list for each team member:

Michael Kelley:

- Project Management
- Box Cooler Contract Management
- Head-loss Analysis
- Electrical load Analysis
- Modeling

James H. Asbury IV

- Heat Rejection Analysis
- Head-loss Analysis
- Structural Analysis
- Computer Aided Design and Drafting
- Modeling

Julia Ciliberti

- Head-loss Analysis
- Structural Analysis
- Computer Aided Design and Drafting
- Testing Specification
- Modeling

Considerations for Environmental, and Socio-Political Impacts

Environmental Impacts:

The proposed closed loop cooling system would have little or no affect on the environment. However, in the event of a catastrophic failure of the cooler some amount of ethylene-glycol could enter the environment.

Socio-Political Impacts:

If the open loop cooling system is not redesigned, the duplex strainers will continue to be contaminated with debris and could potentially shut down the engines. In addition, application of astern thrust while moving ahead will continue to result in air-binding of the engine mounted raw water pumps. If any of the engines fail, it could cause loss of propulsion and subsequent loss of control of the ship. Just such a loss of propulsion was experienced during an accident in New Orleans in 1996, where a cargo ship crashed into a pier after losing control. The pier was subsequently shut down and had to be rebuilt. Over 100 persons were injured and over $200 million dollars in damages were assessed against the owners of the cargo ship.

In addition continued operation of vessel utilizing the existing cooling systems conceivably jeopardizes the vessels operating schedule. Failure to meet the schedule would have a negative impact upon the US Army Corps of Engineers and the Mississippi River Commission's reputation up and down the Mississippi River.

References

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B. U.S. Army Corps of Engineers. (1995 Oct). *Tolerances of Zebra Mussels to various temperatures in the Misissippi and Ohio Rivers, 1988-1992.* Technical Note ZMR-1-32.

C. Caterpillar.(1996).3600 Application and Installation Manual

D. Reintjes.(1997).Workboats

E. Augosto San Cristobal. "*MSE 7505 Performance Information.*" Facsimile Transmission to James Asbury. 23 Sept. 2003.

Appendices

Appendix A

Motor Vessel Mississippi
Engine Cooling Proposal

Michael Kelley
James H. Asbury
US Army Corps of Engineers
Marine Design Center

ABSTRACT

The US Army Corps of Engineers' Motor Vessel Mississippi is a large tow vessel that operates the entire length of the Mississippi River and on the inland waterways. The vessel is used as a tow vessel as well as an inland survey vessel.

The MV Mississippi has been experiencing fouling of the engine cooling system while operating in shallow inland waterways. The fouling has caused unnecessary restriction in vessel operation and increased maintenance costs and time.

This study analyzes several modifications to the vessels engine cooling system that will alleviate these problems.

Keywords: Mississippi, Cooling, Engines

Introduction

The Motor Vessel Mississippi is a large towboat/survey vessel operated by the US Army Corps of Engineers. The vessel is 241ft long, 58ft wide and has a 52ft air draft. The vessel is powered by three Caterpillar 3606 propulsion engines through Reintjes WAV-2480 reduction gears.

The Mississippi's propulsion system is raw water cooled from a single starboard side sea chest. The raw water system also cools the air conditioning system, supplies the ballast system and the shaft seals. The system employs a single duplex strainer on the raw water system.

Problem

The raw water system of the Mississippi has been a source of problems for the vessel in the past. The vessel is required to operate on the inland waterways in order to function as a survey vessel. Raw water system operation in such shallow water draws in debris from the vessel's surroundings. System flow degradation is rapid enough that the duplex strainer need be shifted and cleaned, in the worst case, every fifteen minutes. The raw water system has also been cited as a possible cause for the recent failure of one of the onboard air conditioning units.

Constraints

The following constraints were placed on the system design

1. Maximum inlet temperature to engine aftercooler 122°F.
2. Maximum inlet temperature to reduction gear 95°F.
3. Maximum river water temperature 90°F.
4. Minimum vessel speed at maximum power 1 knot.

Possible Solutions

Any possible solutions to the vessel's cooling system would have to eliminate raw water as the engine cooling medium. This restriction limited the systems considered to keel cooler and box cooler circuits. Several possible configurations were studied from two separate manufacturers. The following configurations are presented herein:

1. 3 keel coolers per engine with an additional cooler for each reduction gear. A parallel flow system from Fernstrum. A series flow system from Duramax.
2. 2 high efficiency keel coolers per engine with an additional cooler for each reduction gear. System proposed by Fernstrum.
3. 1 Box cooler set for each engine and reduction gear by Fernstrum.

Discussion

Three Cooler Configurations

The three cooler configuration was proposed by both Fernstrum and Duramax. The Fernstrum parallel layout is shown in Drawing No. 436-A640-01 sht 1. The Duramax series layout is shown in the same drawing on sheet 4. The overall layout for both types is shown in Drawing No. 436-A640-02 sht 1.

The systems employ a total of twelve keel coolers (3 for each engine, 1 for each reduction gear) placed on the side of the hull. The coolers are stacked two high up the side. The port side would have the coolers for the port engine as well as all three reduction gears. The starboard side coolers would be for the starboard and centerline engines.

The individual engine cooler layouts are designed to maintain aftercooler inlet water at 122°F. Thermostatic control valves are used to meet this requirement as well as preventing excessively cool engine temperatures while operating in regions of lower injection temperature.

Projected equipment cost (coolers only):
Duramax $90,968.00
Fernstrum: $99,916.00

Two Cooler Configuration

The high efficiency two cooler circuit proposed by Fernstrum is shown in Drawing No. 436-A640-01 sht 2. The overall layout is shown in Drawing 436-A460-02 sht 2.

The system employs a total of nine keel coolers (2 for each engine, 1 for each reduction gear). The engine coolers are placed on the side of the hull while the reduction gear coolers are on the rake at the vessel's stern. A thermostatic control valve is used to maintain aftercooler temperature.

Projected equipment cost (coolers only):
Fernstrum: $124,130.00

Box Coolers

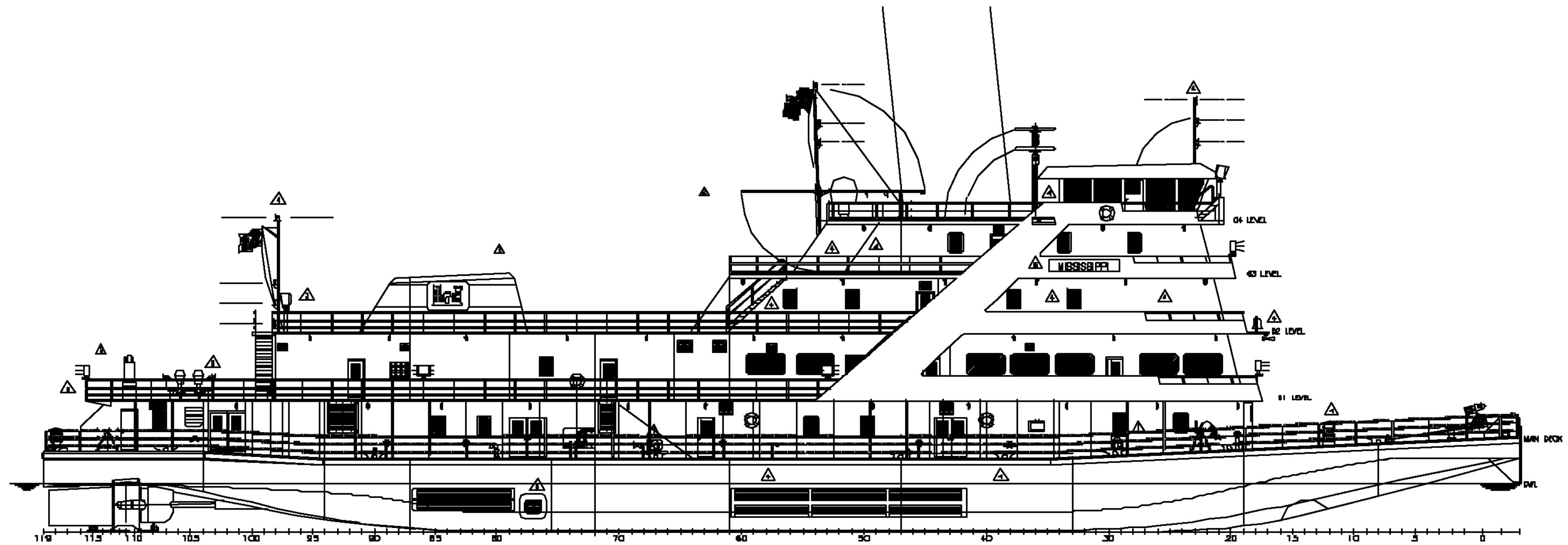
The box cooler arrangement from Fernstrum is shown in Drawing 436-A460-02 sht 3. The overall layout is shown in Drawing 436-A460-02 sht 3.

The system utilizes three box coolers to cool both the engines and reduction gears. Each box cooler is a dual circuit cooler with separate inlet and outlet ports. The coolers for the starboard and centerline units would be on the vessel's starboard side, the cooler for port on the port side. The coolers would be set in small tanks to be built in the bottom of the void spaces.

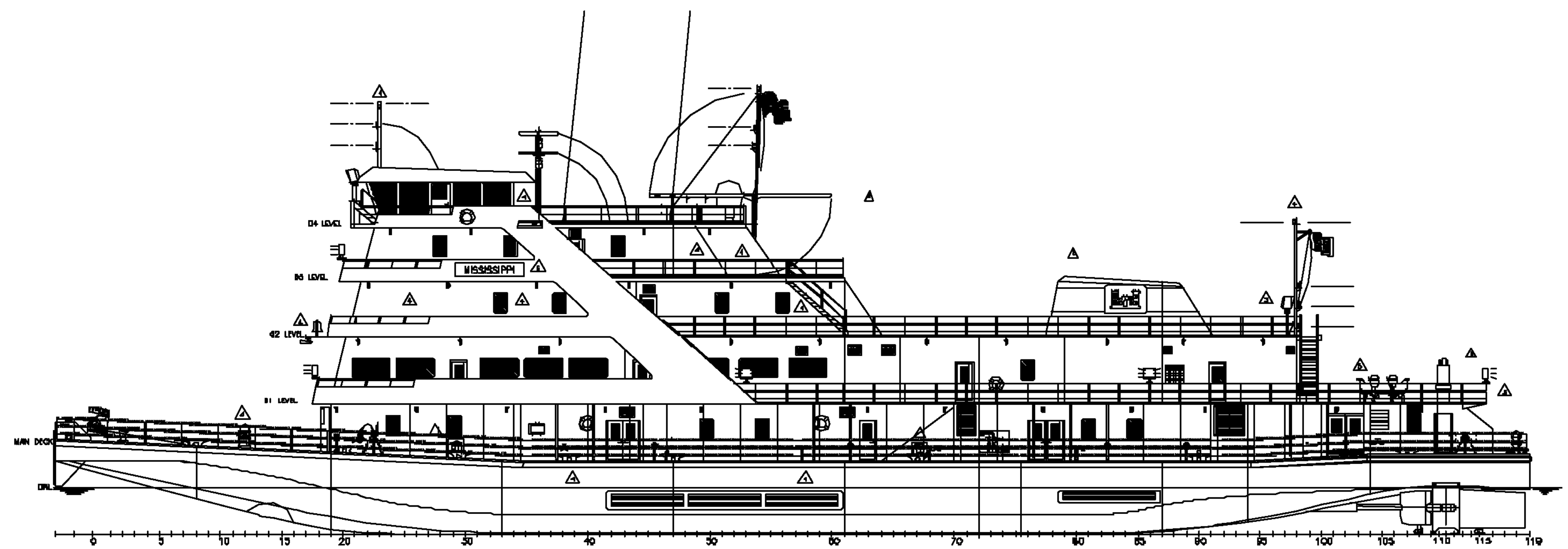
Projected equipment cost (coolers only):
Fernstrum: $79,617.00

Conclusion

The Motor Vessel Mississippi's engine cooling problem may be solved by any of the proposed systems. The decision as to which system to pursue need be based not only on cost but also on crew and district preference. The Marine Design Center recommends further study on the Duramax three cooler system and the Fernstrum Box cooler system.



VIEW FROM STBD SIDE



VIEW FROM PORT SIDE

FERNSTRUM/DURAMAX 3 COOLERS PER ENGINE ARRANGEMENT

MARINE DESIGN CENTER PHILADELPHIA, PA	DEPARTMENT OF THE ARMY MARINE DESIGN CENTER CORPS OF ENGINEERS
	US Army Corps of Engineers — M/V MISSISSIPPI OUTBOARD PROFILE
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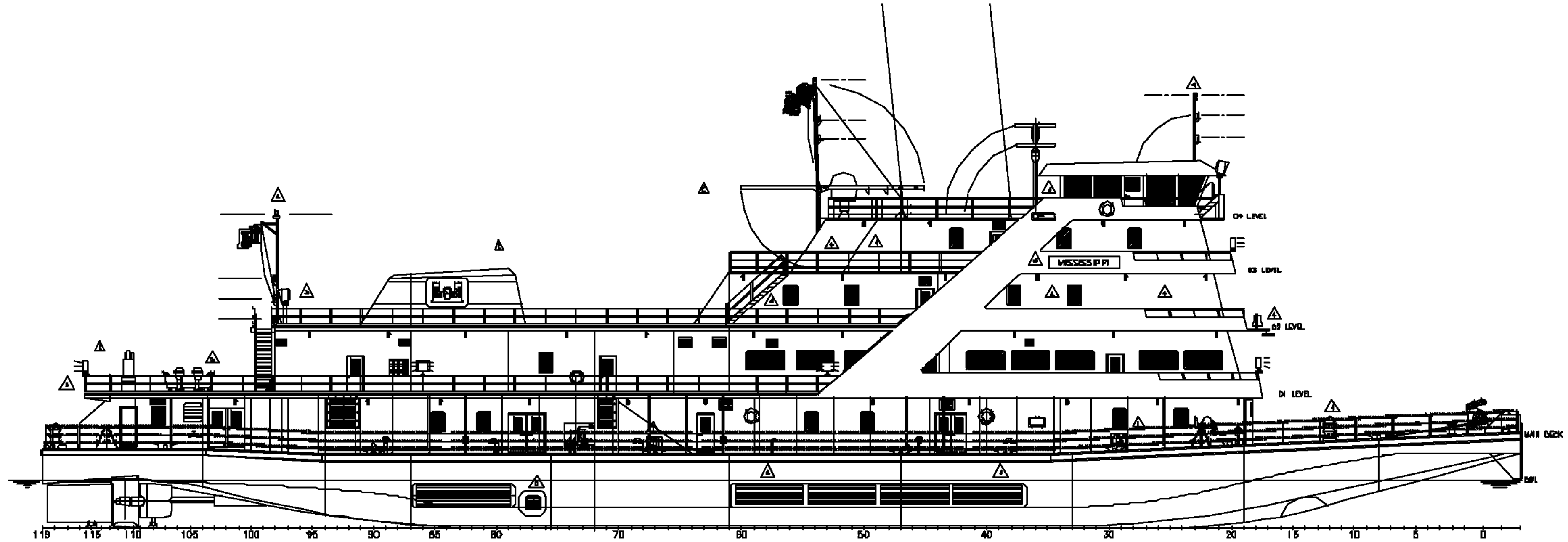

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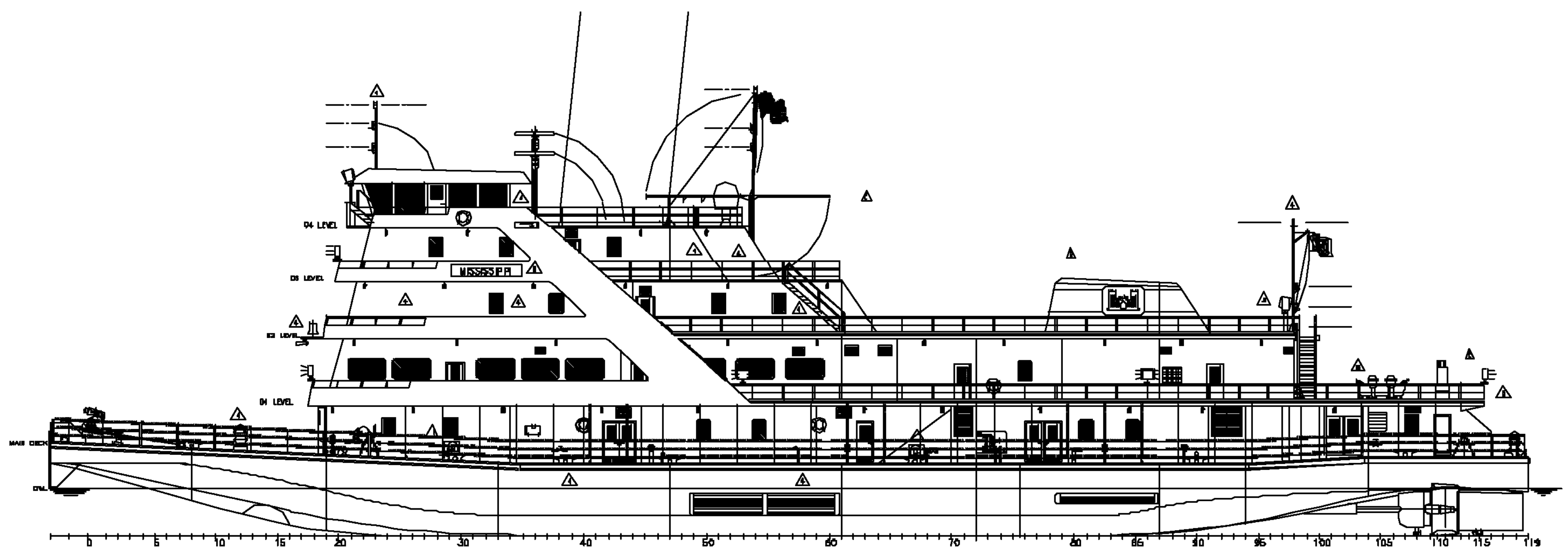

VIEW FROM PORT SIDE

FERNSTRUM 2 COOLERS PER ENGINE

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	M/V MISSISSIPPI OUTBOARD PROFILE
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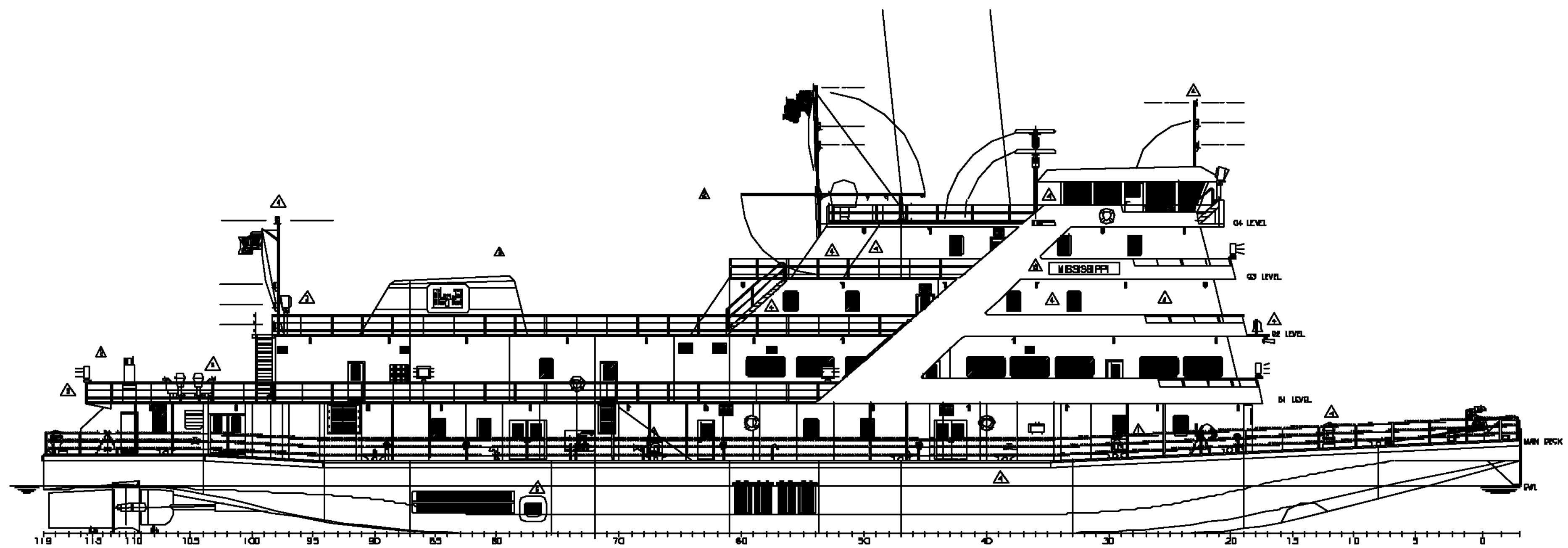
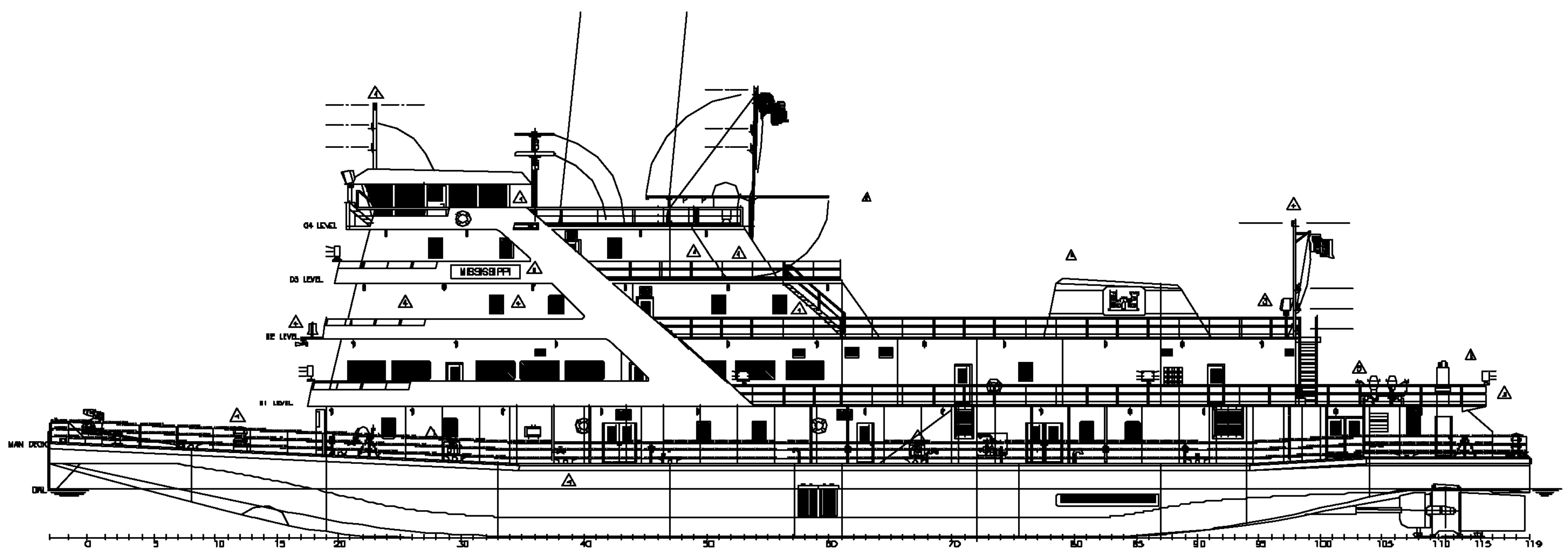


VIEW FROM STBD SIDE



VIEW FROM PORT SIDE

FERNSTRUM BOX COOLERS

MARINE DESIGN CENTER PHILADELPHIA, PA	DEPARTMENT OF THE ARMY MARINE DESIGN CENTER CORPS OF ENGINEERS
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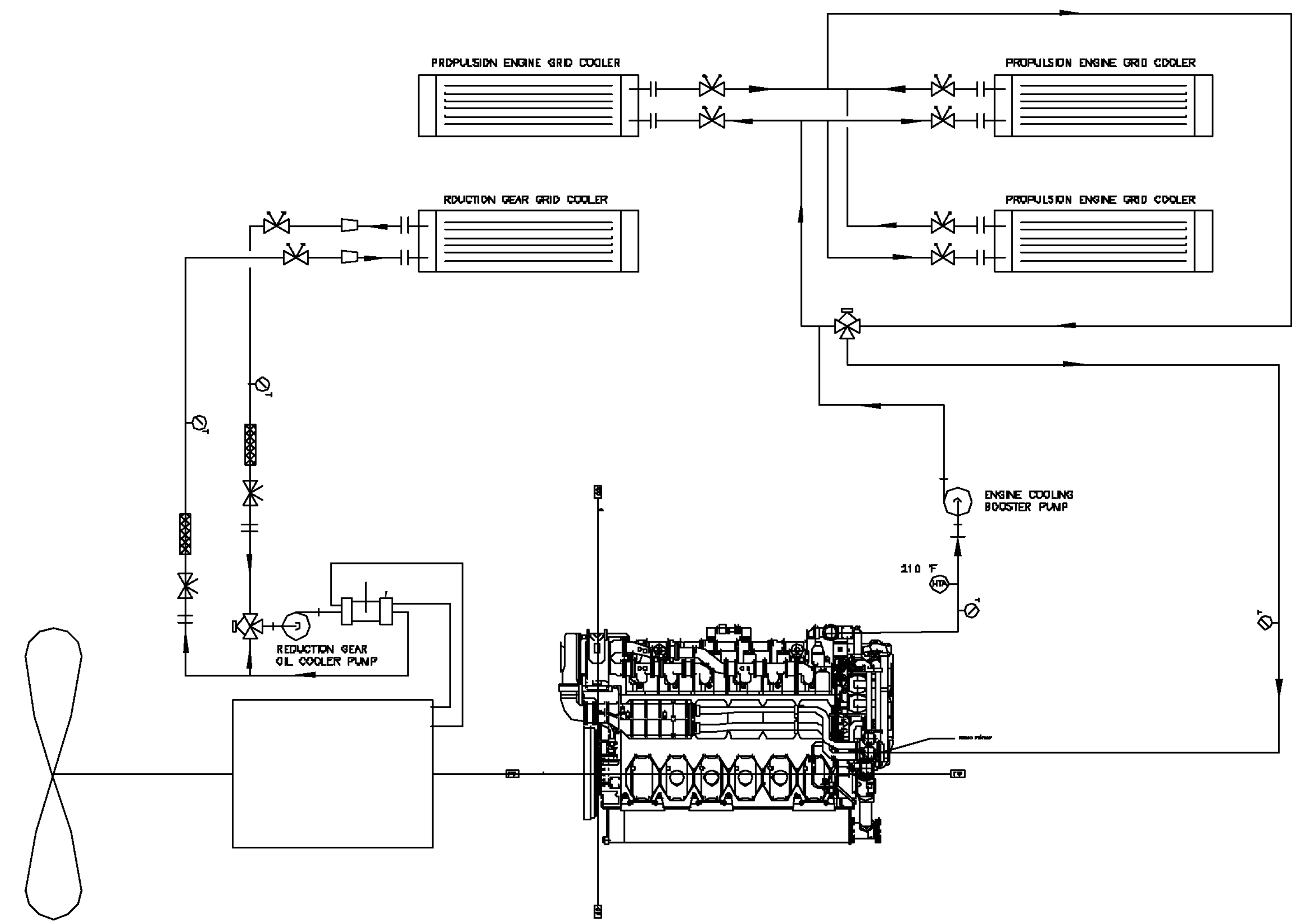

MAIN ENGINE COOLING

FERNSTROM PARALLEL FLOW

PIPING ARRANGEMENT
(TYPICAL 3 PLACES)

MARINE DESIGN CENTER PHILADELPHIA, PA	DEPARTMENT OF THE ARMY MARINE DESIGN CENTER CORPS OF ENGINEERS
M. KELLY J. ASBURY	JIM DeCOUR
J. ASBURY	US Army Corps of Engineers N/V MISSISSIPPI MAIN ENGINE COOLER PIPING ONE-LINE DIAGRAM
10 APR 2002	SIZE D · PROJECT NO. 2606 · DWG NO. 436-A640-01 · REV
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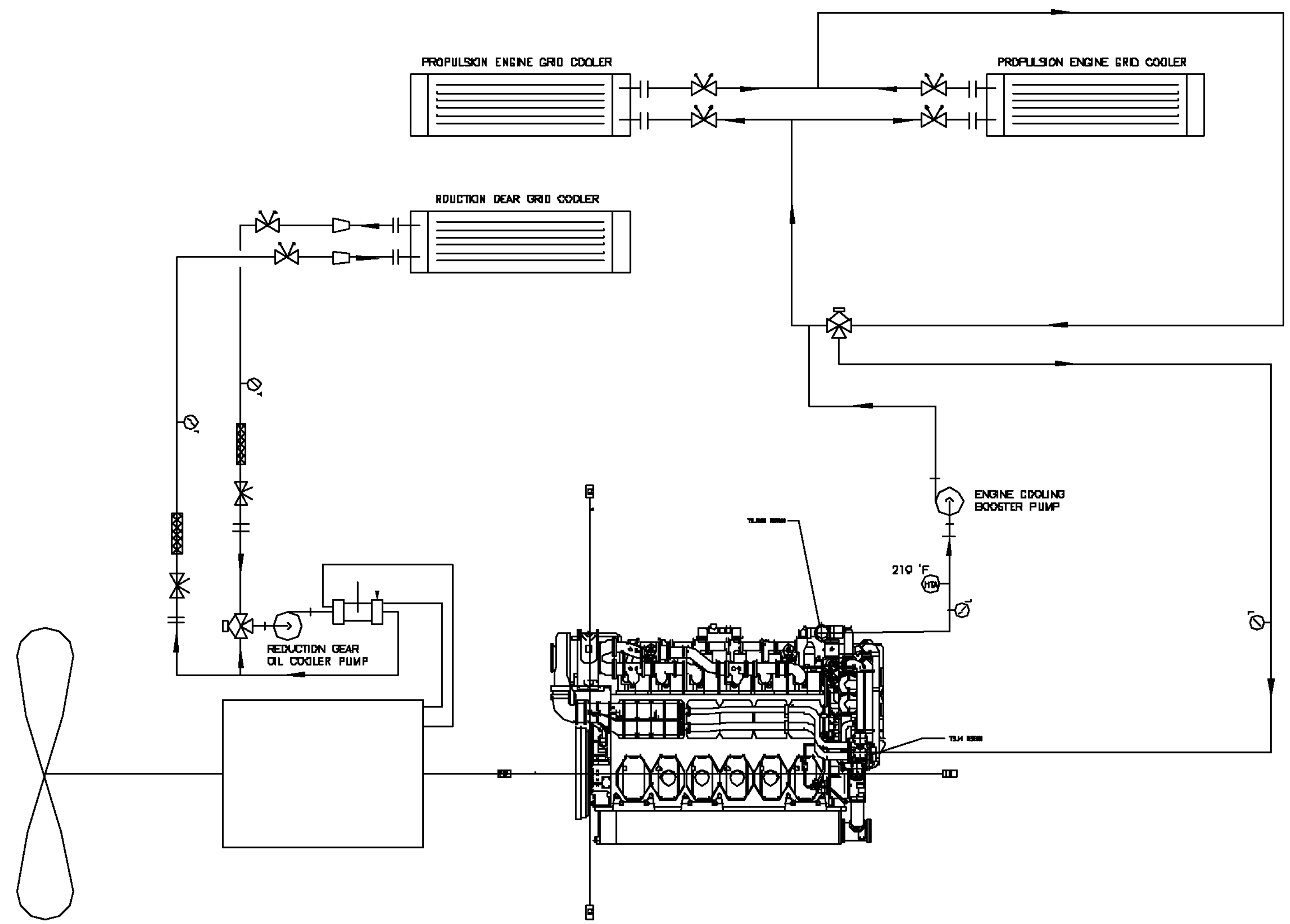

MAIN ENGINE COOLING

FERNSTROM PARALLEL FLOW

PIPING ARRANGEMENT
(TYPICAL 3 PLACES)

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MARINE DESIGN CENTER
CORPS OF ENGINEERS

US Army Corps of Engineers

N/V MISSISSIPPI

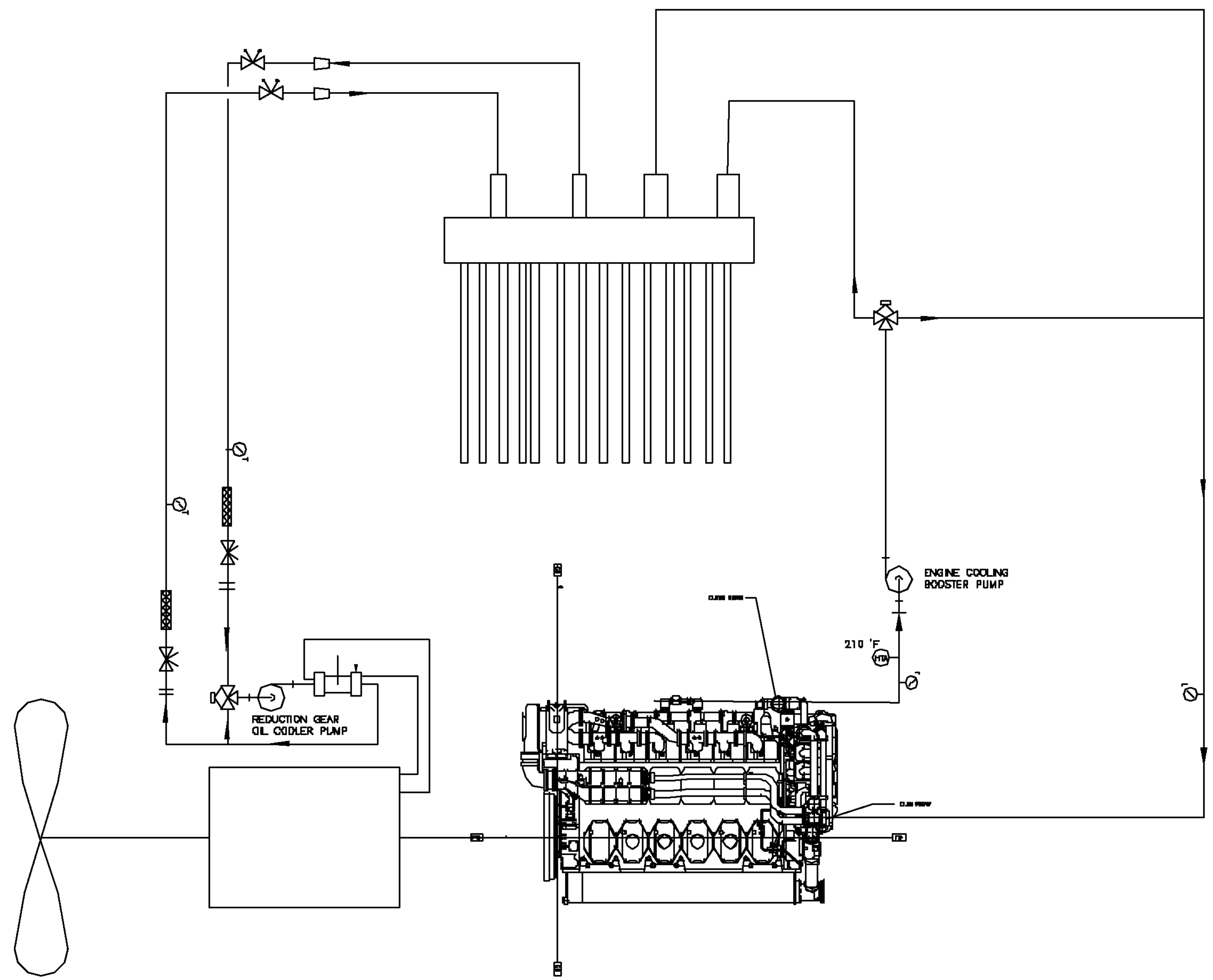
MAIN ENGINE COOLER
PIPING ONE-LINE DIAGRAM

M. KELLY
J. ASBURY
JIM DeCOUR

DRAWN BY J. ASBURY
DATE 10 APR 2002

SIZE D | PROJECT NO. 2606 | DWG NO. 436-A640-01 | REV

SCALE NONE | SHEET 2 OF 4



MAIN ENGINE COOLING

FERNSTROM Box Cooler

PIPING ARRANGEMENT
(TYPICAL 3 PLACES)

MARINE DESIGN CENTER PHILADELPHIA, PA	DEPARTMENT OF THE ARMY MARINE DESIGN CENTER CORPS OF ENGINEERS
M. KELLY J. ASBURY	JIM DeCOUR
J. ASBURY	
10 APR 2002	

US Army Corps of Engineers

M/V MISSISSIPPI

MAIN ENGINE COOLER PIPING ONE-LINE DIAGRAM

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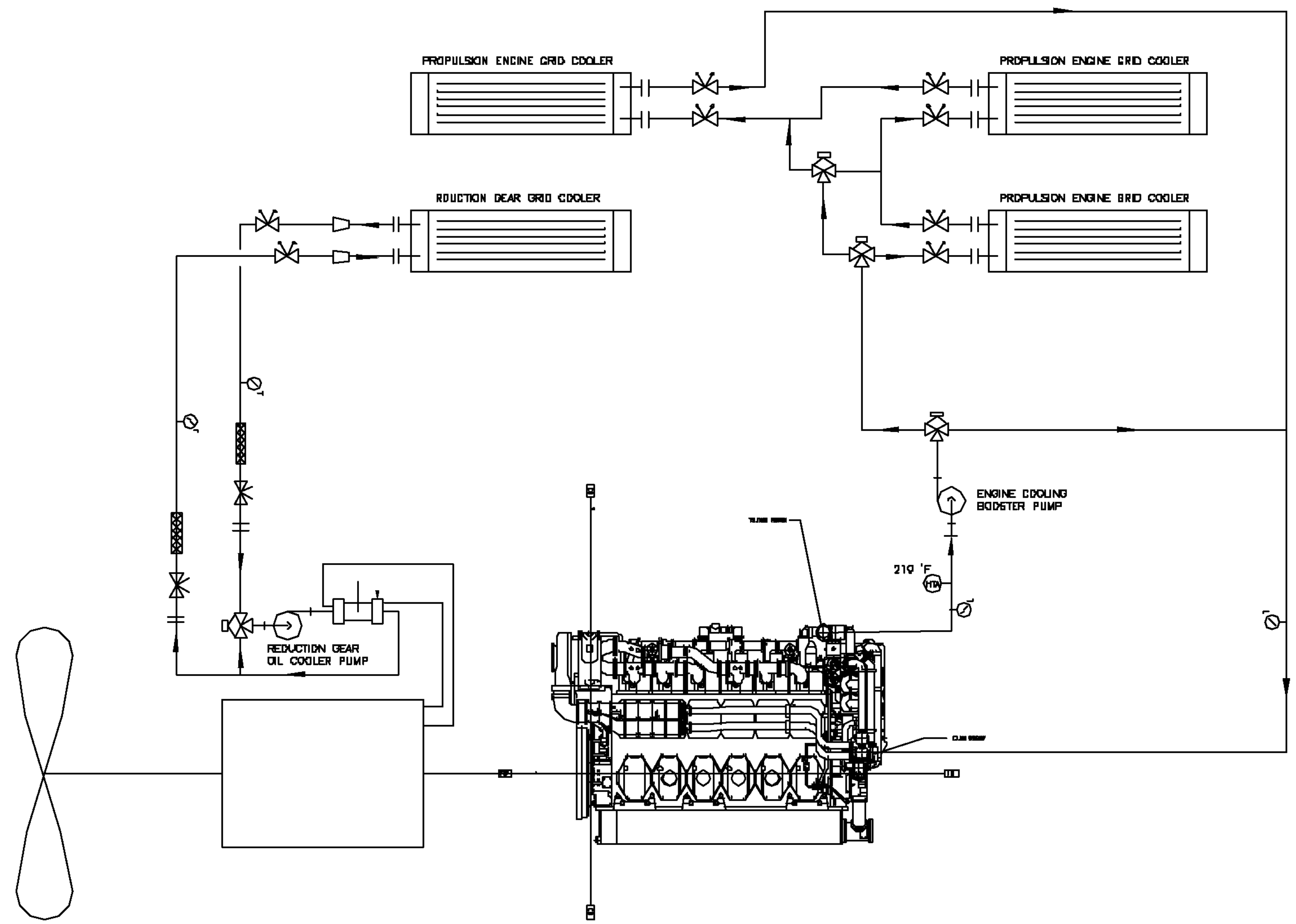

MAIN ENGINE COOLING

DURAMAX SERIES FLOW

PIPING ARRANGEMENT
(TYPICAL 3 PLACES)

ZONE	REV	DESCRIPTION	DATE	APPROVED

MARINE DESIGN CENTER
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MARINE DESIGN CENTER
CORPS OF ENGINEERS

US Army Corps of Engineers

M/V MISSISSIPPI
MAIN ENGINE COOLER
PIPING ONE-LINE DIAGRAM

PRIN ENGR – MACH: M. KELLY, J. ASBURY
SUBMITTED – PROM MGR: JIM DeCOUR
DRAWN BY: J. ASBURY
DATE: 10 APR 2002

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SHEET 4 OF 4

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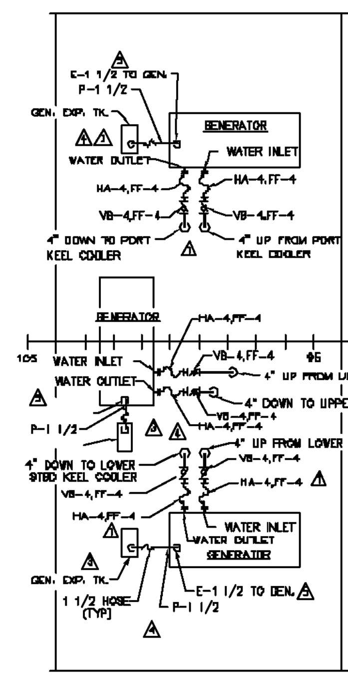


DETAIL 7-B

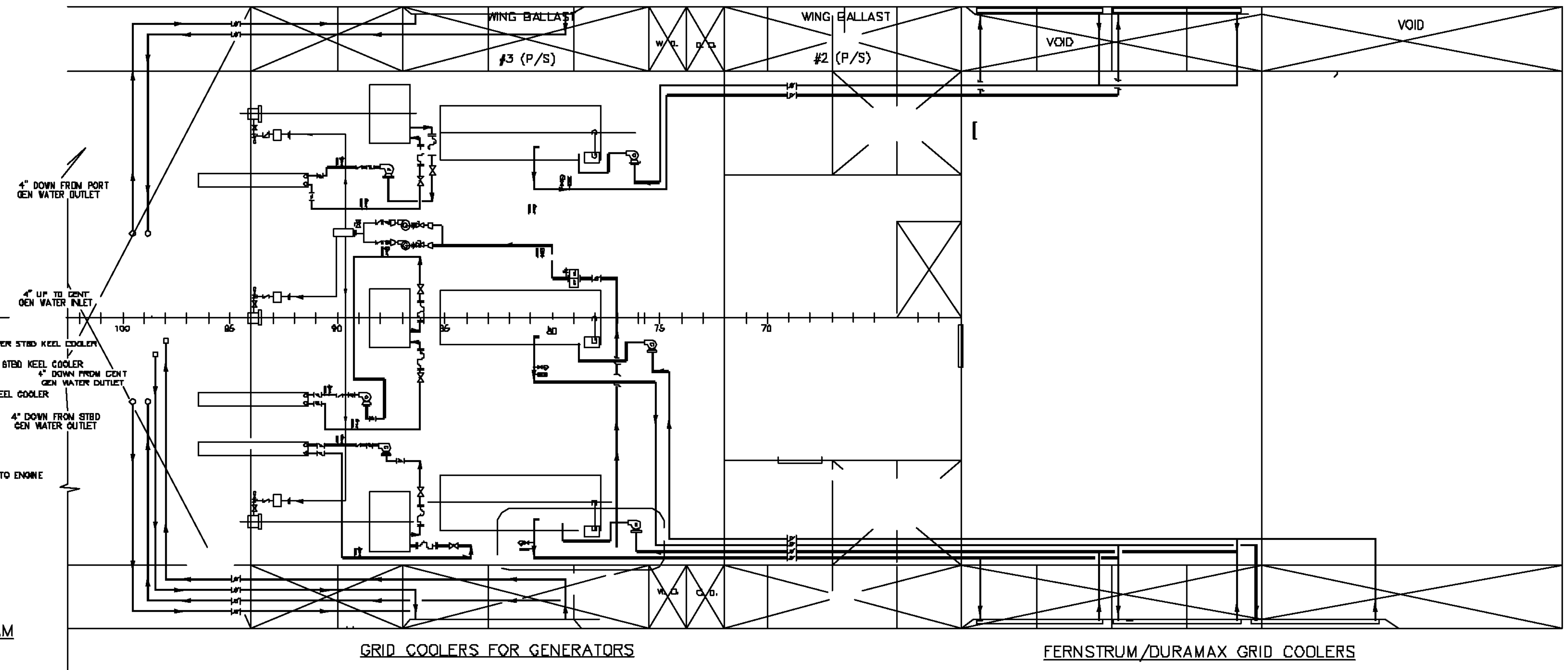
GENERATOR PIPING DIAGRAM

GRID COOLERS FOR GENERATOR

FERNSTRUM/DURAMAX GRID COOLERS

THREE COOLERS PER ENGINE IN PARALLEL PLUS THREE FOR REDUCTION GEARS

COOLERS ARE STACKED TWO HIGH



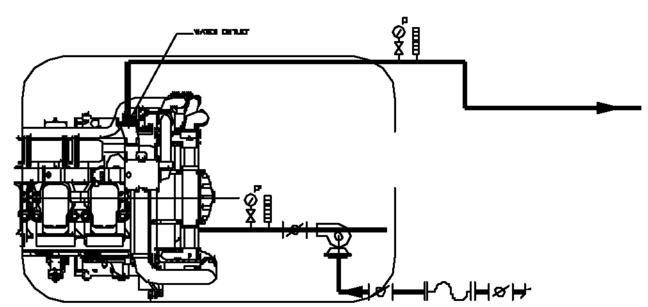
GRID COOLERS FOR GENERATORS

FERNSTRUM/DURAMAX GRID COOLERS

THREE COOLERS PER ENGINE IN PARALLEL

COOLERS ARE STACKED TWO HIGH

DURAMAX COOLERS ARE IN SERIES



ENGINE COOLING PIPING DIAGRAM

TYPICAL MAIN ENGINE CONNECTION

N.T.S.

MARINE DESIGN CENTER PHILADELPHIA, PA	DEPARTMENT OF THE ARMY MARINE DESIGN CENTER CORPS OF ENGINEERS
LEAD PROJ ENGR C. J. Lowe	US Army Corps of Engineers — M/V MISSISSIPPI ENGINE COOLER GENERAL ARRANGEMENT
PROJ ENGR – HULL C. J. Lowe	
PROJ ENGR – MACH / SUBMITTED – PROJ MGR Steve McNamara	
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REVISIONS

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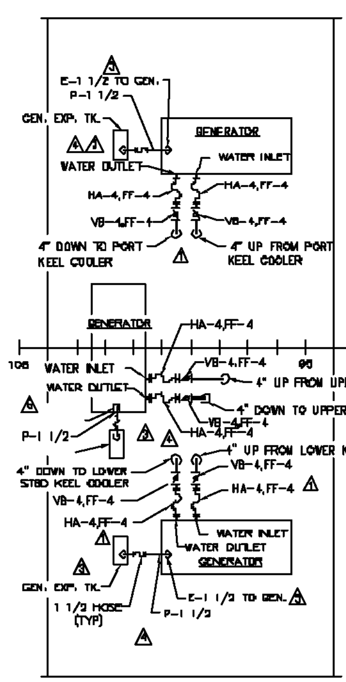
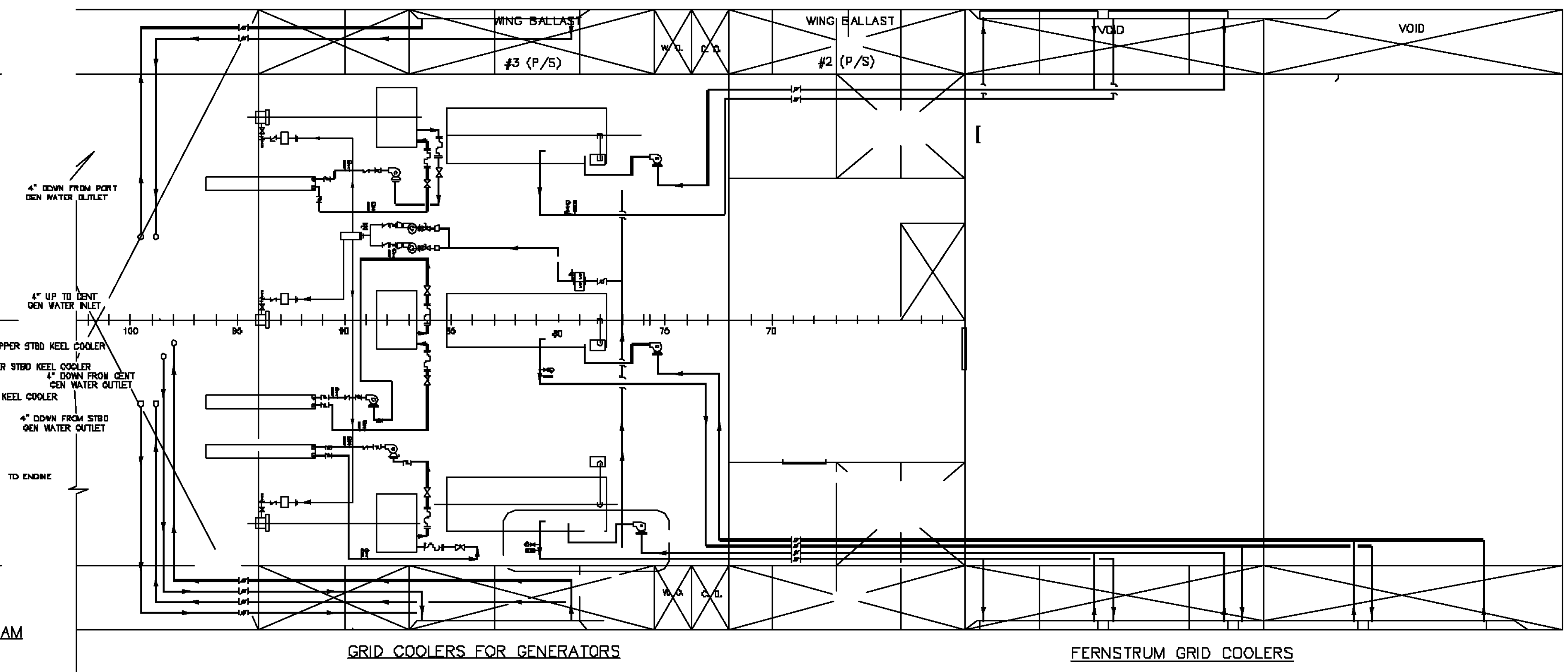
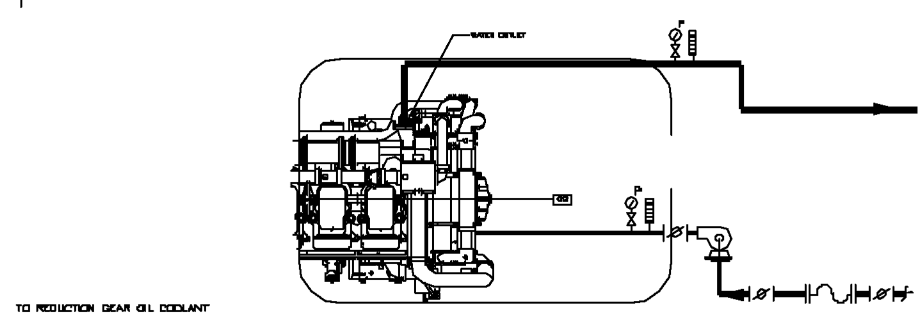


DETAIL 7-B

GENERATOR PIPING DIAGRAM





TO REDUCTION GEAR OIL COOLANT

ENGINE COOLING PIPING DIAGRAM

DETAIL 5-A

TYPICAL MAIN ENGINE CONNECTION

N.T.S.

MARINE DESIGN CENTER
PHILADELPHIA, PA

C. J. Lowe

C. J. Lowe

Steve McNamara

DRAWN BY J. ASBURY

DATE 10 APR 2002

DEPARTMENT OF THE ARMY
MARINE DESIGN CENTER
CORPS OF ENGINEERS

US Army Corps of Engineers

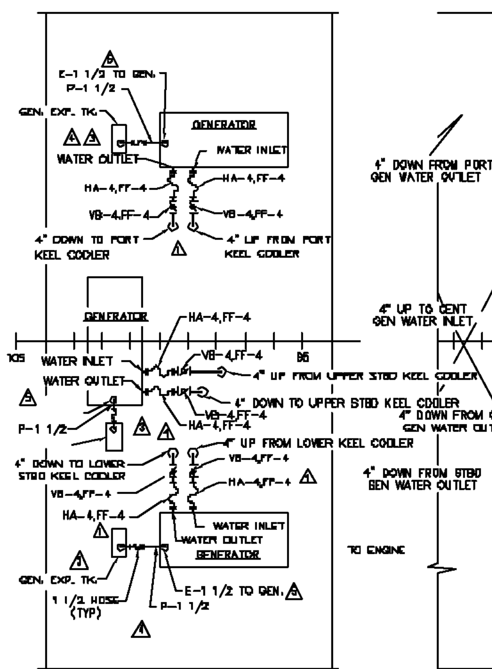
M/V MISSISSIPPI

ENGINE COOLER GENERAL ARRANGEMENT

SIZE D | PROJECT NO. 2606 | DWG NO. 436-A640-02 | REV

SCALE 1/8" = 1'-0" | SHEET 2 OF 3

ZONE	REV	DESCRIPTION	DATE	APPROVED



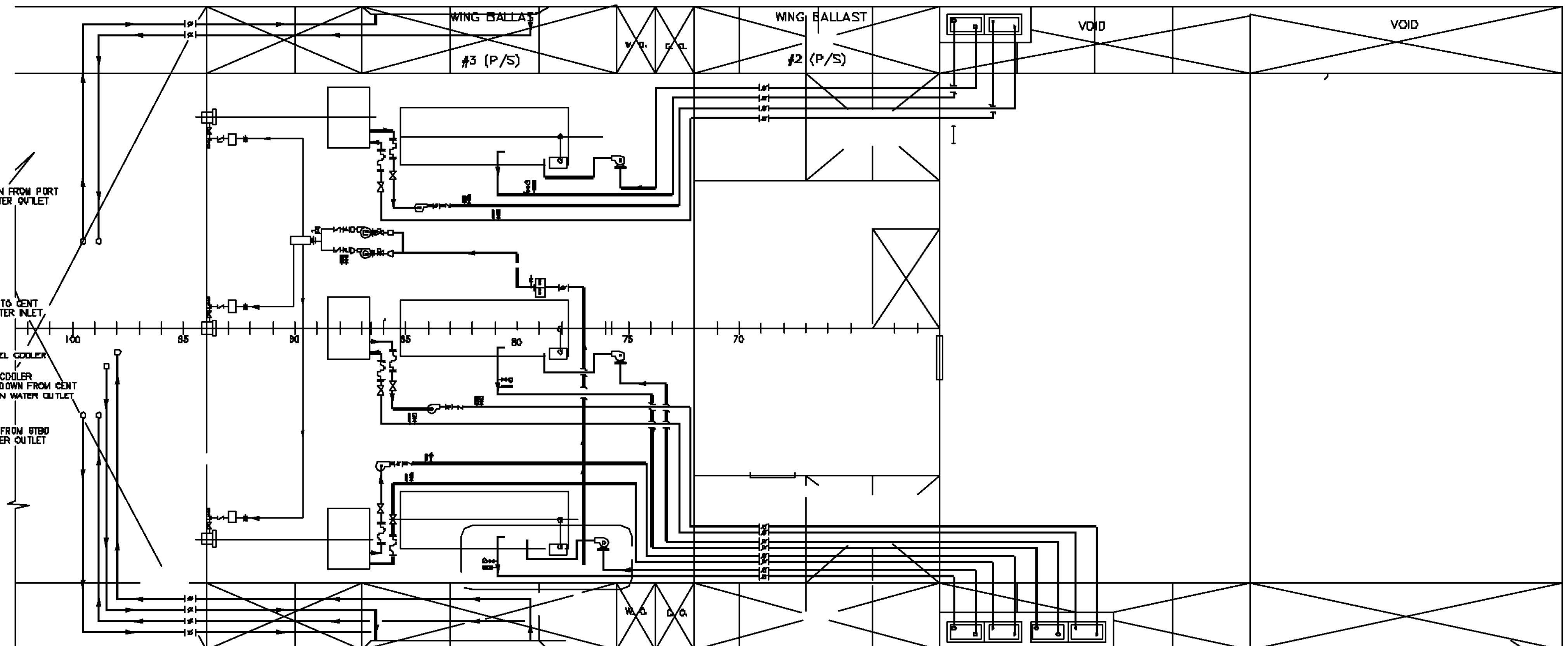
DETAIL 7–B

GENERATOR PIPING DIAGRAM

FERNSTRUM BOX COOLERS

PORT ENGINE AND REDUCTION GEAR

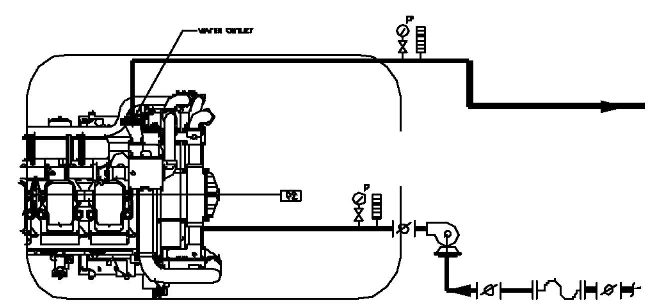
GRID COOLERS FOR GENERATOR



GRID COOLERS FOR GENERATORS

FERNSTRUM BOX COOLERS

STBD AND CENTERLINE ENGINES AND REDUCTION GEARS



ENGINE COOLING PIPING DIAGRAM

DETAIL 5–A

TYPICAL MAIN ENGINE CONNECTION

N.T.S.

MARINE DESIGN CENTER PHILADELPHIA, PA	DEPARTMENT OF THE ARMY MARINE DESIGN CENTER CORPS OF ENGINEERS
FROM ENGR – MECH: M. KELLEY & ASBURY	SUBMITTED – PROJ MGR: JIM DeCOUR
DRAWN BY: J. ASBURY	US Army Corps of Engineers — M/V MISSISSIPPI — ENGINE COOLER GENERAL ARRANGEMENT
DATE: 10 APR 2002	SIZE: D — PROJECT NO. 2606 — DWG NO. 436–A640–02 — REV
	SCALE 1/8" = 1'-0" — SHEET 3 OF 3

Appendix B

Estimates

Independent Government Estimate

MV MISSISSIPPI Box Coolers

For Non-Government Shipyard

Scope:

1. Remove existing plate cooler system and ripout associated piping.
2. Remove existing air conditioning cooler system and piping
3. Fabricate boxes in ballast tanks and voids
4. Install and test new box cooler system for Main Engines and reduction gears
5. Install and test new box coolers for air condiitioning system.

Labor	**Description**	**Burdened Rate**	**Hours**	**Cost**
	Production Labor	$52.50	2558.69	$134,331.23
	Engineering	$80.00	400	$32,000.00
	Project Mgmt Labor	$66.50	400	$26,600.00
	Estimating	$61.00	40	$2,440.00
	Subtotal - Burdened Labor (w/ovhd & profit)			**$195,371.23**

Material	**Description**	**Unit Price**	**Qty**	**Cost**
1.	Main Cool Pump	$7,431.00	3	$22,293.00
2.	Reduction Cool Pump	$3,940.00	3	$11,820.00
3.	AC Cool Pump	$3,000.00	2	$6,000.00
4.	Main and Gear Cooler	$24,039.00	3	$72,117.00
5.	AC Box Cooler	$16,266.00	2	$32,532.00
6.	Corrosion Protector	$2,500.00	5	$12,500.00
7.	4" Pipe (Main)(AC)	$9.25	620	$5,735.00
8.	2-1/2" Pipe (Red Gear)	$4.96	500	$2,480.00
9.	4" Gate Valves	$568.75	28	$15,925.00
10.	4" Check Valves	$367.50	14	$5,145.00
11.	4" 90's	$31.88	88	$2,805.44
12.	4" 45's	$22.38	20	$447.60
13.	2-1/2 Gate Valves	$355.00	24	$8,520.00
14.	2-1/2 Check Valves	$217.50	12	$2,610.00
15.	2-1/2 90's	$15.19	57	$865.83
16.	2-1/2 45's	$20.38	16	$326.08
17.	35A Ckt Bkr ME Pump	$642.50	3	$1,927.50
18.	15A Ckt Bkr RG Pump	$864.50	3	$2,593.50
19.	25A Ckt Bkr AC Pump	$642.50	3	$1,927.50
20.	TTNIA 10 ME	$0.85	450	$382.50
21.	TTNIA 4 RG	$0.76	450	$342.00
22.	TTNIA 10 AC	$0.85	400	$340.00
23.	Steel	$0.28	13368	$3,729.67
25.	Paint	$25.00	10	$250.00
	Subtotal Materials only			$213,614.62
	Consumable Allowance (1%)			$2,136.15
	Profit on Materials (10%)			$21,361.46
	Material Handling (15%)			$32,042.19
	Subtotal - Materials w/profit and Handling			**$269,154.42**

MDC Oversight	**Description**	**Rate**	**Hours/Qty**	**Cost**
	Const. Mgt	$65.00	144	$9,360.00
	Travel Expenses	$7,500.00	1	$7,500.00
	Subtotal - MDC Oversight			**$16,860.00**

Bonding Fees (applied to all subtotals)	**0.50%**	**$2,406.93**
Total Cost		**$483,792.58**

Independent Government Estimate

MV MISSISSIPPI Box Coolers

For Government Shipyard

Scope:

1. Remove existing plate cooler system and ripout associated piping.
2. Remove existing air conditioning cooler system and piping
3. Fabricate boxes in ballast tanks and voids
4. Install and test new box cooler system for Main Engines and reduction gears
5. Install and test new box coolers for air conditioning system.

Labor	**Description**	**Burdened Rate**	**Hours**	**Cost**
	Production Labor	$42.00	2600	$109,200.00
	Project Mgmt Labor	$53.20	240	$12,768.00
	Engineering	$65.00	240	$15,600.00
	Estimating	$48.80	40	$1,952.00
	Subtotal - Burdened Labor (w/ovhd & profit)			**$139,520.00**

Material	**Description**	**Unit Price**	**Qty**	**Cost**
1.	Main Cool Pump	$7,431.00	3	$22,293.00
2.	Reduction Cool Pump	$3,940.00	3	$11,820.00
3.	AC Cool Pump	$3,000.00	2	$6,000.00
4.	Main & Gear Coolers	$24,039.00	3	$72,117.00
5.	AC Box Cooler	$16,266.00	2	$32,532.00
6.	Corrosion Protector	$2,500.00	5	$12,500.00
7.	4" Pipe (Main)(AC)	$9.25	620	$5,735.00
8.	2-1/2" Pipe (Red Gear)	$4.96	500	$2,480.00
9.	4" Gate Valves	$568.75	28	$15,925.00
10.	4" Check Valves	$367.50	14	$5,145.00
11.	4" 90's	$31.88	88	$2,805.44
12.	4" 45's	$22.38	20	$447.60
13.	2-1/2 Gate Valves	$355.00	24	$8,520.00
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15.	2-1/2 90's	$15.19	57	$865.83
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17.	35A Ckt Bkr ME Pump	$642.50	3	$1,927.50
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19.	25A Ckt Bkr AC Pump	$642.50	2	$1,285.00
20.	TTNIA 10 ME	$0.85	450	$382.50
21.	TTNIA 4 RG	$0.76	450	$342.00
22.	TTNIA 10 AC	$0.85	400	$340.00
23.	Steel	$0.28	13368	$3,729.67
25.	Paint	$25.00	10	$250.00
	Subtotal Materials only			$212,972.12
	Consumable Allowance (1%)			$2,129.72
	Subtotal - Materials			**$215,101.84**

MDC Oversight	**Description**	**Rate**	**Hours/Qty**	**Cost**
	Const. Mgt	$65.00	144	$9,360.00
	Travel Expenses	$7,500.00	1	$7,500.00
	Subtotal - MDC Oversight			**$16,860.00**

	Total Cost			**$371,481.84**

Appendix C

Photographs
&
Figures

Figure 1. Typical Main Engine Plate Heat Exchanger

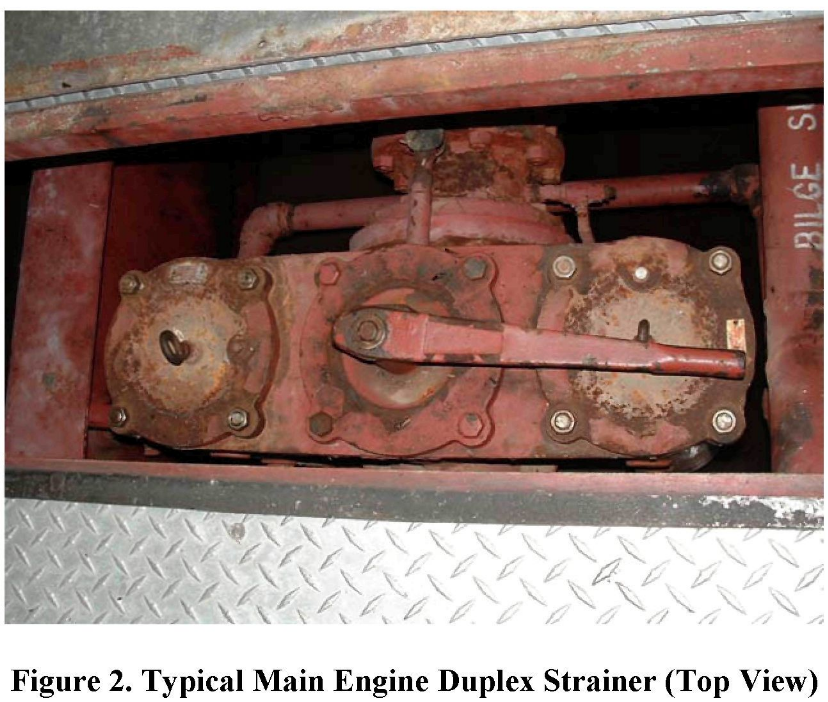

Figure 2. Typical Main Engine Duplex Strainer (Top View)

Figure 2a. Typical Duplex Strainer (Side View).

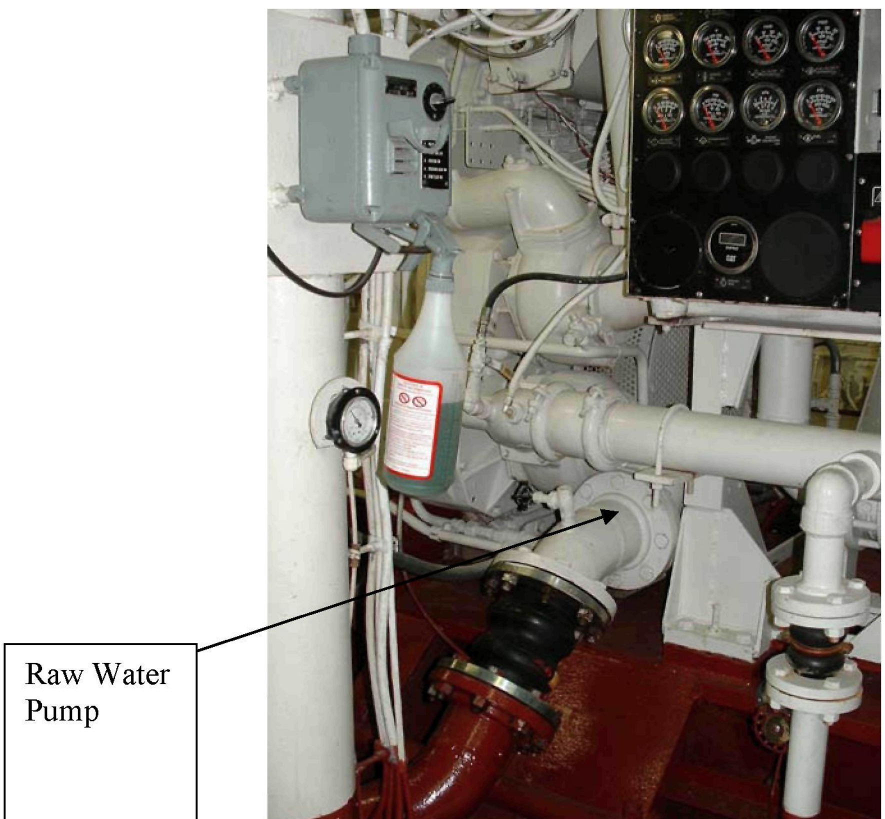

Figure 3. Typical Engine Mounted Raw Water Pump

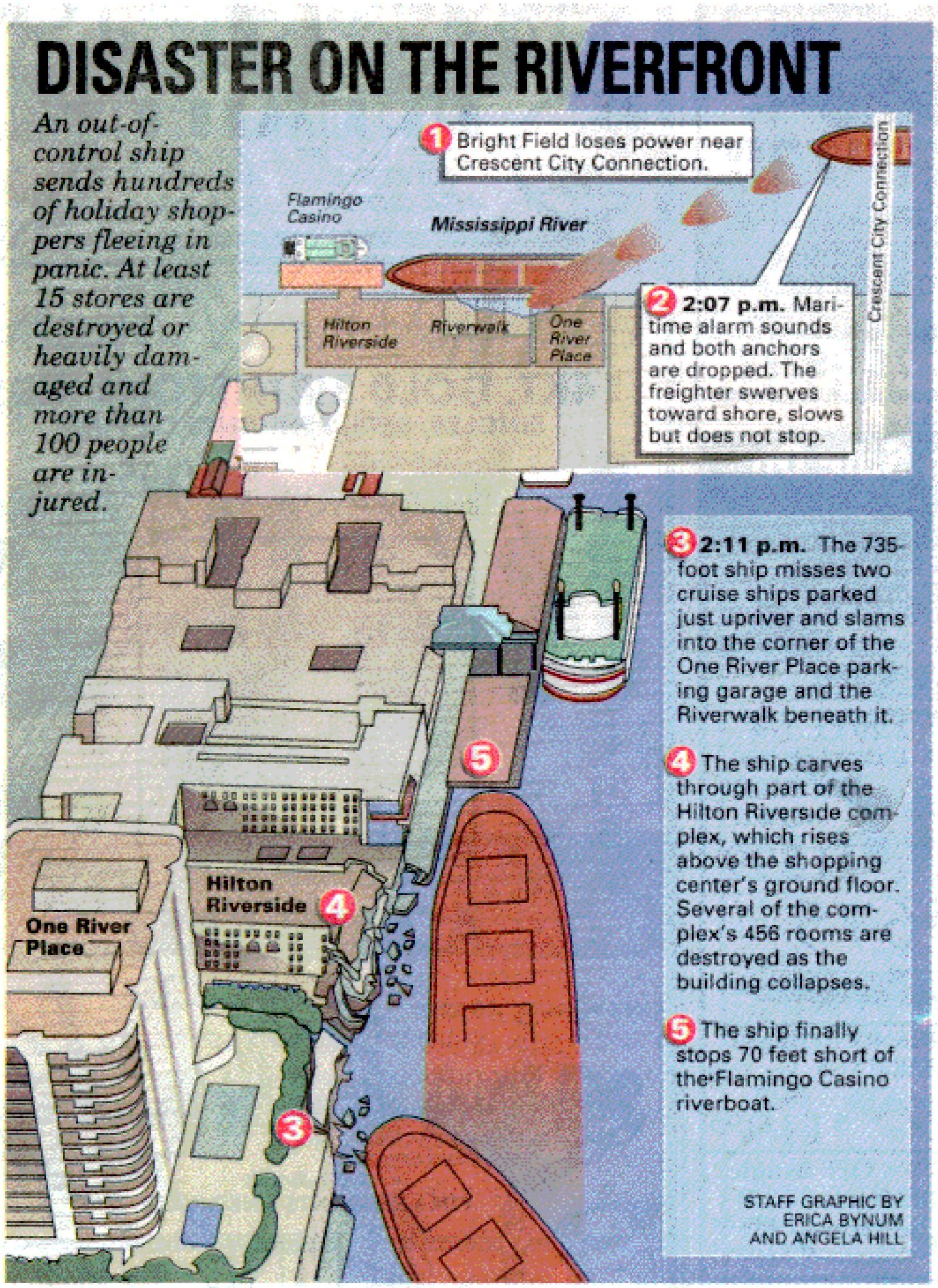

Figure 4. Newspaper graphic depicting *M/V BRIGHT STAR* Accident

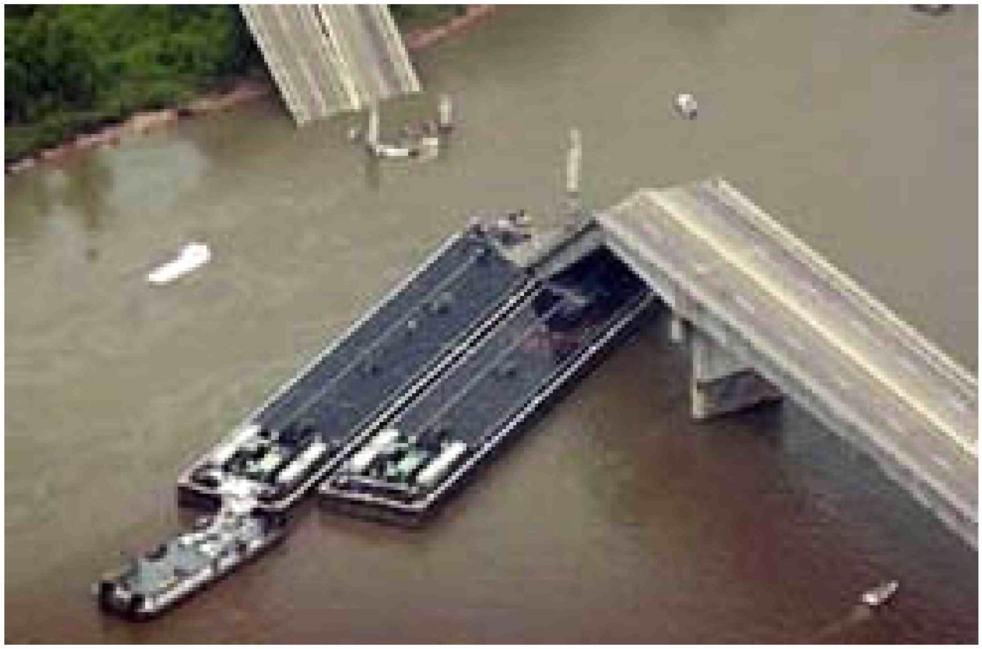

Figure 5. Towboat Accident with I-40 bridge on Arkansas River in Oklahoma

Figure 6. STBD A/C Chiller Plant

Figure 7. Typical severe condenser tube fouling.

Figure 8. Typical Grid Cooler installation in side of a river boat.

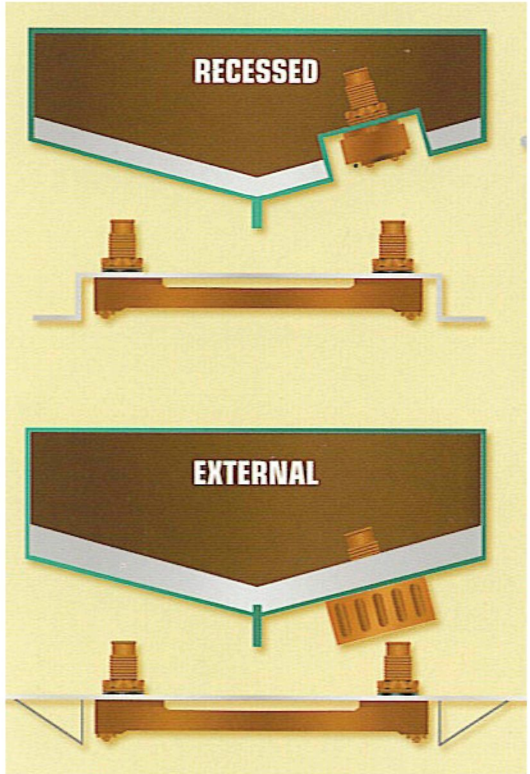

Figure 8a. Alternate mounting positions of Grid Coolers

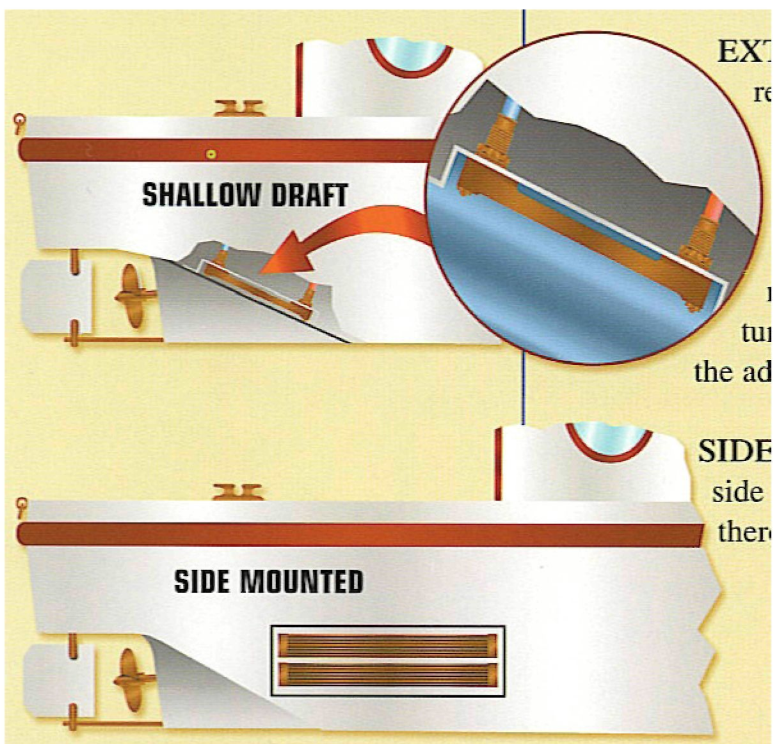

Figure 8b. Alternate mounting positions of Grid Coolers

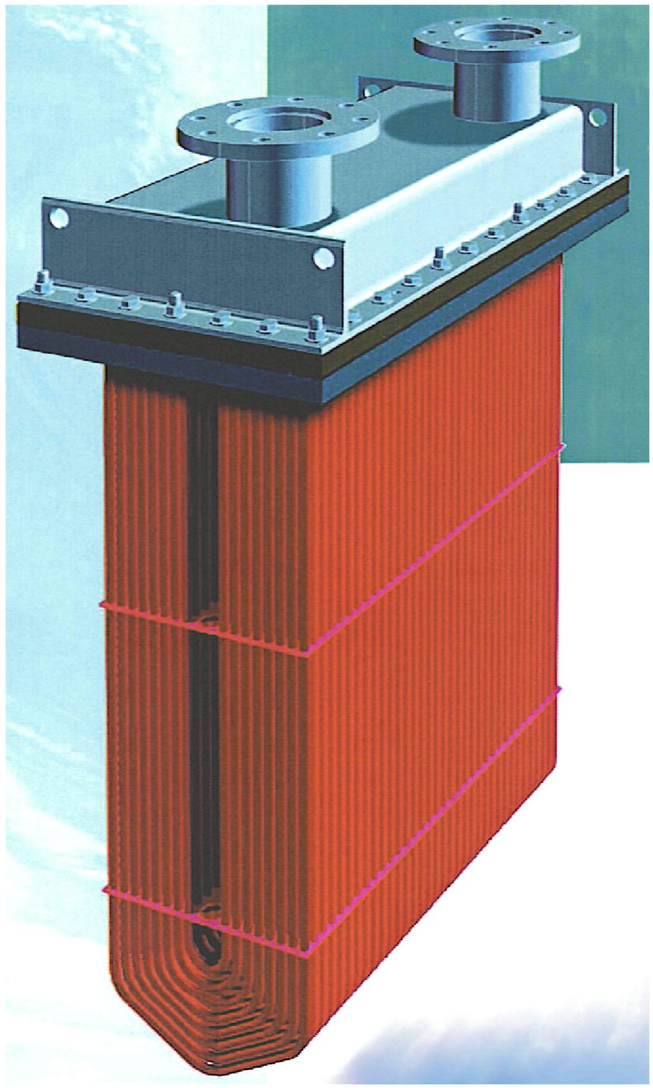

Figure 9. Typical Box Cooler

Appendix D:

Project Management Timeline

Gantt Chart

Appendix E:

Design Teams Vitae