Public Interest Finding Request

For

[redacted]

Proprietary Equipment Specification

Date: 11 November, 2015

Project: *M/V Matanuska* Repower & Ship System Upgrades

References:

1. *M/V Matanuska Repower & Ship System Upgrades – Propulsion Engine Selection Report*

Project Intent: This is a FHWA funded project (No. 70212) to replace the existing main propulsion engines, main propulsion equipment and auxiliary systems on the M/V *Matanuska.*

Background: This purpose of this project is to repower the vessel due to the age and condition of the main propulsion engines and improve vessel maneuverability by replacing the vessel propulsion equipment. To accomplish these goals, new main propulsion engines with fast response time, new controllable pitch propellers, and a new steering gear system will be installed to replace existing equipment.

The existing MaK 9M453B propulsion engines onboard the M/V *Matanuska* were installed in 1985. Maintenance issues due to operating hours and age including engine overheating have resulted in the need to derate the engines to roughly 70% of maximum load or from 3600 BHP down to 2520 BHP. Furthermore, the engine blocks are at the end of their service life and will not support new cylinder liners. Due to these issues, AMHS plans to replace the main propulsion engines with new equipment.

Justification: A propulsion engine selection report (See Reference 1) was completed to investigate several marine diesel engines in the 4000 HP range (original propulsion power level) and determine an engine replacement. The propulsion study investigated six different engine manufacturers against an evaluation criterion that included eight different metrics. The report concluded that the EMD 16-710 scored highest across the eight metrics, which included: price, reliability, life cycle costs, and service network. This engine has strong torque characteristics, fast response time over the full operating range, has service technicians and parts distribution in Washington State and meets applicable emissions requirements.

The EMD 16-710 is also dual-fuel capable. EMD offers a conversion kit that once installed, allows for burning of natural gas. A small portion of diesel "pilot" fuel is used to facilitate combustion.

EMD is a familiar engine to the Alaska Marine Highway System fleet. There are three existing vessels with EMD main propulsion engines. Recently, EMD propulsion engines were also selected for the two new Alaska – Class Ferries currently in production. Therefore AMHS is committed to already have 5 ships with EMD propulsion engines. This is the largest concentration of engines in the AMHS fleet.

We recommend the single source purchase of two EMD 16-710 G7C-T3 engines for the M/V *Matanuska*. Purchase of these engines is in the public interest due to the advantages listed above and as shown in Reference 1. The completed contract design and regulatory submittals are based on installation of these EMD engines, therefore the contract guidance drawings will help simplify the construction process.

Estimated Costs: The estimated costs for two EMD 16-710 engines is approximately $1,750,000.

Finding of Public Interest

consistent

It is hereby found to be in the Public's best interest and ~~consider~~ with the code of Federal Regulations Title 23, Section 635.411 and DOT&PF's Policy and Procedure 10.02.013 to specify the identified proprietary items in this federally funded project.

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Project 70212 – M/V *Matanuska* Repower & Ship Systems Upgrades

Propulsion Engine Selection Report

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DOC: 14104-09	REV: –	FILE: 14104.01	DATE: 3 March 2015

References

1. *Project 70212 – M/V Matanuska Repower & Ship Systems Upgrades, Vessel Maneuvering Report,* Glosten, Document No. 14104-12, Rev. –, 3 March 2015.
2. *NavCad 2012* [software], HydroComp, Inc.
3. *Marine Diesel Power Plant Performance Practices,* SNAME Technical and Research Bulletin No. 3-27, Panel M-15, 1 January 1975.
4. *Existing Open Water Propeller Efficiency* (picture taken from ship documents).
5. 40 CFR §1042, *Control of Emissions from New and In-Use Marine Compression-Ignition Engines and Vessels*, 2013.
6. 40 CFR §1042.104, *Exhaust Emissions Standards for Category 3 Engines, US Code of Federal Regulations*, 11 December 2014.
7. *CFR 40-I-U-1042-G-1042.615: Replacement Engine Exemption, US Code of Federal Regulations, 11 December 2014.*
8. *Stout, Alan, "Repower question for state ferry" (email), US EPA, 04 November 2014.*
9. *Capacity Plan, Dillingham Ship Repair, Portland Oregon, DWG NO SR-7070-S29-1, Rev B, 29 May 1985.*
10. *Trans Marine Propulsion Systems, Inc.* (letter), "AMHS Matanuska load control setting with Berg System – **Preliminary service report.**" 5 July 2011.
11. *Equivalency Determination – Design Criteria for Natural Gas Fuel Systems,* United States Coast Guard (USCG), CG-521 Policy Letter No. 01-12, 19 April 2012.

Background

Existing Propulsion Engines

The original propulsion engines onboard the M/V *Matanuska* were replaced in 1985. Two MaK 9M453B's rated for 3,600 BHP at 600 rpm were installed and remain. Overheating of the MaKs has been reported at the upper end of the power curve and the engines have since been derated to roughly 70% of maximum load or 2520 BHP (Reference 10).

Resistance Prediction

A resistance estimate was calculated to provide a rational basis for engine power. Model test data for the *Matanuska* or *Malaspina* could not be located. However, model test data for the *Columbia* was available.

A hydrostatic model of the *Malaspina*, but not the *Matanuska*, was available. For the purposes of predicting ship resistance, the *Malaspina* was assumed to be sufficiently similar to the *Matanuska*.

A comparison of the principal characteristics of the *Columbia*, as tested, and the *Malaspina* at maximum draft is shown in Table 1.

Table 1 *Columbia* and *Malaspina* particulars

	***Columbia* (full scale)**	***Matanuska* *[Malaspina* (maximum draft)]**
Length between Perpendiculars	385 ft	370 ft
Length on Waterline	385.02 ft	383.44 ft
Breadth on Waterline	72.5 ft	57.1 ft (74 ft overall)
Draft	15.99 ft	16.95 ft
C_B	0.528	0.521
C_P	0.582	0.642
C_X	0.907	0.813
C_{WL}	0.745	0.781

The *Columbia* hull form is slightly different from the *Matanuska* hull form in that it has a forward bulb and fuller midsection, but the non-dimensional coefficients of form are assumed to be similar enough so that the model test results from the *Columbia* may be used as a basis for a resistance prediction for the *Matanuska*.

An aligned prediction of ship resistance using NavCad (Reference 2) was performed for the *Matanuska*. The effective horsepower includes wind resistance, added resistance in waves, and a 10% augment for appendages. The correlation allowance was assumed to be 0.0003. Frictional resistance was based on the ITTC line.

To get from effective horsepower to brake horsepower, a number of efficiencies must be included, as shown below:

$$BHP = \frac{EHP}{\eta_H \eta_R \eta_O \eta_S \eta_B \eta_G} \quad \text{where,}$$

BHP brake horsepower

EHP effective horsepower

η_H hull efficiency = (1-t)/(1-w) where w is wake fraction and t is thrust deduction

η_R relative rotative efficiency

η_O propeller open water efficiency

$\eta_S \eta_B$ stern tube and bearing efficiency

η_G gearing or transmission efficiency

The primary inefficiency is the propeller open water efficiency. The propeller open water efficiency was assumed to be that of the current propellers on the *Matanuska* (Reference 4). Based on the data available, η_O was assumed to be 0.668, corresponding to a ship speed of 17.2 kts with 3060 BHP at 194 RPM. Propeller open water efficiency is a function of both vessel speed through the water and RPM.

The wake fraction, thrust deduction, and rotative efficiency were estimated with NavCad. The stern tube and bearing efficiency was assumed to be 0.98 based on the fact that the main machinery is in the aft of the hull, and the gear efficiency was assumed to be 0.9765 based on guidance for single reduction gear at 3060 BHP (Reference 3). To account for uncertainties in the model, a 15% margin was added to the BHP estimate.

NavCad was used to estimate added resistance in wind and waves. The speed/power curves in a range of sea states are shown in Figure 1.

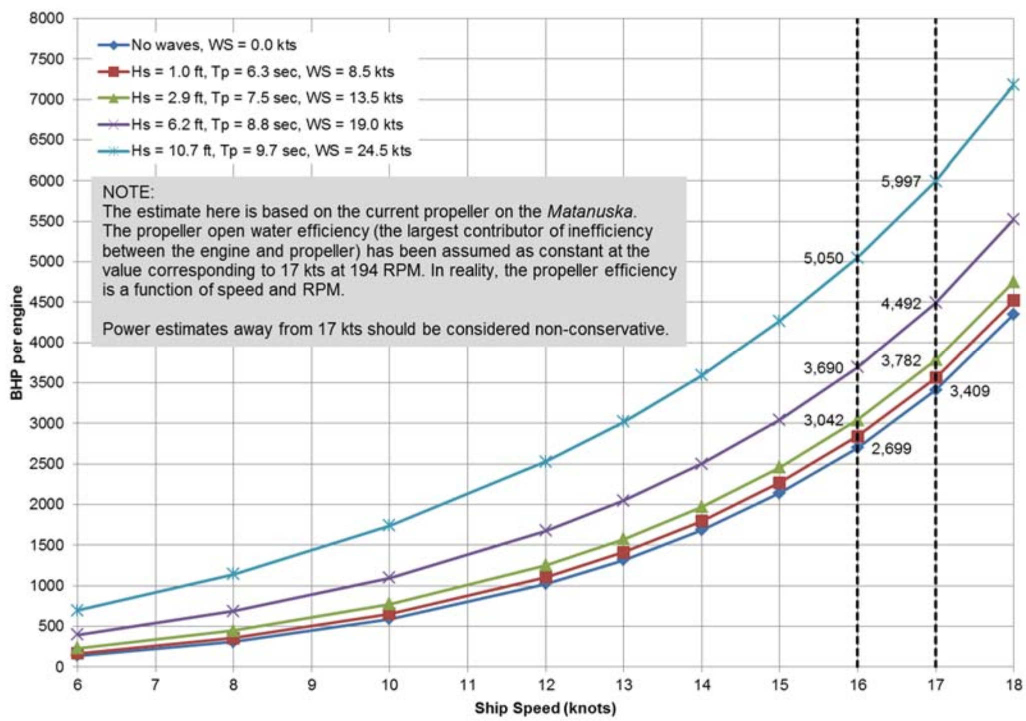

Figure 1 Estimated speed/power curve for *Matanuska*

As currently configured, the *Matanuska* makes approximately 16 knots with about 2500 BHP/engine, slightly less than the no wind and waves estimate for 16 knots of 2699 BHP/engine from Figure 1. This validation point indicates the estimate is fairly accurate, and errs on the conservative side.

A summary of the brake horsepower estimate for the *Matanuska* at her design service speed of 17 kts forward speed is shown in Table 2.

Table 2 Brake horsepower estimate for *Matanuska* at 17 kts

Sea State	Hs ft	Tp sec	Wind Speed kts	Total BHP	BHP/engine
-	-	-	-	6818	3409
2	1.0	6.3	8.5	7127	3564
3	2.9	7.5	13.5	7564	3782
4	6.2	8.8	19.0	8984	4492
5	10.7	9.7	24.5	11994	5997

Based on this estimate, engine replacement candidates were selected in the range of 3600 to 4500 BHP.

US EPA Requirements

The M/V *Matanuska* must comply with emission regulations put forth by the US Environmental Protection Agency (US EPA) for marine vessels, Reference 6. At the time of this report, the Agency mandates a Tier 4 designation for all Category 2 (≥7 & <30 liters/cylinder) marine engines between 2700 – 5000 HP. At the start of 2016, the US EPA will mandate Tier 3 requirements for Category 3 (≥30 liters/cylinder) marine engines in the same power range.

The M/V *Matanuska* has received unofficial written confirmation that it will be granted a Replacement Engine Exemption (Reference 7) by the US EPA. The exemption applies to new installations onboard existing vessels and approves the use of Tier 3 engines for this project. While there are Tier 2 engines discussed in this report, they will only be allowed by US EPA if installed before 1 January 2016 and were therefore discounted as possible candidates.

Table 3 US EPA requirement under Replacement Engine Exemption

Category	Displacement (l/cyl)	Tier	Implementation
2	≥ 7.0 < 30.0	3	2015+
3	≥ 30.0	2	2013-2015
		3	2016+

Liquefied Natural Gas (LNG)

AMHS has directed that LNG be investigated as a potential fuel for the *Matanuska*. While LNG is not readily available at Alaskan ports today, it is emerging as an attractive marine fuel. LNG is being used on vehicle/passenger ferries in Europe and international regulations exist that dictate the design and operational requirements for safely operating ferries with natural gas. LNG is attractive because of its low cost, expected future availability, and reduced exhaust gas emissions compared to diesel fuel.

Despite its benefits, LNG presents several challenges for the vessel designer and the vessel operator when compared to traditional diesel fueled ships, including:

- Bunkering – LNG availability will be limited and refueling arrangements present unique challenges with a cryogenic fluid. LNG availability affects both vessel range discussions and vessel route discussions.
- Crew training – Specialized training will be required for vessel operating engineers which need to be considered when staffing an LNG ship.
- Regulatory interface – while international regulations exist and are evolving for LNG, the USCG has not codified their requirements in the Code of Federal Regulations. This presents uncertainty for the vessel designer.
- LNG storage onboard the vessel - LNG is cryogenic and must be stored in insulated and pressurized tanks (typical LNG storage conditions are -260°F and up to 150 psi). Consequently, these tanks are cylindrical in shape (or spherical) and challenging to locate in ships. Furthermore, the LNG only has about 50% of the energy density of diesel. As a result, LNG typically requires about four times the storage space of diesel fuel.

Of the aforementioned challenges, the greatest technical challenge facing LNG powering of a USCG certified ferry is fuel storage. Current regulations on LNG are from IMO interim guidelines (MSC.285(86)). However, the USCG has one major additional requirement on LNG propulsion that is not imposed by the international classification societies. CG-521 Policy Letter No. 01-12 (Reference 11) states, "*Natural gas fuel storage tanks must not be located below accommodation spaces, service spaces, or control stations, unless the arrangement is accepted by the Commandant (CG-521)*." Further discussions with USCG indicated acceptance will involve a risk analysis comprised of both a frequency analysis (identifying initiating events and estimating likelihoods) and a consequence analysis (modeling the outcomes and estimating the impacts), with a design that adequately addresses all determined risks. To date, no vessel has actually had such an analysis approved by the USCG. This process may be lengthy and does not guarantee USCG approval.

For these reasons LNG is not recommended for the repower of the *Matanuska*.

Potential Replacement Candidates

After initial market research, six engine manufacturers were identified that could meet basic requirements of the vessel. The suitable candidates are the following:

- Anglo Belgian Corporation (ABC)
- Electro Motive Diesel (EMD)
- General Electric* (GE)
- Maschinenbau Kiel GmbH (MaK)
- MAN
- Wärtsilä

* **Confidentiality issues were raised with this engine, see the General Electric (GE) section below.**

The group was selected based on a set of pass-fail criteria that Glosten deemed essential for improved operation of the vessel and a successful installation. These criteria are as follows:

- Rated power between 3600 – 4500 horsepower.
- Minimal arrangement modifications required.
- Suitable for exhaust gas boilers.
- Service technicians located reasonably close to Ketchikan, Alaska.
- Regulatory approval.

In addition to the pass-fail criteria, each engine was investigated further and measured against one another. Eight metrics were used and each was given a weighting factor. The relative scores were normalized to the EMD engine because this engine was identified to have the highest overall score. The metrics and associated weighting factors are the following:

- Low end Torque (10%)
- Full-speed Torque (20%)
- Fleet Commonality (10%)
- Specific Fuel Oil Consumption (20%)
- Overhaul & Maintenance Cost (10%)
- Capital Cost (10%)
- Installation Cost (5%)
- Response Time (15%)

Regardless of engine selection, the vessel will be fitted with new exhaust gas boilers capable of steam production. The existing bypass in the engine exhaust will be removed and a single pipe will be routed from each engine. Inside the machinery casing, a boiler will be fitted to each exhaust.

Anglo Belgian Corporation (ABC)

ABC engines are manufactured in Belgium and distributed and serviced by Trans Marine in Seattle, Washington. Table 4 shows salient characteristics of the 16 cylinder, 750 rpm version of the marine propulsion engine. This engine meets EPA Tier 3 emissions requirements.

There are no ABC engines in the current AMHS fleet.

Table 4 ABC engine specifics

Model	16 DZC-750-179
Rated Continuous Power, hp (kW)	3807 (2840)
US EPA Certification	Tier 3
Cylinders	16
Displacement, in^3/cyl (l/cyl)	976 (16)
Rated Speed, rpm	750
ROM Capital Cost, USD	$817,285
Lead Time, months	7.5

Performance

The ABC engine has the strongest torque characteristics over the full operating range and a full-speed torque near the top of the group (28,602 ft-lbs, see Appendix A). This engine has 34% more rated power than *Matanuska's* existing propulsion engine in its current state. The response time for this engine (0% to 100% speed) also ranks near the top at 18 seconds.

Fuel Consumption

The ABC engine has a specific fuel consumption of 187 g/kWh at 100% load. Assuming a marine diesel oil price of $2.55 per gallon, the fuel cost of this engine operating at 100% load is estimated at $404 per hour (see Appendix B).

Overhaul and Maintenance

Life-cycle cost was considered for roughly 120,000 operating hours on a single engine. Items considered in the analysis were the cost of lube oil, replacement parts, and labor hours. The prices listed below were given by the manufacturer in Euros (€) and have been converted to USD ($) using a 1€ = $1.2 exchange rate.

Total cost: $1,031,700

- Oil: $ 255,000
- Labor: $ 159,745
- Parts: $ 616,955

Installation Cost

Due to oil pan depth at the base of this engine, modification to the ship structure will be necessary. The following tanks, which are located underneath the proposed engine location, will likely be affected (see Reference 9):

- Lube oil sump, port and starboard.
- Cofferdam, port and starboard.
- Oily water tank, port only.
- Jacket water holding tank, starboard only.

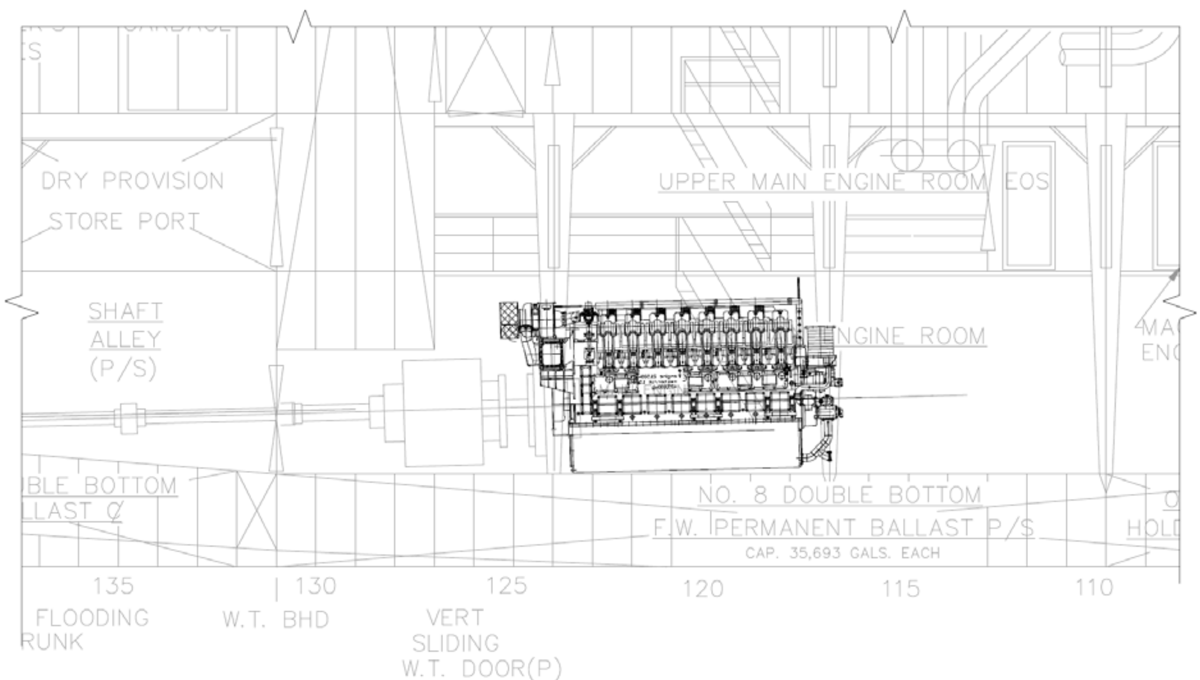

Figure 2 ABC engine in profile

Electro Motive Diesel (EMD)

EMD engines are manufactured in the USA and distributed and serviced locally by Valley Power Systems with offices throughout the western USA. Table 5 shows salient characteristics of the 16 cylinder, 900 rpm version of the marine propulsion engine.

Twelve cylinder versions of this engine will be installed on the Alaska Class ferries currently under construction.

Table 5 EMD engine specifics

Model	16-710 G7C-T3
Rated Continuous Power, HP (kW)	3999 (2983)
US EPA Certification	Tier 3
Cylinders	16
Displacement, in^3/cyl (l/cyl)	710 (11.63)
Rated Speed, rpm	900
ROM Capital Cost, USD	$892,000
Lead Time, months	6

Performance

While the maximum torque is near the middle of the group at 23,602 ft-lbs, this engine shows strong torque characteristics over the full operating range (see Appendix A). This EMD has 37% more rated power than the existing engine in its current state. Response time for this engine (0% to 100% speed) is the best in the group at 9.5 seconds.

Fuel Consumption

The EMD engine has a specific fuel consumption of 201 g/kWh at 100% load (218 g/kWh average). Assuming a marine diesel oil price of $2.55 per gallon, the fuel cost of this engine at 100% load is estimated at $500 per hour (see Appendix B).

This engine is capable of dual fuel (diesel-liquefied natural gas, LNG) operation with addition of a conversion kit. Once converted, the engine maintains original torque and power characteristics. The conversion kit will cost an estimated $400,000 for parts and $80,000 in labor, for a total of $480,000 per engine. This estimate does not consider the cost of auxiliary systems such as fuel transfer and storage.

Overhaul and Maintenance

Life-cycle cost was considered for roughly 120,000 operating hours on a single engine. Items considered in the analysis were the cost of lube oil (0.40 gal/hr), replacement parts, and labor hours.

Total cost: $1,026,600

- Oil: $408,000
- Labor: $55,800
- Parts: $562,800

Installation

Due to oil pan depth at the base of this engine (see Figure 3), modification to the ship structure may be necessary for a successful installation. There appears to be a clearance of roughly 3" between the tank top and the oil pan, however this clearance is considered too small to be confident that no modification is necessary. The following tanks, which are located underneath the proposed engine location, would be affected (see Reference 9):

- Lube oil sump, port and starboard.
- Cofferdam, port and starboard.
- Oily water tank, port only.

- Jacket water holding tank, starboard only.

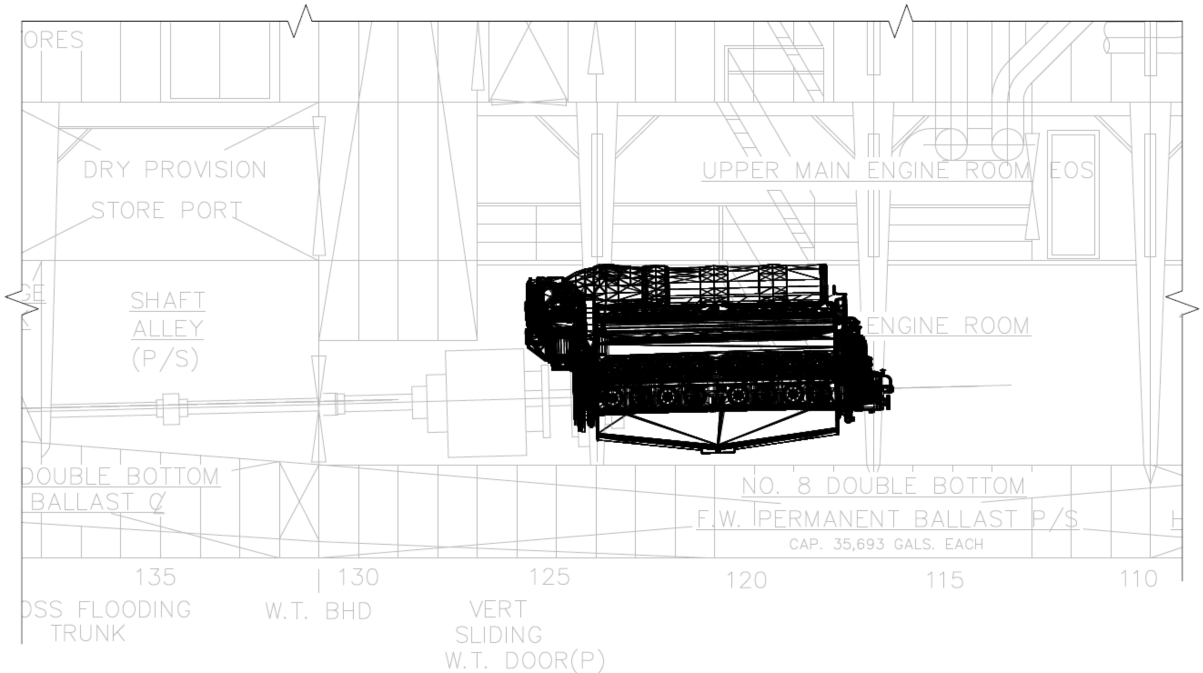

Figure 3 EMD engine in profile

To accommodate the limited backpressure allowance of this 2-stroke engine, exhaust piping modifications are necessary. Current overhead clearance in the upper engine room is an issue for the crew and thus increasing the exhaust pipe diameter is not acceptable. Additionally, the turbo-charger on this engine is positioned at the fixed end, near the reduction gear. To accommodate these two factors, a dual-exhaust pipe solution is proposed with transition pieces at the engine and inside the machinery casing (see Figure 5, Figure 6, and Figure 7). Structural modifications will include enlargement of the Second Deck cut-out above the engines (extension of approximately two frames aft, see Figure 6) and reduction of a non-structural bulkhead aft of the cut-out (see Figure 5).

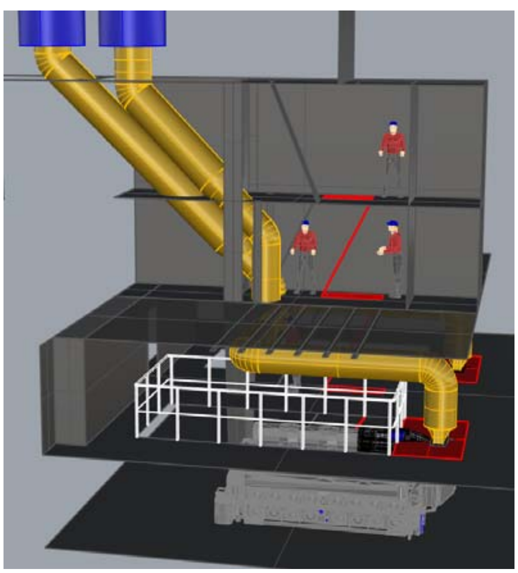

Figure 4 3-D view of the EMD and potential arrangement with one exhaust pipe per engine

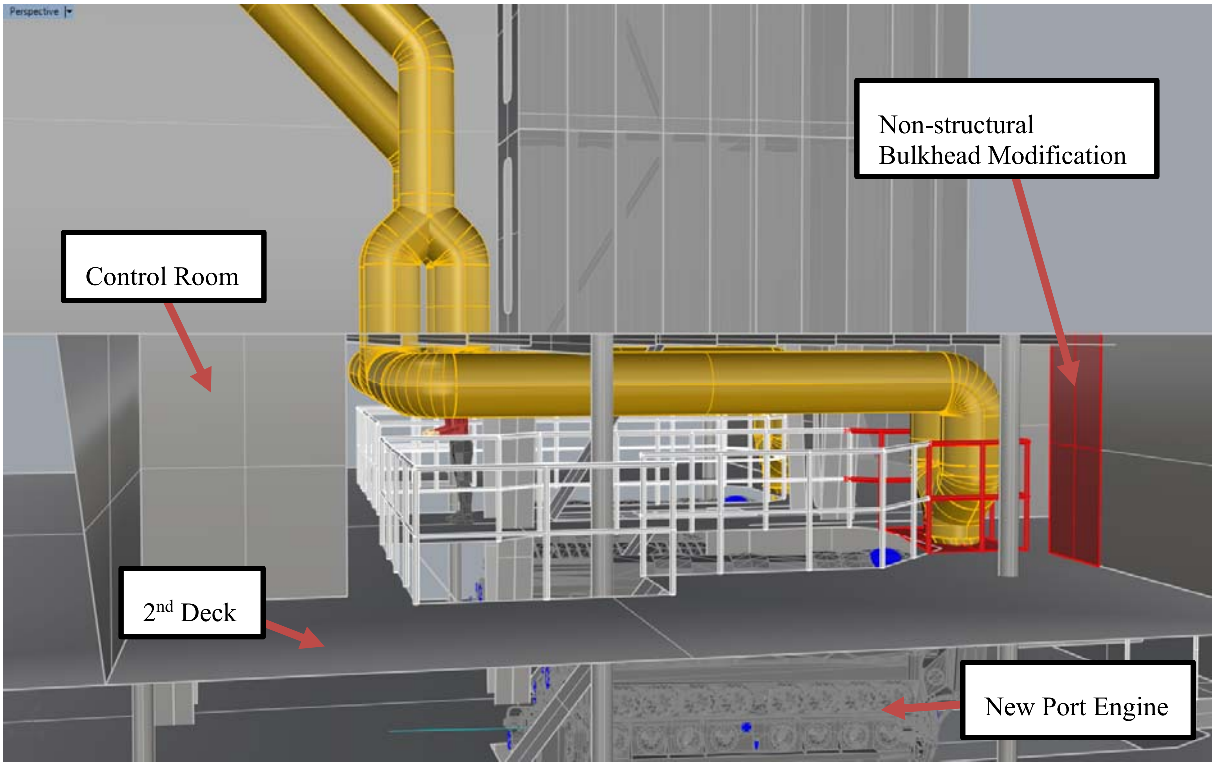

Figure 5 Engine room cut-away at 2nd Deck; view from port side looking inboard (starboard similar) showing an arrangement with two exhaust pipes per engine

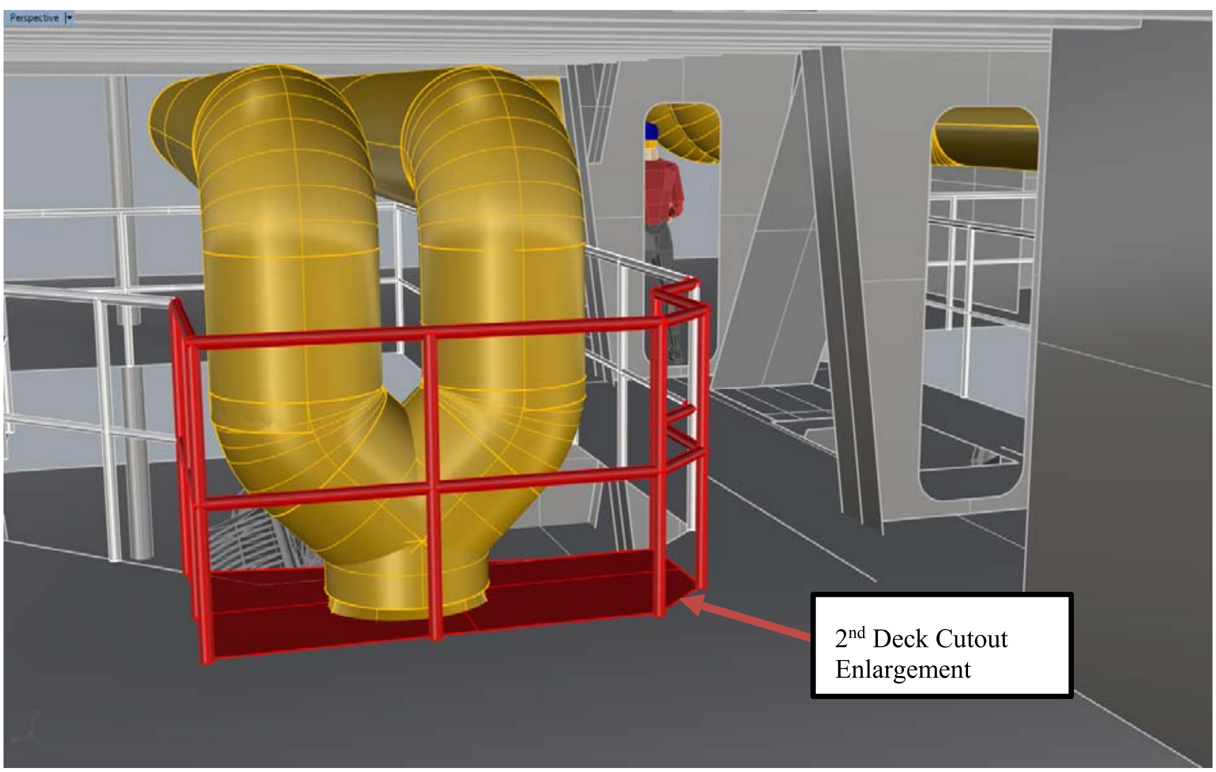

Figure 6 2nd Deck cutout enlargement; Second Deck at FR 120 looking forward (port shown, starboard similar)

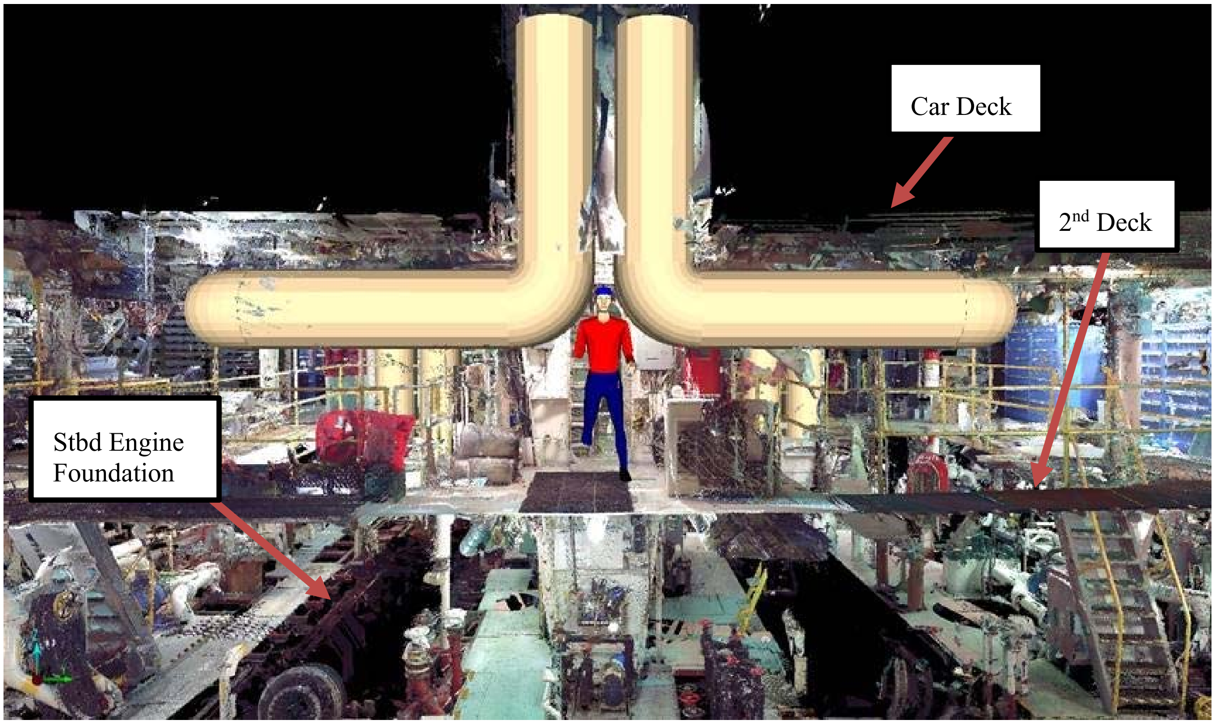

Figure 7 Overhead clearance for 6'2" tall person shown from control room entrance looking aft; exhaust piping shown with appropriate insulation

General Electric (GE)

GE engines are manufactured in the USA and distributed and serviced locally by Hatton Marine with offices in Seattle, Washington. Table 6 shows salient characteristics of the 12 cylinder, 900 rpm version of the marine propulsion engine. These engines will be installed on the M/V *Tustumena* replacement vessel currently in the design phase.

Table 6 GE engine specifics

Model	12V250MDC
Rated Continuous Power, HP (kW)	4423 (3150)
US EPA Certification	Tier 4i
Cylinders	12
Rated Speed, rpm	900

Information about the GE engine was provided to Glosten but considered confidential, and thus cannot be shared in a public space or forum. GE is willing to share information on a confidential basis with interested end users, their naval architects, and shipyards, with a non-disclosure agreement (NDA) in place. Although no specific data was reported, Glosten evaluated this engine and the result is listed in Table 10.

MaK

MaK engines are manufactured in Germany and distributed and serviced locally by Finning Power Solution with offices in Seattle, Washington. Table 7 shows salient characteristics of the 6 cylinder, 600 rpm version of the marine propulsion engine.

Table 7 MaK engine specifics

Model	6M32C
Rated Continuous Power, HP (kW)	3861 (2880)
US EPA Certification	Tier 2
Cylinders	6
Displacement, in^3/cyl (l/cyl)	2362 (38.7)
Rated Speed, rpm	600
ROM Capital Cost, USD	$1,384,000
Lead Time, months	11

As seen in Table 7, this engine has been certified by the US EPA as Tier 2 and may only be installed if the engine is purchased before 1 January 2016. After that time, this MaK engine may not meet regulatory requirements and the engine is thus not recommended.

MAN

MAN engines are manufactured in Germany. Table 8 shows salient characteristics of the 6 cylinder, 750 rpm version of the marine propulsion engine.

Table 8 MAN engine specifics

Model	6L32-40
Rated Continuous Power, HP (kW)	4021 (3000)
US EPA Certification	Tier 2
Cylinders	6
Displacement, in^3/cyl (l/cyl)	1953 (32)
Rated Speed, rpm	750
ROM Capital Cost, USD	$1,400,000
Lead Time, months	8

As seen in MAN engines are manufactured in Germany. Table 8 shows salient characteristics of the 6 cylinder, 750 rpm version of the marine propulsion engine.

Table 8, this engine has been certified by the US EPA as Tier 2 and may only be installed if the engine is purchased before 1 January 2016. After that time, this MAN engine may not meet regulatory requirements and the engine is thus not recommended.

Wärtsilä

Wärtsilä engines are manufactured in Finland and distributed and serviced locally by Wärtsilä North America with offices in Seattle, Washington. Table 9 shows salient characteristics of the 6 cylinder, 750 rpm version of the marine propulsion engine.

Table 9 Wärtsilä engine specifics

Model	6L32
Rated Continuous Power, HP (kW)	4021 (3000)
US EPA Certification	Tier 2
Cylinders	6
Displacement, in^3/cyl (l/cyl)	1965 (32.2)
Rated Speed, rpm	750
ROM Capital Cost, USD	$1,100,000
Lead Time, months	12

As seen in Wärtsilä engines are manufactured in Finland and distributed and serviced locally by Wärtsilä North America with offices in Seattle, Washington. Table 9 shows salient characteristics of the 6 cylinder, 750 rpm version of the marine propulsion engine.

Table 9, this engine has been certified by the US EPA as Tier 2 and may only be installed if the engine is purchased before 1 January 2016. After that time, this Wärtsilä engine may not meet regulatory requirements and the engine is thus not recommended. The W32 series Wärtsilä engines might be certified to EPA Tier 3 requirement, however this investigation is ongoing.

Recommendation

Based on all the factors described in this report and the Engine Selection Matrix shown in Table 10, Glosten recommends the installation of two EMD 16-710 G7C-T3 engines for the *M/V Matanuska*. This engine shows strong torque characteristics and response over the full operating range, has service technicians and parts distribution in Washington State, meets applicable emissions requirements, and is a familiar engine to the Alaska Marine Highway System fleet.

Table 10 Engine comparison summary and selection matrix

Engine	Total Score	Torque @ 600 HP (ft-lb)	Torque @ 3600 HP (ft-lb)	Fleet Commonality	SFOC (g/kWh)	O & M ($/yr)	Capital Cost ($)	Installation Cost (%)	Response Time, 0% - 100% load (sec)
		10%	*20%*	*10%*	*20%*	*10%*	*10%*	*5%*	*15%*
ABC		7,375	28,602	0	194	1,031,701	817,285	75%	18
EMD		13,276	24,893	1	201	1,026,600	892,000	100%	9.5
GE		[redacted]							
MaK		8,851	19,177	1	184	1,235,471	1,380,000	75%	160
MAN		7,007	26,552	0	186	3,000,000	1,400,000	75%	70
Wartsila		8,113	28,027	1	185	3,388,171	1,100,000	75%	80

Engine Selection Matrix (Normalized score compared to EMD)									
ABC	0.85	0.06	0.23	0.00	0.21	0.10	0.11	0.07	0.08
EMD	1.00	0.10	0.20	0.10	0.20	0.10	0.10	0.05	0.15
GE	0.77	[redacted]							
MaK	0.76	0.07	0.15	0.10	0.22	0.08	0.06	0.07	0.01
MAN	0.67	0.05	0.21	0.00	0.22	0.03	0.06	0.07	0.02
Wartsila	0.80	0.06	0.23	0.10	0.22	0.03	0.08	0.07	0.02

Appendix A Torque Curves