



Agenda Item No. 3

To: Building and Operating Committee/Committee of the Whole
Meeting of January 24, 2008

From: James P. Swindler, Deputy General Manager, Ferry Division
Celia G. Kupersmith, General Manager

Subject: **APPROVE ACTIONS RELATIVE TO FERRY EMISSION STANDARDS
FOR THE NEW HIGH-SPEED REPLACEMENT FERRY VESSEL**

Recommendation

The Building and Operating Committee recommends that the Board of Directors take the following actions with respect to procurement of a new high-speed replacement ferry vessel:

1. Approve installation of Tier 2-20 engines in the new vessel, thus exceeding current federal EPA and state CARB requirements; and
2. Approve testing Biodiesel fuel in the new vessel and preparation of status reports by staff that will address the results of the test and the advisability of expanding the program to all other vessels in the Golden Gate Ferry fleet.

Summary

This report provides information regarding current ferry emission standards (both state and federal); options for propulsion equipment to be considered for the new ferry vessel; and recommendations on what type of engines and clean air technologies should be included in the already authorized competitive negotiation procurement process for the new ferry vessel.

Background

In June 2006 the Board of Directors authorized staff to develop and issue, through the competitive negotiation process permitted under California Public Contract Code Section 20217, a Request for Proposals for the purchase of a high-speed, 499-passenger-capacity vessel as a replacement for one of the existing Spaulding vessels, subject to completion of associated environmental analyses. At this meeting the Board also gave direction that the new ferry meet all environmental requirements including those of the Environmental Protection Agency (EPA) and California Air Resources Board (CARB). Several Board members and the public questioned whether there should be a requirement that the vessel exceed state and federal standards.

In March 2007 the District awarded a contract to Fast Ferry Management (Marty Robbins) of Seattle, WA to develop the bid documents and specifications for the new ferry. Additionally, Mr. Robbins conducted a review of current and pending federal and state emission regulations for ferries. Mr. Robbins also researched available engines and technologies for consideration on the new vessel.

On July 13, 2007, in response to Board questions relating to clean air standards, staff provided a report and presentation to address the many issues and questions. The report is included herewith as Attachment (1) to this report. The July 2007 report addressed, among other things, the need for a third, larger, new high-speed ferry; the growing popularity and increased ridership since the July 2004 Larkspur schedule change; the regular overcrowding of certain weekday morning ferry trips; requirements and current status of federal and state environmental regulations; state of available technologies and costs associated with same. The report also included several options to be considered in development of the specifications and requirements for construction of the new vessel.

STATUS OF STATE AND FEDERAL REGULATIONS

There has been no change in the Federal EPA regulations since the July 13, 2007 Board meeting. The current EPA rules mandate that any vessel built must install a Tier 2 engine. A Tier 2 engine is, from an emission standpoint, the cleanest engine currently available, and is mandated by the EPA.

At the time of the July 13, 2007 Board meeting, the State (CARB) regulation for harborcraft was in draft form, and subject to further public comment and consideration. This draft regulation went far beyond the EPA rule, requiring that the construction of any new ferry vessel exceeding 75 passengers would have to, in addition to the installation of a Tier 2 engine, achieve an additional 85% reduction in emissions. The only way to achieve this requirement is to install Selective Catalytic Recovery (SCR) equipment similar to what is installed on the Vallejo ferry.

Over the past few months CARB has conducted several public hearings and held private meetings with various sectors of the maritime industry including ferry vessel operators. Additionally, CARB staff met with Vallejo ferry staff to view first hand the problems experienced with the installation of SCR equipment on one of their vessels.

In November 2007 the CARB Board adopted the final rule for harborcraft, including ferry vessels. In the final rule, CARB removed the requirement to achieve an 85% reduction in emissions, but instead, requires that vessels constructed (keel laying) after January 2009 must, in addition to installing the Tier 2 engine, use best available control technology (BACT). As explained by CARB staff, until there is a successful demonstration of the SCR technology on a small high-speed ferry vessel, the BACT requirement is more appropriate. CARB staff believes BACT provides more flexibility for operators and regulators to craft solutions that may eventually prove successful in reducing marine emissions. The BACT process, which is included in the newly adopted regulation, requires the ferry owner to propose an emission control system which the Air Resources Board (ARB) executive officer evaluates in comparison

to other BACT determinations previously approved. If there are no previous BACT determinations available for comparison, the executive officer will rely on staff's best engineering judgment to determine if the proposed BACT provides the greatest feasible reduction of diesel PM or NOx.

CURRENTLY AVAILABLE TECHNOLOGY

Selective Catalytic Recovery (SCR) – In 2004 Vallejo (Baylink Ferry) constructed a vessel similar in size to the District's high-speed ferry Del Norte. This vessel was designed and constructed to include SCR equipment. At the July 13, 2007 Board meeting Mr. Robbins presented information indicating that recent inspection revealed the system was not functioning properly. In August 2007 further inspection and analysis determined the system had not been working for quite some time, with the result being increased emissions due primarily to the increased fuel consumption associated with the weight of the additional SCR equipment. It was also determined that the SCR equipment was causing increased exhaust backpressure, resulting in accelerated wear and damage to the main engines. As a result, Vallejo has discontinued use of the SCR equipment and removed certain components to minimize the amount of unnecessary fuel consumption.

At the present time we know of only one other SCR installation on a ferry vessel in the U.S., that being the Staten Island Ferry system. The system was installed on the ferry vessel Alice Austin in 2004 and has seen only limited use. The vessel is used sparingly, operating only several evenings a week on a 30 minute crossing. Because the engines must reach temperature prior to activation of the system, according to operations personnel, the system operates only 15 minutes per crossing, or four hours in one evening. The vessel is 200 feet long, 40 feet wide, with a passenger capacity of 1280, and a service speed of 16 knots.

Presently the Water Emergency Transit Agency (WETA) has two vessels under construction, with an estimated delivery date sometime this fall. The vessels are being constructed with SCR equipment.

Main Engine Technologies - There are basically three engine manufacturers that provide engines for installation on commercial high-speed ferries: Cummins; MTU/Detroit; and Caterpillar. Over the past several years each company has developed engine technology to meet the Tiered system mandated by the EPA. Currently, each manufacturer has, or is developing the Tier 2 technology. At the July 13, 2007 Board meeting staff indicated that discussions were ongoing with MTU/Detroit regarding a Tier 2 minus 20% (Tier 2-20) engine. A Tier 2-20 engine is basically an early version of the Tier 3 engine that will be required in 2014. Since that meeting, MTU/Detroit has informed the District that the Tier 2-20 engines can be made available for our project.

Biodiesel – Red and White Fleet is presently using a B-20 blend on several of their vessels and have reported satisfactory results. Red & White reports no loss of power with the use of B-20, but the vessels spend most of their time operating at low power levels and light duty cycles where such effects would probably not be identifiable.

The table below is a comparison of the Tier 2 and Tier 2-20 engine with and without a 20% blend of Biodiesel. As you can see, the effect on total emissions gets worse with utilization of B20, and presumably any other formulizations of Biodiesel. While emissions of UHC and PM improve marginally with the use of B20, the 2% energy penalty results in higher total fuel burn and a total net increase in harmful emissions.

As part of this project, staff recommends that the District experiment with a lesser percentage of Biodiesel, 2% - 5%. We have confirmed that one California operator, using Tier 2_MTU/Detroit engines, is successfully using a 2% blend.

Comparison Tier 2 and Tier 2-20 Engine With and Without Bio-Diesel

	Tier 2 Engine	Tier 2 Engine w/B20	Tier 2-20 Engine	Tier 2-20 Engine w/B20
Operating Power Level (%)	95	97	84	85
Daily NOx (lb)	457	466	366	373
Daily UHC (lb)	13	11	11	9
Daily PM (lb)	13	12	10	9
Total Daily Emissions (lb)	483	489	387	391
Total Annual Emissions (tons)	63	64	50	51
Annual Fuel Consumed (gals)	483,000	492,000	497,000	507,000

Three Optional Pathways

After substantial review, staff has identified three optional pathways that the District could follow in their new vessel procurement. Details and a table of costs associated with each option are provided below.

Option “A” – Comply with Current EPA and CARB Regulations and Install Tier 2 Engine

- *46 % reduction in emissions versus current vessels
- No significant cost increase in projected vessel capital or operating costs
- Minimal increase in fuel consumption

Option “B” – Exceed Current EPA and CARB Regulations by Installing Tier 2-20 Engine and Experimenting with Biodiesel (2 to 5% mixtures)

- *49 % reduction in emission versus current vessels
- Minimal cost increase in projected vessel operating and capital costs.
- Slight increase in fuel consumption
- Slight increase in vessel weight
- Increase costs in experimenting with Biodiesel (Financial assistance may be available)

Option “C” –Exceed EPA and CARB Regulations by Installing Tier 2 Engine and SCR After-Treatment Equipment

- *64 % reduction in emission versus current vessels

- Significant cost increase in projected vessel capital and operating costs
- Significant increase in fuel consumption
- Increased vessel size and weight
- Larger engine to make required speed
- Conditioned upon negotiation of extended warranties and maintenance agreements
- Increased labor maintenance labor costs

* % of emission reduction is based on assumption of high-speed vessel utilization as follows: new vessel 40%, Mendocino 40%, and Del Norte (back up) 20%. Also assumes Mendocino and Del Norte re-powered with Tier 2 engines.

The three options have significantly different impacts on the long-term operating costs of the District. The following table estimates the yearly increase in costs for each option and increase in costs over the likely life of the engine.

Increased Operating Costs

Item	Option “A” Complies with Current Regulations	Option “B” Exceeds Current Regulations	Option “C” Exceeds Current Regulations and Uses SCR Equipment
Fuel	\$ 75,000 (25,000 gallons)	\$342,000 (114,000 gallons)	\$633,000 (211,000 gallons)
Maintenance/Parts	\$ 15,000	\$ 35,000.00	\$ 141,000
Total	\$ 90,000	\$377,000	\$774,000
Operating Costs Over 10 Years	\$0.9M	\$3.8M	\$7.8M

Staff recommends that the actions outlined in Option “B” be implemented in conjunction with the new vessel procurement. By installing the Tier 2-20 engines, the District will assist in moving the engine technology forward by being an early adopter of this developmental version of the Tier 3 engines required in 2014. Additionally, undertaking a Biodiesel experiment will allow us to test the viability of Biodiesel and its applicability to all vessels in our fleet.

Fiscal Impact

The Ferry Division’s 07/08 capital budget includes \$12 million for this project, with the project being funded 80% by the FTA and 20% by the District. Additional operating costs will be included in future Ferry Division operating budgets.

Attachment



Agenda Item No. 10.A.

To: Board of Directors
Meeting of July 13, 2007

From: James P. Swindler, Deputy General Manager, Ferry Division
Celia G. Kupersmith, General Manager

Subject: **DISCUSSION AND POSSIBLE ACTION REGARDING FERRY EMISSIONS STANDARDS FOR NEW HIGH SPEED PASSENGER FERRY PROCUREMENT**

Summary

This report provides information regarding ferry emissions standards and technologies available to meet current and anticipated standards, as requested by the District's Board of Directors (Board) at the June 23, 2006, Board of Directors meeting. The District's Board has provided clear direction that the new high-speed ferry needs to meet all existing Environmental Protection Agency (EPA) and California Air Resources Board (CARB) clean air standards. The question has been raised by some members of the public and by some members of the District's Board regarding whether the District's new high-speed ferry should be built to a standard that exceeds current state and federal standards. Staff seeks direction from the Board regarding what requirement for emission standards should be included in the Request for Proposal for construction of the new high-speed ferry.

General Background

In July 2004, following the continuing success of high-speed ferry service and in accordance with the *Strategic Plan to Achieve Long-Term Financial Stability*, the District introduced two-vessel, high-speed service for all morning, all midday and most evening peak period Larkspur-San Francisco crossings. This service is provided by two high-speed ferries with no high-speed backup vessel available in case of engine failure or annual dry-docking needs.

Using fast ferries has made it possible for the majority of commute period trips to be 30-minute crossings. The popularity of this high-speed Larkspur ferry service has caused average weekday ridership to grow at an annual rate of 6.4 percent per year since April 2005. As of April 2007, weekday ridership had reached an average of 4,966 passenger trips, approximately 624 more daily riders than in 2004 when many of the commute period trips required a 45-minute crossing. Ridership on the three weekday morning peak departures from Larkspur to San Francisco increased 13.4 percent to nearly 1,200 passenger trips between April 2005 and April 2007.

To meet this growing demand for high-speed ferry service, two morning peak period departures (at 7:10 a.m. and 8:20 a.m.) utilize the 450-passenger M.V. Mendocino and one (at 7:50 a.m.) utilizes the 390-passenger M.V. Del Norte. Despite the recent increase in capacity of the M.V. Del Norte from 325 to 390 passengers, all three peak morning departures experience full passenger loads. In fact, since January 2006, all three trips often operate at capacity with the 7:50 a.m. M.V. Del Norte regularly leaving an average of 10 – 15 passengers to either wait for the next trip or drive to the city. The 7:10 a.m. and 8:20 a.m. departures periodically leaves 5 – 10 passengers behind. Our terminal staff believe these numbers are very conservative as they do not account for the passengers still in the parking lot when the vessel departs.

In June 2006, the District authorized purchase of a new high-speed ferry with an approximate passenger capacity of 499 as a replacement for an existing Spaulding boat, subject to completion of associated environmental analyses. The ferry construction project has a total budget of \$12 million (80 percent FTA, 20 percent District funds). In March 2007, the District's Board authorized contracting with Fast Ferry Management, Inc. (Martin J. Robbins, principal) to assist staff by providing project management and construction oversight for the new ferry. The consultant is required, as part of this project, to conduct analysis and prepare a written report regarding options relative to the vessel's propulsion equipment and available emission reduction technology. It is important to note that Mr. Robbins has significant experience in selection of propulsion of equipment for high-speed ferries and the limited after-treatment technology available to achieve reduction of ferry emissions.

Propulsion Systems and Emission Reduction Technologies

Over the past few years there has been significant focus within the maritime industry and regulatory arena on reducing ferry exhaust emissions. Under direction by the District's Board, staff has closely monitored proposed regulations regarding emissions; the status of development of new, cleaner marine engines; and development of and experience with new technology designed to treat engine exhaust emissions (after-treatment).

Regulations:

Several years ago, the Environmental Protection Agency (EPA) created regulations requiring a reduction in the emission of harmful exhausts from marine engines. As a result, in January 2007, certain engine manufacturers made available engines that meet the new Tier 2 requirement. These engines are cleaner than those installed on our existing vessels. The EPA is currently considering additional regulations that would require even further reduction in marine engine exhaust emissions. It is anticipated that these regulations would require reductions in emissions that can not presently be met with engine technology improvements and therefore, additional methods/equipment would have to be considered. This equipment is commonly referred to as after-treatment. While at present, the EPA has not adopted any further regulations mandating a higher level of emission reductions, the engine manufacturing industry has continued to work on developing further engine improvements that are expected to result in what is known as a Tier 3 engine. Such engines are not available today.

In 2006, the California State Assembly introduced draft legislation requiring that all ferry vessels meet an emission reduction criteria similar to what is required of the San Francisco Regional

Water Transit Authority (WTA), Tier 2 engines plus a combined 85 percent additional reduction in particulate matter (PM) and nitrogen oxide (NOx). This standard can only be met using after-treatment technology. Due in part to a desire to see what comes of the California Air Resources Board (CARB) investigation of this same issue, the bill language was ultimately removed and replaced with language regarding an issue unrelated to the topic of marine emissions. At this time, staff is unaware of any proposed legislation proceeding through the legislative process.

CARB is involved in a rulemaking process regarding ferry emissions that could require installation of a Tier 2 or 3 engine and after-treatment technology to achieve an additional 85 percent reduction in exhaust emission (same as the WTA standard). We anticipate this requirement will be applicable to all newly constructed ferries with a capacity of more than 75 passengers. During a CARB presentation in June 2007, we were informed that this item would be scheduled for consideration by CARB's Board this September. However, the published 2007 CARB rulemaking calendar does not include this item, so it is uncertain at this time when a proposed regulation will be considered by CARB.

Main Engine Technologies:

There are basically three engine manufacturers that provide engines for installation on commercial high speed ferries: Cummins, MTU/Detroit, and Caterpillar. Over the past several years, each company has developed engine technology to meet the tiered system mandated by the EPA. Currently, each manufacturer has, or is developing, the Tier 2 technology. For the proposed new vessel, at a minimum, the District will install a Tier 2 engine, and we are investigating the possibility of a Tier 2 (-20) engine. A Tier 2(-20) engine is basically an early version of the Tier 3 engine that will be required in 2012. Using our existing high speed vessels as a baseline, the new vessel, with installation of either the Tier 2 or Tier 2 (-20%) engine, will reduce emissions by 42 to 45 percent as compared to our current boats.

Please note this year's budget includes funds to replace the existing Tier 0 engines on the M.V. Mendocino with the new, cleaner Tier 2 engines. This project will be funded partially with grant monies specifically made available from the Carl Moyer grant program. There are plans to also replace the M.V. Del Norte engines with a Tier 2 engine in the coming years.

After-Treatment Technology:

To meet the level of emission reduction being discussed by both the EPA and CARB, it is generally accepted that after-treatment technology will be necessary. After-treatment technology requires the installation of additional equipment on the vessel to treat the engine exhaust and reduce the amount of harmful emissions being discharged from the vessel. This after-treatment technology is commonly referred to as Selective Catalytic Recovery (SCR) and the process requires the introduction of a liquid urea to create the necessary chemical reaction. This process is explained in detail in Attachment A.

While this technology has been successfully deployed in industrial and commercial applications, and has seen limited use on large vessels, it is relatively new to the high-speed ferry industry. There are only two known installations on high speed ferry vessels: one in Europe and the other in Vallejo, California. The trial use of the equipment on the vessel in Europe was discontinued

shortly after delivery due to lack of government subsidies. The equipment on the Vallejo vessel has been in operation over two years. A recent inspection by the vessel owner of the Vallejo installation has revealed disappointing results, including concerns that the equipment may be contributing to premature engine wear and failures. The full report covering the Vallejo experience as presented to the Vallejo transit system's General Manager is included in Attachment B. The report recommends indefinite suspension of operation of the after-treatment equipment on the Vallejo vessel. Vallejo transit officials have not yet made a decision regarding this recommendation.

The WTA presently has a contract with a Washington shipyard for construction of two small medium-speed passenger vessels with a passenger capacity of 149, and an estimated speed of 26 knots. The specifications for these two vessels will require a Tier 2 engine with a combined 85 percent reduction in PM and NOx. This requirement dictates the installation of after-treatment (SCR) equipment. The shipyard and equipment manufacturers have agreed to meet this specification and will utilize the SCR technology to achieve the 85 percent reduction. While the SCR equipment itself will be fundamentally similar to that installed on the Vallejo vessel, the arrangement and placement of the equipment in the vessel will be different.

The SCR equipment removes primarily NOx and only a small percentage of PM. The percentage of PM estimated to be removed is less than 5 percent. At the present time we are not aware of any technology suitable for a marine application that captures particulate matter beyond this 5 percent level.

The District presently has particulate matter traps installed on most busses. However this technology was developed and tried for a number of years before it was mandated on busses. During the development and trial period there were many mechanical and maintenance issues, resulting in equipment having to be removed from service until repairs could be made.

In 2001 the District's Ferry Division, in partnership with the Clean Air Corporation and Water Transit Authority (WTA), participated in a demonstration project involving a system called Lubrizol PuriNOx. The intent of the project was to reduce reduce NOx and PM. The results of the demonstration project were inconclusive.

Options for the New Golden Gate Transit Fast Ferry

The following options are offered for discussion and consideration in determining the propulsion/emission requirements to be included in the District's Request for Proposals for procurement of the new high-speed ferry. The options are supported with additional detailed information contained in the attached report:

Option A – Comply with Current EPA Regulations and Install Tier 2 Engine

- 42 percent reduction in emission versus current vessels
- No significant cost increase in projected vessel capital or operating costs
- Minimal increase in fuel consumption
- This option is the current approved plan for the new high-speed ferry

Option B – Build to Meet Potential CARB Regulation (i.e. WTA standard): Install Tier 2 Engine and SCR After-Treatment Equipment

- 62 percent reduction in emission versus current vessels
- Significant cost increase in projected vessel capital costs (\$1.7 million; grant funds for some or most of this cost may be available)
- Increase in fuel consumption (211,000 additional gallons; cost \$633,000 annually)
- Increased vessel size and weight
- Larger engine to make required speed (additional \$200,000; grant funds for some or most of this cost may be available)
- Could negotiate extended warranties and maintenance agreements but anticipate additional costs included up front to address supplier's risk

Option C – Comply with Current EPA Regulations and Install Tier 2 (-20) Engine

- 45 percent reduction in emission versus current vessels
- Minimal cost increase in projected vessel capital costs (\$100,000; grant funds may be available for some or most of this cost)
- Increase in fuel consumption (114,000 additional gallons; cost \$314,000 annually)
- Slight increase in vessel weight
- Conditioned upon commitment of available engine technology

Option D – Defer Construction of New High-Speed Ferry

- No added capacity to address passengers left behind

Option D.1 – Defer Construction of New High-Speed Ferry and Add One A.M. Trip Using Spaulding Vessel

- Increased Operating Costs (\$572,000 annually for additional crew and fuel)
- No reduction in vessel emissions (results in net increase in emissions)
- Increased capacity

Fiscal Impact

Options “B” and “C” will require an increase in both the capital and operating budgets for the proposed new high-speed vessel. Option “D-1” will require an increase in the Ferry Division’s Operating Budget. It is reasonable to assume that 50 to 80 percent of the extra capital costs could be funded by grants but at this time there is no commitment from any granting agency to fund the increased costs. There is no outside funding source for additional operating expenses associated with any option presented. The District’s FY 07/08 Capital Budget includes \$12 million for the ferry vessel replacement project funded 80 percent by the FTA and 20 percent by the District.

Attachments



FAST FERRY MANAGEMENT, INC.

P.O. Box 532

Silverdale, WA 98383

Date: July 9, 2007

To: Golden Gate Bridge, Highway, and Transportation District
Attn: James P. Swindler, Deputy General Manager, Ferry Division

Subject: **Engine Selection & Emissions Analysis Report**
Contract Deliverable (2007-FT-8)

Dear Jim,

The subject report is attached. If I can be of any further assistance in this matter, please let me know.

Sincerely yours,

A handwritten signature in black ink that reads 'M. J. Robbins'. The signature is written in a cursive style with a horizontal line through the middle of the letters.

Martin J. Robbins

Engine Selection & Emissions Analysis Report

This document provides a report to support the District's decision with respect to selection of engines and to assist in determining the goal for emissions reduction for the new high-speed passenger ferry project.

REGULATORY PICTURE

Prior to 1999, marine diesel engines in the United States were unregulated. Beginning in 1999, marine engines became subject to regulation by the United States Environmental Protection Agency (EPA). The EPA initiated a tiered approach depending on the cylinder displacement size and horsepower of the engine. The original rulemaking set up standards for Tier 1 and Tier 2. Unregulated engines are often referred to as Tier 0 engines. Tier 1 came into effect in 2004 followed by the Tier 2 rules taking effect on January 1, 2007. Marine engines are regulated in terms of the following harmful emissions:

- NO_x - oxides of nitrogen
- UHC - unburned hydrocarbons
- CO - carbon monoxide
- PM - particulate matter

Of particular concern are NO_x and PM, as they present the most serious health and environmental risks. Elemental nitrogen (N₂) enters the engine as a constituent of combustion air. NO_x is formed in the cylinder due to the break down of elemental nitrogen in the high temperature and high pressure environment of the diesel engine cylinder. PM is primarily made up of solid carbon particles (both from the fuel itself and its impurities) that is not completely burned into carbon dioxide or carbon monoxide (normal exhaust gases).

Marine engines of the type and size applicable to the new ferry must now meet the EPA Tier 2 standards as of January 1, 2007. The following table summarizes the current and proposed EPA emission limits, units are grams per kilowatt-hour (g/kW-h).

	Tier 1	Tier 2	Tier 3 (proposed)	Tier 4 (proposed)
Engine Model Year	2004	2007	2012	2016
NO _x + UHC	9.80 *	7.20	5.40	1.99
CO	-	5.00	5.00	5.00
PM	-	0.20	0.12	0.04
* - NO _x only				

Currently, there is rulemaking activity for marine diesel engines by both the EPA and the California Air Resources Board (CARB). The EPA has announced its proposed Tier 3 and Tier 4 limits for marine diesel engines as listed above; that rule making process is ongoing. CARB has initiated its own program to control diesel exhaust emissions from most harbor craft operating in California, including ferries.

The proposed CARB rules¹ take EPA rules one step further for new ferries carrying more than 75 passengers, the proposed language states that CARB would require an EPA Tier 2 or Tier 3 engine (whichever is currently applicable) plus combined PM and NOx reduction of 85%. The CARB rulemaking process is set to release Initial Statements of Reason in August 2007 with a 45 day comment period prior to presentation to the Board in September 2007. The draft CARB regulations could take effect on January 1, 2009 for any new ferry delivered after that date.

If the assumption is made that the current EPA and CARB rulemakings are approved and put into force, the District would be obligated to outfit the new ferry with Tier 2 engines and engine after-treatment equipment to achieve a combined 85% reduction in PM and NOx.

TECHNOLOGY

It is generally accepted that the engine manufacturers can take today's Tier 2 engine and achieve the Tier 3 limits through "in-cylinder" technology improvements. It is expected that the cost for this improved emissions performance will come in terms of decreased fuel efficiency and increased engine weight. The industry consensus is that the overall fuel efficiency of any given vessel will decrease by up to 10% when re-powered between tiers.

In order to improve diesel engine emissions from Tier 0 through to Tier 3, the diesel engine manufacturers have employed various technology improvements. Mainly, they have optimized the combustion sequence and timing, and have developed more accurate and precise fuel injection systems. Engines have and will become marginally less fuel efficient and heavier in order to attain the EPA emission levels. The introduction of ultra-low sulfur diesel (ULSD) fuel has dramatically reduced emissions of sulfur oxides (SO_x) from engines but at some loss of engine efficiency (as high as 2%). ULSD use is mandatory in California for ferry operators.

In order to take Tier 3 engines to Tier 4, it is generally acknowledged that engine after treatment equipment will be required. The current thinking is that selective catalytic reduction (SCR) systems and diesel particulate filters (DPF) will be required to achieve the proposed Tier 4 limits.

Any discussion of diesel engine exhaust emissions invariably involves fuel, specifically fuel consumption. Simply stated, the more fuel burned, the more

¹ 13 CCR Section 2299.5

emissions produced. Additionally, the in-cylinder emission reduction technologies have all resulted in higher rates of fuel consumption rates.

CURRENT PICTURE

The District currently operates high-speed ferry service five days per week, with twenty round trips per day, using the M.V. DEL NORTE and M.V. MENDOCINO. The following data is presented based on current operations, later referred to as Option D (do nothing).

	DEL NORTE	MENDOCINO	Total
Engine Make/Model	Detroit Diesel 16V-149 × 4 2 stroke	Cummins KTA50 × 4 4 stroke	Total
Rated Power (kW)	4,773	5,072	
Annual parameters:			
Fuel Consumed (gal)	582,000	547,000	1,129,000
NO _x + UHC (lb)	313,000	153,000	465,000
PM (lb)	11,700	12,400	24,000
CO (lb)	49,000	14,000	63,000
Total Emissions (tons)	187	90	276

It is assumed that the District will eventually repower both vessels with Tier 2 engines using the Carl Moyer program, this would result in higher fuel consumption and lower emissions, estimated as follows:

	DEL NORTE	MENDOCINO	Total
Annual parameters:			
Fuel Consumed (gal)	605,000	613,000	1,218,000
NO _x + UHC (lb)	128,000	130,000	258,000
PM (lb)	3,600	3,600	7,200
CO (lbs)	18,000	18,000	36,000
Total Emissions (tons)	75	76	150
Net Emissions Reduction			46%
Annual Cost per Ton of Emissions Reduced			\$2,640 per ton

OPTIONS FOR THE NEW FERRY

Depending on the final rules coming from EPA and CARB, there are options that the District might be able to consider for the new ferry. Presented are four possible options, each with a brief description and table indicating the effects on costs and emissions.

Option A - Compliance with Current EPA Regulations

Build the new vessel with the EPA required Tier 2 engines along with the eventual re-powering of the current vessels as previously described above. The new ferry will require more powerful engines to carry the increased passenger loading of 499. It is also assumed that the DEL NORTE will be reduced to 20% utilization, and that the MENDOCINO and the new ferry will each handle 40% of the schedule.

Performance is expected to be as follows:

	DEL NORTE	MENDOCINO	NEW FERRY	Total
Annual parameters:				
Fuel Consumed (gal)	242,000	490,000	486,000	1,218,000
NO _x + UHC (lb)	51,000	104,000	103,000	258,000
PM (lb)	1,400	2,900	2,900	7,200
CO (lb)	7,000	14,000	14,000	36,000
Total Emissions (tons)	30	61	60	151
Net Emissions Reduction				46%
Annual Cost per Ton of Emissions Reduced				\$2,665 per ton

Under the proposed EPA regulations, the new ferry would need to upgrade to Tier 3 standards when it is re-powered in 2022; perhaps to Tier 4.

The marine industry is currently advising the EPA that conversion of any existing vessel to Tier 4, with the required after-treatment equipment, is not practical given the very large weight and space impacts of SCR and DPF.

Option B - Compliance with Proposed CARB Regulations

Build the new vessel with the EPA required Tier 2 engines plus after treatment (SCR only) to achieve 85% combined reduction in NOx and PM; along with the re-powering of the current vessels as described above.

Once again, it is assumed that the DEL NORTE will be reduced to 20% utilization, and that the MENDOCINO and the new ferry will each handle 40% of the schedule.

There would be a significant capital cost impact to the project. It is estimated that the 85% after treatment system would add about \$1.7 million dollars to the cost of ferry. Much smaller vessels (149 passengers @ 26 knots) currently under construction by the San Francisco Bay Area Water Transit Authority (WTA) have each incurred a \$1.1 million price premium for 85% after treatment equipment on their \$8.0 million ferries.

Performance is expected to be as follows:

	DEL NORTE	MENDOCINO	NEW FERRY	Total
Annual parameters:				
Fuel Consumed (gal)	242,000	490,000	608,000	1,340,000
Annual After Treatment Operating (\$)			912,000	
Annualized After Treatment Capital ² (\$)			135,000	
NO _x + UHC (lb)	51,000	104,000	19,000	174,000
PM (lb)	1,400	2,900	500	4,800
CO (lb)	7,000	14,000	3,000	24,000
Total Emissions (tons)	30	61	11	102
Net Emissions Reduction				63%
Annual Cost per Ton of Emissions Reduced				\$5,996

Note that under the proposed CARB rules the DEL NORTE and MENDOCINO would not require upgrade beyond Tier 2 until 2022, by which time they will have reached the end of their economic life (25 years for high-speed ferries).

² An economic life of 12.5 is assumed for the after treatment equipment.

Option C - Tier 2-20% Engine

Build the new vessel with developmental Tier 2-20% engines if available. Engine manufacturers are already working to achieve Tier 3. The proposed EPA rules will require Tier 3 by 2012. The manufacturers will be building engines incrementally over the next 4 years to achieve the Tier 3 standards. These developmental engines will require field testing to prove their performance. District staff has learned that Tier 2-20% engines might be ready in time for the new ferry construction project.

Once again, it is assumed that the DEL NORTE will be reduced to 20% utilization, and that the MENDOCINO and the new ferry will each handle 40% of the schedule.

Performance is expected to be as follows:

Annually	DEL NORTE	MENDOCINO	NEW FERRY	TOTAL
Fuel Consumed (gal)	242,000	491,000	511,000	1,243,000
NOx + UHC (lb)	51,000	104,000	86,000	242,000
PM (lb)	1,400	2,900	2,400	6,700
CO (lb)	7,000	14,000	12,000	34,000
Total Emissions (tons)	30	61	50	141
Net Emissions Reduction				49%
Annual Cost per Ton of Emissions Reduced				\$3,149

There would be no capital cost impacts to the project.

Option D - Do Nothing

By taking no action, the following performance is expected based on current operating conditions.

Performance is expected to be as follows:

	DEL NORTE	MENDOCINO	NEW FERRY	Total
Annual parameters:				
Fuel Consumed (gal)	582,000	547,000	n/a	1,129,000
NO _x + UHC (lb)	313,000	153,000	n/a	465,000
PM (lb)	11,700	12,300	n/a	24,000
CO (lb)	49,000	14,000	n/a	63,000
Total Emissions (tons)	187	90	n/a	276
Net Emissions Reduction				0%
Annual Cost per Ton of Emissions Reduced				n/a

OPTIONS SUMMARY

The following tables summarizes the annual parameters for all options for ease of comparison.

	Option A	Option B	Option C	Option D
Fuel Consumed (gal)	1,218,000	1,340,000	1,243,000	1,129,000
Annual After Treatment Operating Cost (\$)	0	912,000	0	0
Annualized After Treatment Capital Cost (\$)	0	135,000	0	0
NO _x + UHC (lb)	258,000	174,000	242,000	465,000
PM (lb)	7,200	4,800	6,700	24,000
CO (lb)	36,000	24,000	34,000	63,000
Total Emissions (tons)	151	102	141	276
Emissions Reduction (%)	46	63	49	0
Annual Total Cost per Ton of Emissions Reduction	\$2,665	\$5,996	\$3,149	n/a
Total Annual Emissions per Passenger (lb)	0.25	0.17	0.24	0.46

Total San Francisco Bay Area annual emissions for NO_x, UHC, PM, and CO are estimated at 4,062 tons per day, or 1,483,000 tons per year. Currently, the fast ferry operations of the District account for 0.0186% of that total. The options listed above would further reduce that contribution by one-half to two-thirds.

According to the National Safety Council³:

One person using mass transit for an entire year, instead of driving to work, can keep an average of 9.1 pounds of hydrocarbons, 62.5 pounds of carbon monoxide, and 4.9 pounds of nitrogen oxides from being discharged into the air.

³ http://www.nsc.org/ehc/mobile/mse_fs.htm

AFTER TREATMENT TECHNOLOGY

“In-cylinder” improvements in emissions performance for diesel engines are nearing a practical end point with the proposed EPA Tier 3 limits. EPA and CARB both agree on that point.

EPA and CARB are counting on after treatment technologies such as SCR and DPF to further reduce emissions, albeit on different time scales.

SCR - systems seek to reduce internal combustion engine exhaust emissions, primarily oxides of nitrogen (NO_x) which are harmful to the environment.

The process occurs due to a chemical reaction involving ammonia (NH_3) and NO_x in the presence of a reduction catalyst. NO_x is reduced to elemental oxygen (O_2) and elemental nitrogen (N_2), both of which are normal constituents of the air we breathe.

The catalyst is made of vanadium pentoxide (V_2O_5) and it is supported on a ceramic structure composed of titanium dioxide (TiO_2) and tungsten oxide (WO).

Liquid urea (non-hazardous, odorless, colorless) is sprayed into the exhaust piping just as it leaves the engine. Compressed air is used to atomize the urea as it is injected into the exhaust stream. The urea immediately breaks down to ammonia which enters a mixing duct with engine exhaust gases. The ammonia and NO_x , having been mixed, then enter the SCR catalyst reactor. As the ammonia/ NO_x mixture flows across the catalyst bed in the reactor, the desired chemical reactions occur.

The reaction is temperature dependent and it will occur naturally at temperatures near 1000°C ; albeit very slowly. However, in the presence of the V_2O_5 catalyst the desired reactions will occur much more efficiently; and at temperatures between 160°C and 450°C (a more manageable and safer temperature range).

The effectiveness of the reaction is based on several factors, primarily the amount of ammonia introduced, the degree of gaseous mixing, exhaust gas temperature and flow rate, and the amount of catalyst surface area presented in the reactor.

Due to the heat generated in the catalyst bed, there is some collateral reduction in the amount of UHC and PM contained in the exhaust stream. These pollutants are reduced, but not to any great degree.

The following pictures show the mixing duct and the catalyst reactor for the 50% NO_x reduction rated system for SOLANO, prior to installation.

SOLANO MIXING DUCTS - ONE DUCT PER ENGINE



For judging scale, that is a letter sized piece of paper in the foreground, the ducts are 10 feet long and weigh 340 pounds each.

SOLANO SCR CATALYST REACTOR - ONE PER ENGINE

For judging scale, the flange on the SCR catalyst reactor pictured above is about 24 inches in diameter, each reactor weighs 3,070 pounds.

The EPA is putting Tier 4 out to the year 2016 for engines of the size and type required by the District. This allows some time for the technology to develop and come of age. They cite parallels for this development path and timeline within the on-highway diesel industry. Time will tell if those parallels can be achieved on the marine engine segment where the number of units are orders of magnitude smaller.

CARB is looking to rapidly accelerate on the EPA plan; mandating Tier 4 type after treatment emissions levels for all new ferries upon approval of their proposed regulations, as early as 2008.

Marine diesel after treatment, as a technology, remains unproven. There are only two high-speed passenger ferries in the world with after treatment installed. M.S. PRINSEN operating in Oslo, Norway and SOLANO operated by the City of Vallejo. Both ferries have urea based SCR systems installed, PRINSEN is sized at 85% reduction of NO_x, while SOLANO is sized for 50% reduction. There are no high-speed passenger ferries in operation with DPFs.

PRINSEN was tested for two weeks following construction in 2002 and then the system was shut down by the operator because the government subsidy had been exhausted.

The SOLANO has been in operation since July 2004 with mixed results. The SCR system has been plagued by a number of maintenance and repair issues. Complicating matters, there have been delays in receiving repair parts and services from the overseas manufacturer. Overall the system has been functional only 15% of the time. Just recently the SOLANO started to experience engine cylinder high temperature alarms. After investigation it was determined that engine cylinders are experiencing unusual wear to the point of premature failure. In troubleshooting the engine problems the SCR reactor was opened and inspected for the first time since the beginning of service. All catalyst bricks within the reactor were found to be severely damaged. Investigations into the premature engine wear and the failure of the catalyst are ongoing. However, at this time they cannot rule out the possibility that the SCR has caused the premature wear and damage to the engine.

The consensus at this time is that the SOLANO's SCR system has been unreliable, that it is not a durable design, and that it may be causing premature wear of the engine.

SCR systems add considerable weight to the vessel, and take up considerable volume in the machinery spaces. Due to their weight, they also drive up the total power required to achieve a given service speed. The result is higher fuel costs in addition to the capital costs, costs for urea, catalyst replacement, and system maintenance.

DPF - or diesel particulate filters are designed to trap PM before it can exit the exhaust pipe. These soot particles are then burned off the filter media in a step known as regeneration. The carbon in the soot is burned to either carbon dioxide or carbon monoxide on the filter media and these gases are then able to pass through the filter and exit to the atmosphere.

Application of DPF on marine engines is virtually non-existent at this time. There is talk of a test installation for one of the vessels that serves the Alcatraz route in the San Francisco Bay Area. DPF applications on bus fleets has proven to be problematic.

It is estimated that the impact of a DPF on a high-speed ferry, in terms of weight, volume, fuel consumption, and costs, will approach that of the SCR systems described above.

EPA is counting on fairly rapid technology advances over the next several years in order for the industry to achieve Tier 4 by 2016. With marine application of SCR technology clearly in its infancy, and DPF even less advanced, there is a lot of work to do. In recent testimony to the EPA in Seattle, the after treatment manufacturers indicated that the 2016 timeline was appropriate given the state of the technology and the rate of advancement.

CARB is pushing for even quicker results with their pending regulation. They are hoping that the vessels currently under construction for the WTA meet their stated goals of 85% emissions reduction. Completion of those vessels is over a year away, and it will be some time after that before the reliability, durability, and cost performance of the WTA systems can be judged. Clearly this is a situation where regulations might be too far in front of reliable and demonstrated technology.

Both agencies are considering some mechanism for reporting or monitoring marine diesel exhaust emission performance; as well as enforcement strategies with the possibility of fines or other civil penalties for non-compliance.

Qualitative comparison of impacts on the new ferry for the options presented:

Impact	Option A	Option B	Option C	Option D
Energy Consumption	↑	↑↑↑	↑↑	↔
Operating Cost Impacts	↑	↑↑↑	↑	↔
Capital Cost Impacts	↔	↑↑↑	↔	↔
Overall Vessel Reliability	↔	↓	↔	↔
Vessel Maintainability	↔	↓↓	↔	↔
Vessel Weight Impact	↔	↓↓	↔	↔
Wake Production	↔	↓↓	↔	↔
Emissions Profile	↑	↑↑↑	↑	↔

KEY ASSUMPTIONS

Key assumptions made for purposes of completing this study are as follows:

- All cost values are in 2007 dollars, no inflation is assumed
- Diesel fuel price of \$3.00 per gallon
- Urea price of \$1.75 per gallon
- SCR catalyst and maintenance costs are liner per SOLANO results
- Daily high-speed ridership on Larkspur route is 4,600 passengers
- Calculated emissions reductions are based on the current and proposed EPA limits; it is certain that the actual performance of Tier 2 & 3 engines will exceed the published limits
- For DEL NORTE and MENDOCINO, power was taken as total rated power per factory data sheets, with specific fuel consumption adjusted to match observed (actual) fuel consumption recorded by the District
- DEL NORTE and MENDOCINO engines have never been tested, emissions values are per the factory data sheets, or based on testing of similar vessels
- Generator sets have been ignored as their total contribution to emissions and fuel consumption is negligible compared to the main propulsion engines ... note that generators sets for the new vessel must meet EPA and CARB rules

Questions, concerns, or comment ...please contact me as follows:

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END OF REPORT



REPORT

Date: June 30, 2007 {July 9, 2007 update}

Subject: SCR Project – M/V SOLANO

This report serves to document the status and results of the Selective Catalytic Reduction (SCR) project on the City of Vallejo's vessel M/V SOLANO; from inception to the current day.

What is SCR?

SCR systems seek to reduce internal combustion engine exhaust emissions, primarily oxides of nitrogen (NO_x) which are harmful to the environment and to human health.

The process occurs due to a chemical reaction involving ammonia (NH_3) and NO_x in the presence of a reduction catalyst. NO_x is reduced to elemental oxygen (O_2) and elemental nitrogen (N_2), both of which are normal constituents of the air we breathe.

The catalyst is made of vanadium pentoxide (V_2O_5) and it is supported on a ceramic structure composed of titanium dioxide (TiO_2) and tungsten oxide (WO).

Liquid urea (non-hazardous, odorless, colorless) is sprayed into the exhaust piping just as it leaves the engine. Compressed air is used to atomize the urea as it is injected into the exhaust stream. The urea immediately breaks down to ammonia which enters a mixing duct with engine exhaust gases. The ammonia and NO_x , having been mixed, then enter the SCR catalyst reactor. As the ammonia/ NO_x mixture flows across the catalyst bed in the reactor, the desired chemical reactions occur.

The reaction is temperature dependent and it will occur naturally at temperatures near 1000°C ; albeit very slowly. However, in the presence of the V_2O_5 catalyst the desired reactions will occur much more efficiently; and at temperatures between 160°C and 450°C (a more manageable and safer temperature range).

The effectiveness of the reaction is based on several factors, primarily the amount of ammonia introduced, the degree of gaseous mixing, exhaust gas temperature and flow rate, and the amount of catalyst surface area presented in the reactor.

Due to the heat generated in the catalyst bed, there is some collateral reduction in the amount of UHC and PM contained in the exhaust stream. These pollutants are reduced, but not to any great degree.

Project Background

SOLANO was procured and delivered to the City of Vallejo as a low-emissions ferry in August 2004.

The vessel was designed by Advanced Multihull Designs (AMD) of Sydney, Australia and built by Dakota Creek Industries, Inc. (DCI) of Anacortes, WA. The main engines and the SCR system were supplied by Pacific Power Products of Kent, WA with main engines manufactured by MTU and the SCR system manufactured by Steuler, both German companies.

SCR technology was chosen because it was the only diesel exhaust after treatment system installed on a high-speed passenger ferry. In fact there was only one such vessel in the world at that time, the M/S PRINSEN operating in Oslo, Norway. PRINSEN also had MTU engines with a Steuler SCR system. The PRINSEN project was underwritten by the Norwegian government. The vessel was operated successfully for a few weeks following delivery and the level of NO_x was proven to meet the stated goals of 0.6 g/kW-h. Shortly thereafter the owner of the vessel shut the system down as the government subsidy had been exhausted. Even with this very limited marine industry experience with SCR, the City of Vallejo committed to the SCR option in the shipbuilding contract and the order was placed.

AMD and DCI were tasked with getting as much NO_x performance out of the vessel within the constraints of the project budget, and within the constraints of the current fleet of Vallejo ferries. From the naval architecture, marine engineering, and shipbuilding aspect, the incorporation of SCR represented a significant design challenge.

SCR technology is proven and mature in stationary application. It was unproven in mobile application, even more so in a marine mobile environment. Steuler had taken the stationary technology and converted it to mobile technology as best they could given the limited number of applications, only one (PRINSEN) to be exact.

The SCR system for SOLANO was maximized to reduce NO_x by 50%. This was the practical limit given the weight carrying and space limitations of the vessel. Even with the fore knowledge of the system, the design task was arduous. SCR systems are very heavy and take up a great deal of volume. With high-speed ferry designs, weight is extremely critical, as is the location of the weight. Added weight high in a vessel leads to vessel stability concerns. Added weight in the stern of the vessel leads to adverse trim which results in higher fuel consumption and increased wake wash production. Space is also at a premium in fast ferry design.

The installed weight of the SCR systems in SOLANO totaled 8,206 pounds or about 4 tonnes. Due to the weight of the SCR, SOLANO had to be equipped with larger, more

powerful engines than her otherwise identical sister vessels. These larger engines added another 5 tonnes of weight to the vessel. Due to the larger engines, the fuel tanks had to be expanded to accommodate the higher fuel consumption. The larger tanks and the weight of the extra fuel added another 4 tonnes. In total we were looking at 13 additional tonnes of vessel weight, this represented about 10% of total vessel weight. So the potential impact was very large.

AMD and DCI went to great lengths to reduce vessel weight in other areas, and were able to reduce the net effect on overall lightship displacement to 4 tonnes (basically the weight of the SCR system alone). But they were unable to compensate for the placement of the weight to any significant degree. In the end the vessel's longitudinal center of gravity shifted 3 feet aft to the stern and this caused the vessel to trim significantly, increasing fuel consumption and increasing the wake wash generated.

Capital Cost Impacts

The SCR system added \$472,594 to the cost of the \$11,300,000 vessel, or 4.2% of the total cost of construction. This is the cost of the SCR equipment only, and does not cover the cost of the larger engines or other vessel systems.

Operating Cost Impacts

Beyond the capital cost investment, the SCR was known to have ongoing operational costs for urea, catalyst replacement, and system maintenance. Additionally, there was extra fuel consumption to carry the SCR system, fuel the larger and heavier engines, and to overcome the stern trim. It was estimated that this would amount to about 300 gallons of fuel per operating day.

As the SOLANO entered service in August 2004 the operating cost impact was judged to be \$723 per day as follows:

- Five round trips per day, 60 gallons per round trip, \$1.75 per gallon = \$525
- 100 gallons of urea per day, \$1.46 per gallon = \$146
- Catalyst use projected at 18 bricks every three years = \$52

Initially, there was no estimate made for the level of maintenance required to keep the system operational, as there was no operational history available to base an estimate on.

Operations Since Inception – System Reliability

The system has been plagued by minor problems since it went into service. The problem list includes:

- The air compressors that serve to atomize the urea and clear the lance on system shut down have failed three times, each time requiring replacement with a new compressor.
- Twice, the compressors have had to be removed and cleaned following back-flow of urea into the compressor.

- There have been numerous leaks in the urea piping and tubing inside the dosing panels.
- Urea filter plugging has been a constant problem. The filter has been plugged with crystalline deposits, impurities, and other small debris.
- We have had the injection lance plug up on ten different occasions.
- Twice the flow meter controller has failed.
- The urea gear pump head has failed.
- The urea storage tanks developed cracks and leaks requiring the tanks to be removed and re-welded.
- Upon initial use, the controlling software would often lock-up the system with nuisance alarm codes.
- Batteries have failed and required replacement.

Contributing to the operational problems, there have been significant delays in receiving technical assistance, replacement parts, and service from Steuler in Germany. They have limited technical resources; one field technician covers the globe.

After working through the early software problems, the system seemed to work well with limited involvement in terms of crew operating time. The urea tanks were replenished daily and the system was simply turned on every morning, and turned off at the end of daily operations. However, the problems listed above began to occur on a regular basis. If it wasn't one thing it was another; or a long wait on parts or assistance from Germany.

In order to determine the level of system availability (or reliability) one can look at the amount of urea used as compared to total vessel hours of operation. If urea is not being consumed, then the system is not operational.

Since inception in August 2004 the urea use history is as follows:

Date	Urea Purchased (gallons)	
8/12/04	550	Initial supply
9/28/04	4,875	First delivery
4/29/05	4,931	Second delivery
6/13/06	-1,056	Sold back to vendor for another user
7/13/06	5,000	Third delivery
Net Purchased	14,300	
- in the tank	-3,457	As of 6/30/07
Total Urea Used	10,843	

Given that urea usage was programmed to be 10 gallons per hour based on our route and service profile, it can be concluded that the system has been operational for about 1,100 hours. SOLANO had 9,971 total vessel hours of service as of today.

Assuming a generous 2,500 hour allowance for initial sea trials, deadhead trips, idling at the beginning and end of each day, post repair sea trials where the SCR would not have been turned on, and times when maintenance priorities were elsewhere, the system has been operational no more than 15% of the available time.

Based on these facts, the system as designed, furnished, and installed on SOLANO has not been proven reliable by any definition.

A note in terms of emissions economics is worth making. Originally, it was anticipated that the cost of NO_x emissions reduction would approach \$7,300 per ton considering full time operation and 50% NO_x reduction. While we achieved 50% NO_x reduction on trials, due to down time since then, the actual cost of NO_x reduction is on the order of \$60,000 per ton of NO_x.¹

Recent Developments

In the past several months we have noted a negative trend with respect to temperatures in individual cylinders on the main engines. We finally reached an alarm condition on two of the cylinders in early June.

Upon examination, we found broken rings, severely worn rings, and badly scuffed and scored cylinder liner walls. Each of these cylinder kits were replaced with new. Meanwhile we are carefully monitoring other cylinders for temperature performance.

In trying to determine the possible causes for the negative trends in cylinder temperatures, it was decided to inspect the SCR reactor. The SCR reactor is a sealed steel box that contains 27 catalyst bricks. The operating instructions from the outset were to open the reactor after 3 years or 12,000 hours of operation, and perform a routine catalyst replacement.

Under the routine catalyst replacement, the leading row of 9 catalyst bricks are removed, the next two rows are moved forward, and a row of 9 new catalyst bricks are inserted in the aft most position. The cycle was then to be repeated every 12,000 hours or 3 years.

We had planned on opening and inspecting the reactor later this summer as we approached the three year point.

Steuler then advised us to wait until 12,000 hours, rather than open at three years. They indicated that operating hours, rather than calendar time, was the governing criteria. But given the engine temperature problems, and catalyst temperatures that also appeared to be rising nearer their alarm points, we decided to open and inspect the port reactor. The port engine had experienced the cylinder failures; so that reactor was opened for inspection.

¹ The U.S. Environmental Protection Agency has forecast a NO_x reduction cost of \$580 per ton by the year 2030.

Inside the port catalyst reactor we found that all 27 bricks had been severely damaged and their supporting structures had been completely compromised. Representative pictures are presented below.



There is evidence of salt damage, thermal damage, and possibly vibration or physical shock damage to all of the bricks. Samples have been sent to a laboratory in Germany for forensic analysis and we are awaiting the results.

In descriptive terms, many bricks in the aft most row, and all bricks on the bottom of the reactor have been exposed to salt water and salt air. In these areas the catalyst has simply been eaten away or has disintegrated.

All bricks are composed of four catalyst units, surrounded by a blanket of fiberglass insulation, then wrapped in a stainless steel shell with cross bracing. All of the stainless steel shells were either wasted or corroded to the point of failure. The fiberglass insulation has largely turned to a hard, concrete-like consistency. The stainless steel cross bracing, where it had come loose from the shell, had obviously been working on the end of the catalyst units causing physical wear and fretting. Some bricks were cracked nearly in half, and several were severely fractured. Other bricks showed signs of thermoplastic deformation (as if melting had occurred).

Just before catalyst removal the system was operational and was showing an after catalyst temperature of 895-925°F, where the alarm point is 950°F. The differential pressure across the catalyst was running at 10 mbar, and we were advised that differential pressure should be < 8 mbar.

All bricks were removed, a new gasket was installed on the reactor door, and the system was closed back up. We only have 18 spare bricks in stock, enough for the first scheduled catalyst maintenance. So we do not have enough bricks to fully load the reactor. Since ammonia slip will occur if the catalyst reactor is not full of bricks, and since we do not yet have a definitive cause for the failures, we have left the reactor empty for the time being.

We have not inspected the starboard reactor yet, but we expect to find the same conditions.

In 2004 the catalyst bricks sold for \$856 each. To replace all 54 blocks would amount to ~\$70,000 including shipping and labor and accounting for some inflation and foreign exchange rate effects. But without a failure analysis and a fix, we would be throwing good money after bad.

Based on these facts and discoveries, the catalyst system as designed, furnished, and installed on SOLANO has not been proven durable by any definition.

Main Engine Effects

Beyond the problems described above with SCR system reliability and durability, it appears that the SCR may be having a serious detrimental effect on the SOLANO main engines.

Going into the SCR project we were optimistic because we were told that the system would have zero effect on the main engine and the power produced. We have confirmed that the power output of the engine was not diminished in any way by the SCR. However, the large back pressure penalty on the engines might be leading us towards

accelerated engine wear and tear, shorter time between overhaul, increased vessel operating costs, and reduced engine reliability.

MTU specifications limit back pressure on the 16V4000 engine to 51 mbar. Upon initial sea trials the back pressure was recorded at 40.5 mbar, near the upper limit.

Also of concern are the negative trends being seen with combined exhaust temperatures from both the A-bank and B-bank of cylinders. On initial sea trials these temperatures ranged from 613°C to 623°C. Just recently we were recording combined exhaust temperatures up to 730°C. Also, sea trials data was recorded at 2000 RPM, we have since lowered full throttle to 1945 RPM. Clearly the engines are seeing much more internal heat even at lower power levels.

High back pressures and elevated in-cylinder temperatures certainly make an engine work harder, and certainly lead to increased rates of wear.

After removal of the damaged catalyst on the port side, we were able to do some more data gathering, with a unique opportunity to compare the port engine without SCR, to the starboard engine with SCR. The significant findings are as follows:

Parameter	Unit	Port Engine without SCR	Stbd Engine with SCR "on"	Stbd Engine with SCR "off"
Back pressure	mbar	13.5	47.4	47.4
Average combined exhaust temperature	°C	683	719	693
Fuel consumption	l/m	8.66	9.04	9.03
Engine Speed	rpm	1945	1945	1945

On initial sea trials, the data was as follows:

Parameter	Unit	Port Engine with SCR	Stbd Engine with SCR
Back pressure	mbar	40.6	30.5
Average combined exhaust temperature	°C	618	624
Fuel consumption	l/m	9.49	9.63
Engine Speed	rpm	2000	2000

Additionally, we have checked fuel consumption over the past several weeks and we see that the consumption of the port main engine has dropped by ~ 90 gallons per day since the catalyst was removed.

What is obvious to us after looking at the data, is that both engines are running hotter than they were on initial sea trials. You would expect the opposite for an engine that is only about half way to overhaul, with some loosening of the engine after break in. Even though we have reduced power demand, the cylinder temperatures and combined exhaust temperatures have risen significantly.

The back pressure on the starboard main engine has increased from 30.5 mbar to 47.4 mbar, and it appears to be approaching the 51 mbar limit. There was also a dramatic reduction in back pressure after the port catalyst was emptied. The port main engine now appears to have become more fuel efficient with the removal of back pressure.

Also of note is the average combined exhaust temperatures in the starboard main engine with the SCR turned “off” and “on”. The temperature differential is 26°C.

Next week we will be renting a boroscope so we can inspect the remaining 14 cylinders on the port main engine and all 16 cylinders on the starboard main engine for signs of advanced wear and damage. Additionally, we are attempting to arrange for NOx testing on the starboard SCR unit, in order to document its performance prior to any further actions. A vibration analysis of the catalyst reactor will also be undertaken to rule out any harmful ship generated vibration that could be causing catalyst damage. Results of all tests and inspections will be included in a follow up report, as will any analysis we receive on the damaged catalyst units.

Summary & Recommendation

Based on these facts and discoveries noted in this report:

1. The SCR system as designed, furnished, and installed on SOLANO has not been proven to be either durable or reliable, by any reasonable definition.
2. The SCR system may be causing accelerated wear and damage to the main engines, thereby reducing the time to overhaul, decreasing engine and vessel reliability, and increasing maintenance and operating costs.
3. The SCR system may incur a fuel penalty greater than originally estimated when system operating costs were first estimated. The penalty was originally estimated at 300 gallons per day, it may be as much as 480 gallons per day given recent findings.

Pending receipt of reports on the condition of the main engines and the forensic analysis of the failed catalyst units, I would recommend the following to the City of Vallejo:

1. That the SCR system on the starboard main engine be shut down (already done).
2. That the catalyst bricks be removed from the starboard SCR unit.
3. That operation of the SCR systems be suspended indefinitely pending investigations to determine the cause of the catalyst failure.

4. If a fix to the catalyst failure is identified, that the entire SCR program undergo a financial re-analysis to determine its true operating cost, and the true cost of NO_x reduction. The analysis should include provision for accelerated main engine wear if further investigations support initial indications.
5. That operation of the SCR system be suspended permanently if acceptable fixes cannot be identified, or if financial analysis proves the system to be too expensive in terms of cost per ton of NO_x.

It is important to note that the City of Vallejo entered into this experimental testing of marine diesel exhaust emissions reduction equipment with full knowledge that the technology was unproven in this application. In my opinion, fault should not be assigned to the naval architect, the shipyard, the suppliers and manufacturers of the equipment, to the operators, or to any other party involved in the project. This report is being made public in its preliminary form so that other agencies may be better informed of the results, no matter how disappointing they may appear to be at this time.

Further, it is hoped that the industry will learn from the ultimate lessons of the SOLANO and that the technology for application of diesel exhaust after treatment in the marine industry will move forward towards the ultimate goal of reduced emissions and environmental and public health benefit.

The City of Vallejo and Fast Ferry Management, Inc. welcome all feedback, questions, and dialogue on the contents of this report and on the SOLANO SCR Project.

This report is watermarked “Preliminary” pending further investigations, analyses, and reports. Updated reports will be issued as this additional information becomes available. Finally, I would like to thank and acknowledge all the persons who helped me assemble and present this information.

End of Report

Respectfully submitted:



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City and County of San Francisco



GERARDO C. SANDOVAL
Board of Supervisors

June 5, 2007

John J. Moylan
President
Golden Gate Bridge Highway and Transportation District
P.O. Box 9000, Presidio Station
San Francisco, CA 94129-0601

Dear President Moylan,

I am enclosing a resolution regarding the District's upcoming purchase of a new ferry. As you know, there has been significant interest by many members of the board regarding the emission systems of this new ferry. To that end, seven Directors have sponsored the enclosed resolution.

I respectfully request that this resolution be heard by the entire board sitting as a committee of the whole. I hope to bring a number of technical experts, some from outside the Bay Area, to provide testimony. By calendaring this item at a full board meeting, it is my hope that the entire board will be able to benefit from their input as we make a decision on this important matter.

I will give you a call in the coming days to discuss this matter with you and to discuss any questions you may have.

Sincerely,

A handwritten signature in cursive script that reads "Gerardo Sandoval".

Gerardo Sandoval

cc: Celia G. Kupersmith, General Manager

(Golden Gate Bridge District Clean Ferry Resolution)

[Resolution requiring that the Bridge District's new high-speed passenger ferry meet an emissions standard that is 85 percent more stringent than current EPA standards.]

WHEREAS, In 2006, the Golden Gate Bridge, Highway and Transportation District (Bridge District) approved the purchase of a new \$12 million high-speed diesel passenger ferry; and,

WHEREAS, Ferries and harborcraft emit five tons of deadly diesel particulate matter and 10 tons of smog-forming nitrogen-oxides per day in California; and

WHEREAS, The California Air Resources Board (CARB) declared diesel particulate matter a toxic air contaminant and California has listed diesel exhaust as a carcinogen since 1990; and,

WHEREAS, Without additional Bridge District action, the high-speed ferry will only meet obsolete emission standards that do not adequately protect public health, the environment and Bay Area air quality; and

WHEREAS, In 2002, CARB determined that high-speed ferry engines must be 85 percent cleaner than EPA standards in order to prevent increases in emissions per passenger compared to driving; and,

WHEREAS, In 2003, Senate Bill 915 required the San Francisco Bay Area Water Transit Authority (WTA) to meet CARB's emissions standard for all its new vessels to protect public health, the environment and Bay Area air quality and;

WHEREAS, Two new WTA fast diesel ferries meeting the standard are under contract for construction and are scheduled for delivery in 2008 and 2009; and,

WHEREAS, The California Air Resources Board is proposing that all new ferries in California built after 2009 meet the WTA standard or better; and,

WHEREAS, The EPA is proposing that all new commercial marine engines meet an even stronger standard of 90 percent below EPA Tier II standards for particulate matter and 80 percent below EPA Tier II standards for nitrogen oxides beginning in 2014; and,

WHEREAS, If the Bridge District does not require the new ferry to meet the CARB standard, it will very likely be building the last dirty diesel fast-ferry in California; and

WHEREAS, With a useful life that can exceed 20 years, the Bridge District Ferry will affect public health, the environment and Bay Area air quality for decades to come; now, therefore, be it

RESOLVED, That the Board of Directors of the Golden Gate Bridge, Highway and Transportation District finds that the negative impact of dirty diesel ferries on public health, the

environment and Bay Area air quality are substantial and necessitate action by the Bridge District to mitigate those impacts; and, be it

FURTHER RESOLVED, That the Board of Directors of the Golden Gate Bridge, Highway and Transportation District finds that requiring that the Bridge District's new high-speed ferry meet the CARB proposed standard for new high-speed ferries will minimize the ferry's impacts on public health, the environment and Bay Area Air Quality; and be it

FURTHER RESOLVED, That the Board of Directors of the Golden Gate Bridge Highway and Transportation District hereby directs the Ferry Division to require that the Request for Proposals for the new high-speed passenger diesel ferry mandate that the main engines meet an air emissions standard that is 85 percent stronger than EPA Tier II standards for nitrogen oxides and diesel particulate matter (the CARB standard); and, be it

FURTHER RESOLVED, That the Board of Directors directs the Ferry Division to investigate the feasibility of purchasing a high-speed ferry that meets the EPA's Tier IV standards proposed for 2014 and that the Ferry Division report back to the Board with their findings.