Exhaust Gas Cleaning Systems Selection Guide

Prepared for
Ship Operations Cooperative Program (SOCP)
Ellicott City, MD

File No. 10047.01
22 February 2011
Rev. A

U.S. Department of Transportation

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SOCP®

THE GLOSTEN ASSOCIATES
Consulting Engineers Serving the Marine Community

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The guidance of SOCP member Susan Hayman of Foss Maritime was invaluable. Johnny Eliasson of ABS performed a technical review of the Guide. Paul Smith, Richard Strong, Darren Monzingo, and Sean Caughlan of The Glosten Associates provided input and performed technical review.

It is the intent of SOCP to update this Guide annually. Corrections, suggestions for additional content, and installation experiences provided by web at www.socp.us or by email to programadmin@socp.us will be considered for these updates.

Revision History

Section	Rev	Description	Date	Approved
All	—	Initial release.	12 January 2011	KJR
Cover	A	Added DOT, MARAD, SOCP Logos.	22 February 2011	KJR
2.5.3	A	Reworded "local regulatory issue" to "potential area of concern."	22 February 2011	KJR
6	A	Added Non OGV Discussion	22 February 2011	KJR

Executive Summary

As of 2015, ship operators that trade in emissions control areas (ECAs) will be required to burn fuel with less than 0.1% sulfur content. A ship operator may meet this requirement by burning high-sulfur fuel at sea, and then "switching" to low-sulfur fuel within the ECA. Other ship operators may choose to reduce operational efforts by "converting" such that they always burn low-sulfur diesel fuel oil, or utilize natural gas that has almost no sulfur content.

Alternatively, international convention allows a ship operator to burn high-sulfur diesel fuel if using an exhaust gas cleaning system (EGCS) that can reach an equivalent level of emission reductions. These systems "scrub" most of the sulfur, and some amount of particulate, out of the exhaust gas after the high-sulfur fuel is burned.

This Guide has been developed to assist members of the Ship Operations Cooperative Program (SOCP) in determining their emissions requirements, calculating potential cost savings, and understanding the integration and operational challenges of various EGCS technologies. Each ship operator will need to consider the discussions for and against each EGCS presented herein. With the coming deadline of 2015, ship operators considering this option should conduct an individual analysis, and consider a prototype installation in the near future.

	FUEL OIL SWITCHING	CONVERSION TO DISTILLATE ONLY	CONVERSION TO NATURAL GAS	EXHAUST GAS CLEANING SYSTEM
EMISSIONS CONTROL AREA OPERATIONS	Burn Low-Sulfur Fuel	Burn Distillate	Burn Natural Gas	Burn High-Sulfur Fuel Scrubber ON
NON-CONTROLLED AREA OPERATIONS	Burn High-Sulfur Fuel	Burn Distillate	Burn Natural Gas	Burn High-Sulfur Fuel Scrubber OFF
ADVANTAGES	Low Cost Fuel in Non-Controlled Areas	Simplified Fuel & Waste Stream Operations	Low Cost Fuel in All Areas, Clean Burning	Low Fuel Cost in All Areas
CHALLENGES	High Cost Fuel in ECA, & Risks Inherent with Fuel Switching	High Fuel Cost	Impractical for Many Ships, Complex Gas Handling Logistics & Equipment	Complex Operations, High Capital Cost, & Waste Stream/ Chemical Management

Figure 1. Sulfur Emissions Control Strategies

Discussion for EGCS

The cost of 0.1% distillate fuel oil has historically been 50% higher than higher sulfur marine grade residual fuel oils. An analysis of three ship types, each of which operated at least partially within an ECA, predicts net present values between $5M and $20M, and internal rates of return between 20% and 53%. This assumes operations from 2015 through 2025, and an 8% fuel escalation rate. If fuel prices were to escalate at a rate of 11% annually, the net present value would increase by almost 50%. These cost savings are so significant that some ship operators may find installing an EGCS a competitive necessity.

Discussion against EGCS

Most systems are still in their prototype development phase, and therefore carry with them technical risks. Even assuming early technical issues are overcome, the ongoing impact of these large and complex devices may include: heavy fuel oil heating, purifying, and waste stream management; treatment and waste chemical handling and storage; approximate doubling of the engine stack size to accommodate scrubber units; weight and stability issues; and additional engineering staff to run the machinery and monitoring equipment. Also, it is not yet clear if wet scrubbers can remove fine particulates to an equivalent level of reduction as is achieved by switching to low sulfur fuel oil. While there is no current requirement for particulate removal, the United States Environmental Protection Agency (EPA) published discussions have opened this possibility.

EGCS Ship Candidates

In general the ship candidates for engaging in this dialogue will meet the following criteria:

- New and existing ships built before International Maritime Organization (IMO) Tier III NOx requirements (Pre-2016 for USCG Category 3 Ships), and
- The ship burns at least 4,000 metric tons of fuel oil annually within an ECA, for a period of at least six years starting in 2015, and
- The ship passes a technical survey ensuring that an EGCS can be integrated with ship arrangements, stability, and operations. For closed loop and dry chemical systems, chemical supply chains are confirmed.

Ships that must comply with the IMO Tier III NOx requirements may not be able to install “wet” scrubber style EGCS. These ships will require advanced systems that process NOx and sulfur emissions, and possibly fine particulates.

Section 1 Introduction

1.1 Sulfur Limit Requirements

In certain geographic areas, environmental regulations require that ship operators burn low-sulfur fuel to directly limit sulfur-oxide emissions. A secondary, but important consideration, is that these measures are expected to indirectly reduce particulate matter emissions. As an alternative to utilizing low-sulfur fuel, MARPOL Annex VI recognizes exhaust gas cleaning systems (EGCS) provided they provide reductions in sulfur emissions at least as effective as that obtained by using low-sulfur fuel.

The geographic scope of these requirements is a patch-work that includes International Maritime Organization (IMO) designated emissions control areas (ECAs), European Union (EU) designated port areas, and a California State designated coastal zone. Each of these programs has its own phased implementation schedule, but all reach a fuel quality limit of 0.1% sulfur on or before 1 January 2015.

ECAs currently in force include the Black Sea and Baltic Sea, and will expand to add the North American zone, extending approximately 200 nautical miles offshore, in 2012. Zones for Puerto Rico and U.S. Virgin Islands have been accepted, and submittals are being prepared for Korea, Japan, and Singapore. Eventually, the ECA scope may include all coastal areas of the world. The area outside of ECAs is subject to world-wide limits set by IMO. The current world-wide sulfur limit of 4.5% is more generous than typical fuel quality which averages 2.7% sulfur by weight. This limit changes, in principal, to a 3.5% sulfur limit in 2012. This limit changes, in practice, to a world-wide sulfur limit of 0.5% in either 2020 or 2025 depending on a fuel availability review to be conducted in the interim.

1.2 Sulfur Limit Approaches

Ship operators have several options for complying with the low-sulfur fuel requirements:

- Fuel Conversion. Convert all fuel storage tanks, fuel piping systems, and combustion equipment for compatibility with low-sulfur fuel. The ship will then only burn low-sulfur fuel. This might be distillate diesel fuel oil, or natural gas.
- Fuel Switching. Install a secondary low-sulfur fuel storage and piping system. Convert combustion equipment for compatibility for dual (low- and high-sulfur) fuel. The ship will then burn low-sulfur fuel when operating inside an ECA, and high sulfur fuel when outside ECAs.
- Exhaust Gas Cleaning System (EGCS). Install an EGCS to scrub sulfur oxides that result from burning high-sulfur fuel when operating inside an ECA.

The term “distillate” is used in this report to refer to light, refined diesel fuel with a sulfur content of 0.5% or less. This fuel is called marine gas oil (MGO) in industry, and ISO DMA. Marine diesel oil (MDO), ISO DMB, although inclusive of some residual content is also considered “distillate” provided sulfur contents are below 0.5%.

The term “residual” is used to refer to the lesser refined heavy fuel oils, which have current have sulfur contents on average of 2.7%. Industrial names for the residual or heavy fuel oil (HFO) diesel grades are IFO180 and IFO380, correspondingly ISO RME25 and ISO RMG35.

1.3 Issues Addressed by This Guide

This Guide has been developed to assist members of the Ship Operators Cooperative Program (SOCP) in determining if an EGCS is a practical, lower-cost solution for their fleet. Specifically, the Guide addresses key issues as follows:

- Regulatory Requirements. ***"What am I required to do?"*** The Guide will provide a basic overview of the regulatory requirements, including phase-in dates and fuel sulfur requirements. The requirements for an EGCS will be outlined. The impact of nitrogen oxides (NOx) and particulate matter (PM) requirements on an EGCS will be discussed.
- Life-Cycle Cost. ***"How much fuel cost savings can be realized from an EGCS?"*** The Guide will identify the life-cycle cost of several ECGS technologies for a Transpacific Containership, Alaska to Puget Sound Containership, and a U.S. West Coast Tankship. These vessel type/route pairs were selected to demonstrate the variability in life cycle costs. Additionally, the evaluation provides a base-line cost if these vessels did not use scrubbers, but rather just switched from residual to distillate.
- Scrubbing Technology Options. ***"Which EGCS technology will work for my fleet?"*** The Guide will identify the efficiencies and challenges of the EGCS technologies in adequately removing sulfur and particulate from the exhaust stream. The challenges can significantly limit an operator's technology options. For example, open-loop systems depends on the alkalinity of ambient seawater, which for low-salinity locations can increase the demand for washwater volume to the point where a system may not be practical. Closed loop systems solve the low alkalinity challenge with the addition of a caustic solution, but at a significant increase in expense and logistics. Additionally, scrubbing systems may either hinder or enhance the ship's ability to control other emissions, such as NOx.
- Operations and Maintenance Practicality. ***"Can an EGCS be practically integrated with ship operations?"*** The Guide considers the practicality of the various scrubber systems. This practicality covers maintenance requirements, the practicality of fitting the unit into the machinery space, impact on engine performance, and the ability to integrate the system into ship operations and machinery.
- Discussion. Finally a discussion is provided that pulls together the analysis for the ship operator.

The Appendix provides a technology supplier survey summary including: state of technology development, efficacy results, environmental impact evaluations, physical plant size, integration efforts, and life-cycle costs. The results of this survey can serve as an initial assessment tool for operators that want to further explore EGCS for their fleet.

The manufacturer's of these systems have formed the Exhaust Gas Cleaning Systems Association (http://www.egcsa.com/). The association is a resource for keeping current on system promotions and industry provided information: "Member companies of the Exhaust Gas Cleaning Systems Association are involved in the development, design and final installed configuration and design approval and acceptance of turnkey exhaust gas cleaning systems to meet the current and future emissions regulations of IMO and where applicable additional regulations introduced by regional and national authorities."

Section 2 Sulfur and Other Emissions Requirements and Guidelines

"What am I required to do?"

This section guides ship operators in identifying applicable air emissions requirements, while focusing on opportunities to utilize exhaust gas cleaning systems (EGCS) for compliance with sulfur emissions.

Recent regulatory changes have created continuously evolving and increasingly stringent emission standards. Engine manufacturers are required to significantly reduce air emissions for both new and remanufactured engines. Lower sulfur fuel and reduced sulfur emissions regulations are currently in effect and further reductions are planned in the coming years.

In general, any ship operating in an ECA will have to either burn low-sulfur fuel or utilize an EGCS. The ship operator is also burdened to comply with NOx emissions requirements. In general, all EGCS reviewed herein are compatible with IMO Tier I and Tier II NOx solutions. Ships built in 2016 or later will need to meet IMO Tier III NOx requirements, which may not be compatible with the "wet" scrubber solutions reviewed.

2.1 Applicability

Emission regulations are largely dependent on the vessel registry and operational area. The following describes the specific requirement applicable to vessels based on their specific registry and operating area.

2.1.1 International

Ship's that operate on international voyages are generally subject to the agreements of the IMO, as detailed in Annex VI of the International Convention for the Prevention of Pollution from Ships (MARPOL). These requirements are comprehensive including requirements for low sulfur fuel or sulfur scrubbing, particulate matter and nitrogen oxide levels, and hydrocarbon management. In addition, significant recordkeeping and certifications are required.

Flag State is a general term referring to the administration where a ship is registered. Flag States that are party to Annex VI are required to enforce the annex within the international ocean going fleet that they administer. In some cases, such as the United States, the Flag State may have additional requirements.

Port State is a general term referring to an administration that controls a port(s) where ships registered by other administrations may call. Port States that are party to Annex VI have the right to board commercial ships arriving from international voyages to determine compliance with the Annex. In general, the Port State will review documentation in accordance with the Annex, and perform a visual inspection of any installed equipment.

There are numerous exemptions and exceptions from Annex VI. Ship operators considering such exemptions and exceptions should perform a detailed analysis of the Annex, and gain acceptance from their Flag State prior to implementing a strategy. In general, exemptions include: vessels under 400 gross tons (international), diesel engines less than 130 kW output, technology research trials, emergency equipment, emergency situations, military and government vessels, emissions from sea-bed mineral exploration. There are also time phased exemptions for older ships, specifically for engines manufactured prior to 1990. Additionally, there are exclusions based on geographical considerations such as transport on the US/Canada Great Lakes where regional agreements are more appropriate.

This Guide does not address ozone depleting substances, volatile organic compounds, shipboard incineration or various exemptions and exceptions in depth.

2.1.2 Emissions Control Areas (ECAs)

The International Maritime Organization defines two sets of emissions and fuel quality requirements within Annex VI. Vessels operating within an Emissions Control Areas (ECAs) are required to meet reduced emissions standards and burn lower sulfur fuels. Vessels operating outside of these ECAs are required to meet a second set of lesser requirements applicable at all remaining locations.

ECA geographic scope currently in force includes the Black Sea and Baltic Sea, and will expand to add the North American zone, extending approximately 200 nautical miles offshore, in 2012. Zones for Puerto Rico and U.S. Virgin Islands have been accepted, and submittals are being prepared for Korea, Japan, and Singapore. Eventually, the ECA scope may include all coastal areas of the world. The area outside of ECA zones is subject to world-wide limits set by IMO.

2.1.3 Federal – United States

Federal regulation in the United States applies to all vessels flagged or registered in the United States. In addition, the U.S. has the authority and has stated that it will enforce IMO Annex VI on all U.S. and foreign vessels operating in U.S. waters, as per the Act to Prevent Pollution from Ships. U.S. regulation of air emissions is dictated by the U.S. Environmental Protection Agency. As such, rather than regulating by the international standard of engine speed, diesel powered compression engines are broken into three categories designated by the engine cylinder volume.

Category 3 vessels, those with an engine of cylinder displacements above 30 liters, are required to meet equivalent standards to MARPOL Annex VI. In addition, the U.S. is finalizing standards for Category 3 engine to control hydrocarbons (HC) and carbon monoxide (CO), as well as monitoring of particulate matter (PM) emissions. Control of Emissions From New Marine Compression-Ignition Engines at or Above 30 Liters per Cylinder (40 CFR Parts 80, 85, 86, et al.) took effect in June 2010. This rule is equivalent to the IMO Annex VI that governs ocean going vessels (OGV). Like Annex VI, it includes fuel standards targeting sulfur emissions and a phased in schedule for NOx reductions. EPA has indicated two important clarifications to the rules governing OGVs:

- Category 1 and 2 engines on Category 3 vessels can be certified as meeting Annex VI instead of gaining EPA certification.
- OGVs that are Category 1 or 2 vessels and operate offshore extensively, can comply with Annex VI as an alternate to meeting EPA designated tier requirements.

Category 1 and 2 vessels, those with cylinder displacements below 30 liters, that are not OGVs are required to meet the more stringent EPA 2008 Final Rule.

2.1.4 Regional

Ships are also subject to regional requirements depending on their operating location. Most regional requirements are driven by demands particular to the people living in those areas, and in some cases topography that results in the acute impact of air emissions on local population health. The Los Angeles basin is a primary example of regional requirements, where air quality is poor, population density is high, and the public is politically engaged on environmental issues.

Regional requirements are the most likely to change in a short timeframe. Such changes provide significant challenges to ship operators that are making air emissions abatement decisions. As such, the ship operator must understand the requirements of various port locations at which they are likely to call. The programs reviewed in this Guide include:

- EU Ports. The European Union port locations require either the switching to low sulfur fuels or the use of sulfur scrubbers while operating in ports or inland waterways.
- California Coastal Zone. The State of California requires the use of low sulfur fuel while operating within its 24 nautical mile coastal zone. California does not specifically allow scrubbers as an alternative to burning low sulfur fuels. There are a few options for scrubber use that must be reviewed on a case-by-case basis. Also, it is the intent of California to sunset the state program once the North American ECA comes into effect.
- Port of Long Beach. The Port of Long Beach has a stated goal to provide electrical infrastructure for shore-side power (cold-ironing) at 100% of container terminals.

2.2 NOx Focused Tier Requirements

The International Maritime Organization and the Environmental Protection Agency have implemented emissions standards in order to reduce emissions from all engines. A tier system has been adopted in an effort to phase in lower emission engines as early as possible, while setting a long term goal to significantly reducing emissions using an after-treatment technology.

Currently, new engines in vessels subject to Annex VI are required to meet Tier I emissions levels. Tier II engines will be required in 2011 as an interim solution to reduce emissions until after-treatment based Tier III engines are phased-in in 2014.

New engines in U.S. flagged category 1 and 2 vessels are required by EPA to meet Tier 2 emissions levels. Tier 3 engines will be phased-in in 2012 as an interim solution to reduce emissions until after-treatment based Tier 4 engines are phased-in in 2014.

The IMO and EPA have different rules regarding major refits and engine remanufacturing. IMO requires vessels built prior to 2000 to meet Tier I emissions levels. Vessels built in 2000 or later must meet the current standard if possible. The EPA requires engines over 600 kW to reduce their NO_x by 25%, except for Tier 3 engines. EPA has set limits of 2.0 and 5.0 grams per kilowatt-hour for HC and CO respectively.

IMO and EPA define various requirements based on vessel build date, engine model year, engine power, and displacement. The emission regulations are summarized below in Tables 4 through 6.

Wet EGCS impede the use of advanced SCR systems by cooling the exhaust stream, wetting the gas stream, and increasing backpressure on the engine. As such, the below tables highlight cases where an SCR may be required to meet NOx requirements.

Table 2. Vessel Emissions Requirements, International & Domestic (EPA Category 3)

Registry	Operational Area	Ship / Engine Particulars						Requirement
		Build Date	Gross Tons	LOA (m)	Total (kW)	Power (kW)	Bore (liters)	
All	International	All Vessels						Annex VI Sulfur Limits
All	International	Jan-00 to Dec-10	>400			>130		Annex VI Tier I
All	International	Built after Dec-10	>400			>130		Annex VI Tier II
All	ECA	Built after Dec-15	>400	>24	>750	>130		Annex VI Tier III
US	Domestic	All Vessels				All	>30	Per Annex VI

Table 3. Vessel Emissions Requirements, Domestic (EPA Category 1 & 2)

Registry	Operational Area	Ship / Engine Particulars			Requirement
		Engine Model Year	Power (kW)	Bore (liters)	
US	Domestic	All Vessels			EPA Sulfur Limits
US	Domestic	Jan-04 + engines	>37	>2.5	EPA Tier I = Annex VI Tier I
US	Domestic	Jan-04 + engines	>37	<2.5	EPA Tier 2
US	Domestic	Jan-07 + engines	>37	2.5-30	EPA Tier 2
US	Domestic	Jan-12 + engines	75-3700	<0.9 & 3.5-7	EPA Tier 3
US	Domestic	Jan-13 + engines	75-3700	0.9-1.2 & 2.5-3.5	EPA Tier 3
US	Domestic	Jan-14 + engines	75-3700	1.2-2.5	EPA Tier 3
US	Domestic	Jan-13 + engines	>3700	7-15	EPA Tier 3
US	Domestic	Jan-14 + engines	>3700	15-30	EPA Tier 3
US	Domestic	Jan-14 + engines	>2000	15-30	EPA Tier 4
US	Domestic	Jan-16 + engines	1400-2000	<30	EPA Tier 4
US	Domestic	Jan-17 + engines	600-1400	<30	EPA Tier 4

Table 4. IMO Major Conversion / Remanufactured Engine Tier Requirements

Registry	Operational Area	Ship / Engine Particulars			Requirement
		Build Date	Gross Tons	Major Conversion / Remanufacture Date	
All	International	before Jan-00	>400	Any	Annex VI Tier I
All	International	after Dec-99	>400	Jan-00 to Dec-10	Annex VI Tier I
All	International	after Dec-99	>400	after Dec-10	Annex VI Tier II
All	ECA	after Dec-99	>400	after Dec-15	Annex VI Tier III

Table 5. EPA Major Conversion / Remanufactured Engine Tier Requirements

Registry	Operational Area	Engine Particulars: EPA Tier	Power (kW)	Remanufacture Date	Requirement
US	Domestic	Tier 0	>600	after Jan-00	Tier 0+ (25% NO_x Reduction)
US	Domestic	Tier 1	>600	after Jan-00	Tier 1+ (25% NO_x Reduction)
US	Domestic	Tier 2	>600	after Jan-13	Tier 2+ (25% NO_x Reduction)
US	Domestic	Tier 3	>600	Any	Tier 3

2.2.1 IMO Annex VI NOx Details

Regulation 13 of IMO Annex VI applies to non-emergency marine diesel engines with an output of more than 130 kW installed or substantially modified on or after 1 January 2000. NO_x limitations for these engines are tiered as indicated below, where n = rated engine speed. The Regulation includes numerous exceptions, including engines only used in an emergency and in minerals exploration. Figure 2 and Table 6 present the IMO Annex VI Tier NO_x requirements.

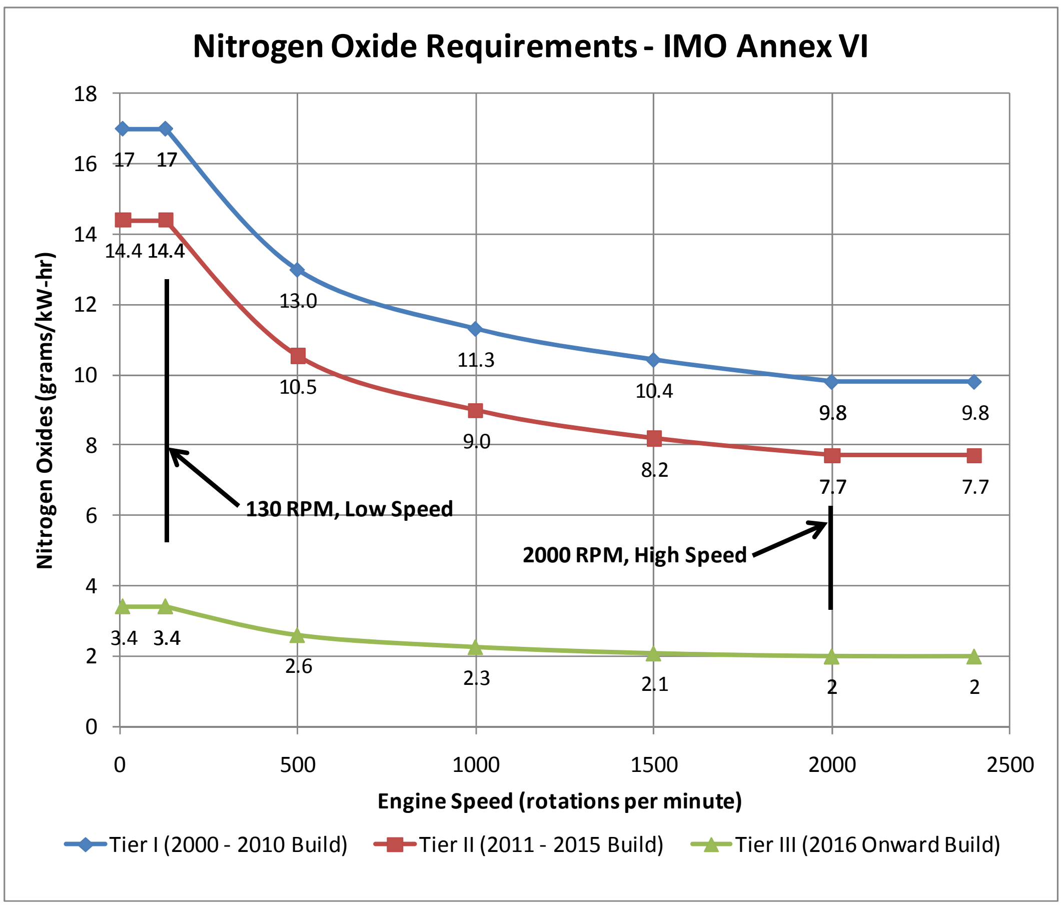

Figure 2. IMO Annex VI Tier NO_x Requirements

Table 6. IMO Annex VI Tier NOx Requirements

	Rated Speed		
	Less than 130 RPM	131 Through 2,000 RPM	Greater than 2,000 RPM
Construction Date	(g/kW-hr)	(g/kW-hr)	(g/kW-hr)
Tier I. 2000 - 2010	17	45 * n^-0.2	9.8
Tier II. 2011 - 2015	14.4	44 * n^-0.23	7.7
Tier III. 2016 Onward	3.4	9 * n^-0.2	2

2.2.2 EPA Category 1 and 2 Tier Details

The EPA marine engine emissions are regulated by a number of different rules, each contributing to the current four tier rating system. Emission regulations vary by power, cylinder displacement, and model year.

In general, Tier 1 requirements are similar to the IMO Annex VI Tier I requirements. Tier 2 and Tier 3 regulation incrementally reduce emissions with the intent that manufacturers can meet the requirements through modifications to piston rings, cylinder walls, timing, and fuel management. This is similar to the intent of IMO Annex VI Tier II requirements.

EPA Tier 4 emissions limits will require engines to use after-treatment devices similar to the IMO Annex VI Tier III requirements. The EPA Tier 4 standard is very similar to the IMO Annex VI Tier III.

Specific EPA emission requirements including NOx, HC, and PM limits can be found in 40 CFR Parts 9 and 85.

2.3 Sulfur Requirements

The EGCS market is being driven by regulatory requirements to reduce ship emissions of sulfur oxides. Ships have the option of either using a low sulfur fuel oil or scrubbing their exhaust gas to an equivalent sulfur level. The following table summarizes the low sulfur phase-in dates specified in each of the presented regulations.

Table 7. Low Sulfur Phase-In Dates

	Category 3 Ships				
Starting Year (Jan 1st)	Oceans	Emission Control Areas	EU Ports	California Coastal	Cat. 1 & 2 Ships
2010	4.5%	1.0%	0.1%	0.5% *	0.0500%
2012	3.5%	1.0%	0.1%	0.1%	0.0015%
2015	3.5%	0.1%	0.1%	0.1%	0.0015%
2020 (2025) **	0.5%	0.1%	0.1%	0.1%	0.0015%

*0.5% Marine Gas Oil, or 0.1% Marine Diesel Oil

**Implementation of Oceans limit at 0.5% Sulfur subject to review in 2018

2.3.1 MARPOL Annex VI, 2008

Oceans: The current marine bunker fuel sulfur limit of 4.5% is reduced to 3.5% in 2012. A further reduction to 0.5% will be reviewed in 2018, with implementation options of 2020 or

2025. There is considerable debate as to whether the 0.5% requirement will be met with distillate or residual fuel. This report assumes that desulfurization of residual fuel will be the more common approach.

Emissions Control Areas: The current marine bunker fuel sulfur limit of 1.0% is further reduced to 0.1% in 2015. To practically achieve 0.1% sulfur, use of distillate is required.

2.3.2 EU Ports (Directive 2005/33/EC of the European Parliament and of the Council)

Marine bunker fuel sulfur limits apply to inland waterway vessels and ships at berth. "At berth" effectively limits the requirement to auxiliary loads while dockside or at anchor. The current 1.5% limit applies to passenger vessels, and vessels operating in the Baltic and North Seas. January 2010 limits all vessels to 0.1%, effectively requiring a distillate fuel.

2.3.3 California Coastal (California Air Resources Board)

Current marine bunker fuel options for ocean going vessels (OGVs) are either marine gas oil (DMA) limited to 1.5% sulfur, or marine diesel oil (DMB) limited to 0.5% sulfur (see asterisk in above table). These grades of distillate fuels are expected to reduce particulate matter significantly in exhaust emissions. January 2012 allows use of either of these distillate fuels, but with a limit of 0.1% sulfur. Category 1 and 2 vessels are limited to 15 ppm sulfur fuel (0.0015%).

2.3.4 US – EPA Category 1 and 2 Engine Vessels

With the implementation of higher Tiers (3 and 4) of regulation for Category 1 and 2 engines, the EPA has mandated the supply chain to distribute lower sulfur content in fuel. As of 2010, all marine fuel is required to contain 1,000 ppm (0.1000%) of sulfur or less. Then in 2012, locomotive and marine fuel is required to be ULSD, or less than 15 ppm (0.0015%) of sulfur. EPA has indicated two important clarifications to the rules governing U.S. Flagged ocean going vessels (OGVs):

- Category 1 and 2 engines on Category 3 vessels can be certified as meeting Annex VI instead of gaining EPA certification.
- OGVs that are Category 1 or 2 vessels and operate offshore extensively, can comply with Annex VI as an alternate to meeting EPA designated tier requirements.

2.4 Exhaust Gas Cleaning System Use

The IMO and EPA both recognize Exhaust Gas Cleaning Systems (EGCS) as acceptable alternatives to low sulfur fuels.

The *IMO 2008 Guidelines for Exhaust Gas Cleaning Systems* (Guidelines) specifies the process for testing, certification, and verification for the use of exhaust gas cleaning systems (ECGS). The Guidelines provide specific requirements for measuring of the sulfur content in the exhaust gas and monitoring wash water discharge quality, including pH changes and contaminant levels. This regulation is continuing to evolve as technology providers gain application experience.

Compliance with IMO sulfur reduction requirements options are detailed in the Guidelines and termed Scheme A – Type Approval, and Scheme B – Continuous Emissions Monitoring (CEM). The Scheme A approach demands a significant testing and approval process resulting in a Type Approval. The Scheme B approach requires the use of sophisticated emissions monitoring equipment. Such a monitoring system however, although to perhaps a somewhat lower standard, will still be required for Scheme A systems.

EPA provides guidance in its Vessel General Permit program regarding wash water requirements, and follows the IMO Guidelines. However, the EPA has instituted a particulate matter testing program for Category 3 engines, and may in the future define PM requirements related to the use of EGCS.

2.5 Uncertainty with EGCS Use

There are a number of sources for uncertainty that must be understood before selecting an EGCS. These include technology compatibility among both current and future required equipment technology. Additionally, future regulatory changes both on sulfur, NO_x and PM will affect the practicality of implementing an EGCS.

Scrubber suppliers use different designs, and have different water and power requirements. As such, the ship operator should study the engineering details of several providers before making a selection decision.

2.5.1 Nitrogen Oxide (NOx) Requirements

Ship operators must consider requirements for the abatement of NOx when selecting a suitable sulfur abatement strategy. In general, sulfur scrubbers are compatible with NOx abatement strategies, such as engine tuning, that target currently enforced IMO Tier I/II and EPA Tier 1/2/3 emission limit. This strategy is compatible as it does not significantly impact engine backpressure that is important to EGCS.

However, some sulfur scrubbers are not compatible with NOx abatement strategies, such as selective catalytic reduction (SCR), that target the IMO Tier III and EPA Tier 4 NOx requirements that phase-in starting in 2016. SCRs work best with hot, dry, low sulfur exhaust streams. Also, the combined EGCS and SCR use will require fan use to avoid excessive backpressure on the engines. As such, NOx requirements will not significantly affect the adoption of sulfur scrubbers until 2016, when more advanced NOx abatement technologies will be required.

2.5.2 Particulate Matter Requirements

EPA is currently in a program that is evaluating the efficiency of PM10 and PM2.5 reduction resulting from diesel combustion of low sulfur fuels. It is possible that a PM limit will be added to EGCS requirements. There is uncertainty as to the efficacy of EGCS in the removal of particulate matter, in particular PM2.5.

2.5.3 Wash Water

Wash water discharge impacts local water quality, and as such will remain a potential area of concern. It is possible that local regulations will develop, or that local environmental concerns will be voiced over wash water discharges in certain areas. This creates uncertainty for the use of open loop scrubbers in certain environmentally sensitive areas.

The monitoring of wash water, as per IMO guidance, includes polycyclic aromatic hydrocarbons (PAH) and turbidity. These instruments require significant effort to maintain and keep in calibration.

Table 8. Regulatory Compliance Overview

	Compliance Options			
	Low Sulfur Fuels	**Engine Modifications**	**Sulfur Scrubbers**	**Advanced Technologies**
Sulfur Regulations				
1.5% S	A	C	A	B
0.5% S	A	C	A	B
0.1% S	A	C	A	B
Particulate Matter				
PM 2.5	B	C	C	B
PM 10	B	B	B	B
Nitrogen Oxides				
Tier I / Tier 1	C	B	C	B
Tier II / Tier 2 & 3	C	B	C	B
Tier III/ Tier 4	C	C	D	B

Key: *A - Full Solution, B - Varies by Technology, Possible Full Solution*
C - Typically Not a Solution but Likely Compatible with Other Solutions
D - Typically Not a Solution and Likely Not Compatible with Other Solutions

Nitrogen oxide Tiers I, II, and III are IMO standards. Tiers 1, 2, 3, and 4 are EPA standards.

Section 3 Life Cycle Cost Analysis

“How much fuel cost savings can be realized from an EGCS?”

Exhaust gas cleaning systems (EGCSs) offer potential fuel cost savings for ships that operate in emissions control areas (ECAs). Although California and EU Ports currently require significantly low sulfur levels in marine fuel, widespread implementation takes place in 2015 when 0.1% sulfur “distillate” fuel, or an EGCS, becomes mandatory. Potential cost saving is the product of fuel consumed in an ECA and the cost differential between distillate and residual fuel. This savings is then reduced by EGCS capital and operating expenses, including crew, maintenance and repair, consumed chemicals, and machinery loads.

$$\begin{aligned}&Fuel\ Cost\ Savings\\&\quad = (ECA\ Fuel\ Consumption * \ Distillate\ Cost\ Differential)\\&\quad - (EGCS\ Capital\ and\ Operating\ Expenses)\end{aligned}$$

This section provides life cycle cost analysis (LCCA) examples designed to inform the ship operator of the key variables that impact life cycle cost, and key uncertainties that will have a substantial impact on potential projects budget. It is envisioned that the ship operator will set-up a customized LCCA for their own ship or fleet. This analysis is broken into the following parts:

- Baseline. Three ship/route combinations are analyzed to highlight the impacts of quantity of fuel consumed in an ECA. One baseline ship is used for the remaining analysis.
- Technology cost differences. Four scrubber technologies are analyzed to review the impact of capital and operating expenses on life cycle.
- Uncertainty and Sensitivity. Factors that a ship operator can neither predict nor reliably control are reviewed. The baseline ship is then used to demonstrate analysis sensitivity to both uncertain factors, and those the ship operator can control.

3.1 Baseline

A baseline life cycle cost analysis is provided in Table 9 for three ship/route pairs. This side-by-side analysis estimates different capital expenses for installing a similar EGCS on each ship due to differences in propulsion plant sizes. The annual fuel consumption within an ECA for each ship is a function of ship propulsion, ship service, and cargo loads, as well as the ship’s route and ports of call.

The remainder of the key variables are consistent for each ship/route pair. This includes predicted fuel cost differentials for distillate, inflation and labor rates, and EGCS operating expenses.

Table 9. Life Cycle Cost Analysis, Baseline for Three Ship/Route Pairs

	Ship/Route Pair	Containership Transpacific	Containership Alaska to Puget Sound	Tankship US West Coast
	Scrubber Type	**Open Loop**	**Open Loop**	**Open Loop**
VARIABLES - CONTROLLED				
Investment Terms				
Life Cycle	*(# of Years)*	10	10	10
Analysis Date (Today)	*(Year)*	2011	2011	2011
Scrubber Installation Date	*(Year)*	2014	2014	2014
Discount Rate	*(%)*	10.0%	10.0%	10.0%
Capital Expense for Scrubber				
Equipment (Today)	*(USD/One Time)*	$5,260,000	$5,060,000	$3,960,000
Engineering/Design	*(% Equip Cost)*	7.0%	7.0%	7.0%
Training/Documents	*(% Equip Cost)*	2.0%	2.0%	2.0%
Install/Commission	*(% Equip Cost)*	50.0%	50.0%	50.0%
Operating Expense - Annual				
ECA Fuel Consumption	*(MT/Annual)*	6,212	9,636	10,840
Chemical Consumption	*(% of Fuel Cost)*	0.0%	0.0%	0.0%
Scrubber Parasitic Loads	*(% of Fuel Cost)*	2.0%	2.0%	2.0%
Distillate Calorie Correction	*(% of Fuel Cost)*	4.0%	4.0%	4.0%
HFO Process and Heating	*(% of Fuel Cost)*	0.8%	0.8%	0.8%
Operating Engineer (Today)	*(USD/Annual)*	$292,000	$292,000	$292,000
Operating Engineer	*(% of Position)*	50.0%	50.0%	50.0%
M&R Equipment	*(% Equip Cost/Annual)*	4.0%	4.0%	4.0%
Variables - Uncertain				
Fuel Differential (Today)	*(USD/MT)*	$255.50	$255.50	$255.50
Fuel/Chemical Escalation Rate	*(% - Annual for Op Period)*	8.0%	8.0%	8.0%
Personnel Inflation Rate	*(% - Annual for Op Period)*	3.0%	3.0%	3.0%
Equipment Inflation Rate	*(% - Annual for Op Period)*	3.3%	3.3%	3.3%
Analysis Results - Overview (Nearest $1,000)				
Capital Cost	*(USD - Year Zero Dollars)*	(9,219,000)	(8,868,000)	(6,941,000)
Expenses - Year One	*(USD - Year One Dollars)*	(551,000)	(623,000)	(601,000)
Fuel Savings - Year One	*(USD - Year One Dollars)*	2,159,000	3,350,000	3,768,000
Net Present Value	*(USD - 2011 Dollars)*	4,851,000	14,562,000	20,110,000
Internal Rate of Return	*(%)*	20%	36%	53%

3.1.1 Analysis Results

The analysis demonstrates that the quantity of fuel consumed within an ECA is the key driver of the potential savings through the project life cycle. Capital equipment cost is also important as a one-time expense that extends the investment payback period.

The net present value for all three pairs is positive, ranging from approximately five to twenty million in U.S. dollars, with the higher value corresponding to the higher in ECA fuel consumption.

The internal rate of return (IRR) ranges from 20% to 53%, with the highest return corresponding to the highest ECA fuel consumption. Each ship operator will need to set the minimum rate of return for themselves.

Assumptions and annual calculations to support the tables in this section may be found in the Appendix.

3.1.2 Vessel/Route Combinations

Three vessel/route combinations were selected to demonstrate the impact of fuel consumption within an ECA on life cycle cost.

Transpacific containership. This 4,000 TEU ship transits between Shanghai, Los Angeles, and Oakland in a round trip of 25 days at 23 knots. It operates a 36 megawatt propulsion plant at 30.2 megawatts to maintain speed. A combined 3,000 kilowatt ship's service plant typically runs at 1,200 kilowatts, increasing to 2,000 kilowatts while in port. Annual fuel consumption estimated at 35,000 metric tons, with 6,200 in an ECA. This assumes that Shanghai will be an ECA by 2015.

Containership Puget Sound to Alaska. This 2,000 TEU ship transits between Tacoma and Anchorage in a round trip of 7 days at 20 knots. It operates a 16 megawatt propulsion plant at 14.7 megawatts to maintain speed. A combined 3,000 kilowatt ship's service plant typically runs at 800 kilowatts, increasing to 1,600 kilowatts while in port. Annual fuel consumption estimated at 19,000 metric tons, with 9,600 in an ECA. This assumes that the ship would divert course to outside of the ECA for 50% of its voyage starting in 2015 once distillate fuel consumption is required.

Tankship US West Coast. This 60,000 DWT product carrier transits between Anacortes and Long Beach in a round trip of 8 days at 14.5 knots. It operates a 10 megawatt propulsion plant at 9 megawatts to maintain speed. A combined 3,000 kilowatt ship's service plant typically runs at 350 kilowatts, increasing to 2,350 kilowatts while in port. Annual fuel consumption estimated at 11,000 metric tons, all of which will be within an ECA beginning is 2015.

3.1.3 Acquisition Costs

For each of the subject ships, acquisition costs of scrubbing technologies have been broken down into equipment, engineering/design, installation/commissioning, and training/ documentation costs.

Equipment costs shown in Table 10 are based on budget estimates provided by the equipment suppliers for this analysis. These budgets were normalized such that each covers roughly the same scope of supply, such as equipment engineering, equipment supply, and installation oversight. In each case, each propulsion engine is paired with a single scrubber unit, and multiple electric generating units are served by a single scrubber unit. Where multiple suppliers provided budgets for the same technology, they were generally averaged. Actual prices for ship-specific scrubber systems must be obtained directly from the suppliers, in order to account for arrangements and other specifics.

Table 10. Estimated Scrubber Equipment Only Costs for Subject Ships

	Open Loop	Closed Loop	Hybrid	Dry
Scrubber Ratings (by Engine Size)	(USD)	(USD)	(USD)	(USD)
36MW	3,100,000	3,850,000	3,600,000	6,050,000
16MW	2,900,000	3,600,000	3,120,000	3,200,000
12MW	2,000,000	2,500,000	2,220,000	1,900,000
10MW	1,800,000	2,150,000	1,920,000	1,600,000
3MW	1,300,000	1,850,000	1,560,000	1,250,000
1MW	1,000,000	1,750,000	1,260,000	930,000
Containership Transpacific	5,260,000	6,430,000	5,904,000	7,970,000
Containership Alaska to Puget Sound	5,060,000	6,180,000	5,424,000	5,120,000
Tankship US West Coast	3,960,000	4,730,000	4,224,000	3,520,000

Installation and commissioning is assumed to be 50% of the equipment cost for all technologies. Other costs are also based on percentages of equipment cost: 7% for engineering/design, and 2% for training and documentation.

Given that very few scrubbers have been installed, there is uncertainty with both the equipment costs and the support costs. Also, each ship is unique and will require a custom cost estimate. As such, these budgets are rough order of magnitude.

3.1.4 Expenses

Maintenance and repair expenses are assumed to be 4% annually of the equipment costs. For operations, it is assumed that an additional engineer will be required spending at least half time on scrubber operations. The cost of the engineer will vary significantly based on the flag of the ship.

Consumables and parasitic loads have been converted to a percentage of fuel consumption. For closed loop and dry scrubbers, chemical supply lines and costs are significant. Caustic soda prices are highly volatile, with the “free on board” cost per metric ton escalating from $270 in August to $340 in October of 2010. Although these fluctuations do not necessarily follow fuel prices, this analysis links the two. It is assumed that caustic soda will average 50% the cost of residual fuel oil on a weight basis. The amount of caustic soda consumed, is based on supplier information assuming 2.7% sulfur fuel.

Burning residual fuel requires significant heating, purifying, and waste management efforts that require energy, maintenance, and operational efforts. Typically the tanks and combustion fuel lines are heated by waste heat generated steam, meaning that energy costs are relatively low. A small percentage, 0.8% of fuel consumption, is assumed to be expended managing the residual fuel oil.

A 5% correction factor is applied to account for the difference in heating value of distillate on a weight basis, as compared to residual fuel. On the other hand distillate is lighter, and therefore requires a higher volume for storage, and more importantly for piping work and mechanical systems. This volume difference results in a diesel engine energy loss. The baseline assumes an aggregate 4% reduction in weight based fuel consumption when burning distillate.

3.1.5 Fuel Futures and Inflation

There is no consensus on future fuel prices. More importantly to scrubber life cycle costs is the fuel cost differential between residual fuel and distillate fuel. Bunkerworld.com listed Los Angeles IFO380 at $540.50, and MGO at $796.00 on 11 January 2011. This differential is $255.50 per metric ton, or a 47% premium for the low sulfur distillate fuel.

Fuel cost predictions on this differential fall into the following general categories:

- In 2015 distillate will become scarce because of the demand created by ships attempting to comply with ECA requirements. The distillate premium will then escalate very quickly, as refineries are forced to employ energy intensive and expensive means of refining more distillate.
- There is a fixed amount of energy and effort to refine distillate. Therefore, the distillate premium over residual fuel should remain steady, accounting for inflation.
- The premium for low sulfur distillate (marine gas oil) has generally been 50% over residual fuel, and is likely to remain that way.

This analysis assumes that the distillate premium will be 50% above the price of residual fuel. As a baseline, this analysis assumes fuel price escalation at 8% annually as generally supportive of a ten-year life cycle for a system installation.

Currently, inflation as measured by the consumer and producer price indices is low. However, this analysis is looking at expenditures that target ship operations over a long term period from 2015 through 2025. We have elected to use rates of 3.3% for PPI and 3.0% for CPI are assumed in the baseline.

Ship operators are encouraged to utilize their own predictions for energy prices and inflation in future years.

3.2 Technology Comparisons

The vessel/route comparisons demonstrated that fuel consumption volumes within an ECA are the key factor in predicting the economic advantage of a scrubber. This section focuses on the Containership Alaska to Puget Sound ship/route pair in order to compare the impact of various EGCS technologies on life cycle cost.

Table 11. EGCS Technology Impact on Life Cycle Cost

	Ship/Route Pair	Containership Alaska to Puget Sound	Containership Alaska to Puget Sound	Containership Alaska to Puget Sound	Containership Alaska to Puget Sound
	Scrubber Type	**Open Loop**	**Closed Loop**	**Hybrid**	**Dry**
Sensitivity Analysis	**Scrubber Types**	**Open Loop**	**Closed Loop**	**Hybrid**	**Dry**
VARIABLES - CONTROLLED					
Investment Terms					
Life Cycle	*(# of Years)*	10	10	10	10
Analysis Date (Today)	*(Year)*	2011	2011	2011	2011
Scrubber Installation Date	*(Year)*	2014	2014	2014	2014
Discount Rate	*(%)*	10.0%	10.0%	10.0%	10.0%
Capital Expense for Scrubber					
Equipment (Today)	*(USD/One Time)*	$5,060,000	$6,180,000	$5,424,000	$5,120,000
Engineering/Design	*(% Equip Cost)*	7.0%	9.0%	9.0%	11.0%
Training/Documents	*(% Equip Cost)*	2.0%	2.0%	2.0%	2.0%
Install/Commission	*(% Equip Cost)*	50.0%	65.0%	75.0%	85.0%
Operating Expense - Annual					
ECA Fuel Consumption	*(MT/Annual)*	9,636	9,636	9,636	9,636
Chemical Consumption	*(% of Fuel Cost)*	0.0%	3.0%	1.5%	3.0%
Scrubber Parasitic Loads	*(% of Fuel Cost)*	2.0%	1.0%	1.5%	1.0%
Distillate Calorie Correction	*(% of Fuel Cost)*	4.0%	4.0%	4.0%	4.0%
HFO Process and Heating	*(% of Fuel Cost)*	0.8%	0.8%	0.8%	0.8%
Operating Engineer (Today)	*(USD/Annual)*	$292,000	$292,000	$292,000	$292,000
Operating Engineer	*(% of Position)*	50.0%	65.0%	65.0%	65.0%
M&R Equipment	*(% Equip Cost/Annual)*	4.0%	4.0%	4.0%	4.0%
Variables - Uncertain					
Fuel Differential (Today)	*(USD/MT)*	$255.50	$255.50	$255.50	$255.50
Fuel/Chemical Escalation Rate	*(% - Annual for Op Period)*	8.0%	8.0%	8.0%	8.0%
Personnel Inflation Rate	*(% - Annual for Op Period)*	3.0%	3.0%	3.0%	3.0%
Equipment Inflation Rate	*(% - Annual for Op Period)*	3.3%	3.3%	3.3%	3.3%
Analysis Results - Overview (Nearest $1,000)					
Capital Cost	*(USD - Year Zero Dollars)*	(8,868,000)	(11,990,000)	(11,121,000)	(11,175,000)
Expenses - Year One	*(USD - Year One Dollars)*	(623,000)	(790,000)	(722,000)	(742,000)
Fuel Savings - Year One	*(USD - Year One Dollars)*	3,350,000	3,350,000	3,350,000	3,350,000
Net Present Value	*(USD - Present Dollars)*	14,562,000	10,185,000	11,574,000	11,336,000
Internal Rate of Return	*(%)*	36%	25%	28%	27%

All technologies show positive net present values, and relatively high IRR ranging from 25% for the closed loop scrubber, to 36% for the open loop scrubber. Although there is a fiscal advantage for the open loop scrubber, net present value shows adequate margin to allow a ship operator to select the most appropriate technology for their operation.

The open loop technology holds a financial advantage because both capital and operating expenses are less. The system has the fewest number of components resulting in lower cost for engineering and installation

Higher engineering, installation, and operating expenses are assumed for the closed loop and hybrid systems. This is a function of the chemical consumable that requires holding tanks, handling systems, labor to move on board, and disposal of the waste product. The dry system sees an additional installation cost increase due to the large dry chemical hopper tanks and conveyor systems that require installation, operations, and maintenance.

3.3 Sensitivity Analyses

A ship operator has some control, or ability to predict, the amount of fuel that will be burned within an ECA, the operating life of the ship/system, and crew baseline salaries. These are primary factors in determining life cycle cost. However, there are other factors that are more difficult to predict. This includes fuel escalation and inflation rates, as well as some risk with the installation costs of the project.

This section continues with the Containership Alaska to Puget Sound in order to determine the sensitivity of the analysis to these variables. Following these descriptions, a table is provided that considers several combinations of these sensitive variables in attempt to bracket fiscal risk of an EGCS project. Table 12 brackets the best case IRR at 62%, and the worst case IRR as 6% for the baseline ship.

<u>ECA Fuel Consumption Volume – High Sensitivity</u>. The baseline assumed that the ship burned roughly 50% of its fuel in an ECA for an IRR of 36%. If the ship must stay within the ECA 75% or 100% of the time, the IRR increases to 55% and 73% respectively. The same ship, if it were to only burn 4,000 metric tons (~21% of its annual consumption) would have a negative NPV. As such, this is considered a minimum fuel consumption volume for EGCS consideration for an ocean going ship.

<u>Inflation and Fuel Cost Escalation – Moderate Sensitivity</u>. Inflation as it impacts equipment and labor costs has a negative impact on EGCS life cycle costs. However, if that inflation also impacts distillate fuel cost differentials, the net impact is positive. The net result is that the two forces work to counter-act each other to some extent. The baseline example assumes 3% CPI, 3.3% PPI, and 8% fuel escalation on an annual basis for an IRR of 36%. A high inflation period of 5% for CPI and PPI, and 11% for fuel results in an IRR of 44%. A low inflation period of 2% CPI and PPI, and 5% for fuel results in an IRR of 24%.

<u>Operating life – Moderate Sensitivity</u>. The baseline operating life is ten years, providing a return of 36%. If the operating life is extended to 15 or 20 years, the IRR remains relatively flat at 39%. However, it should be noted that the NPV increases from $14.5M to $25.1M to $34.9M for 10, 15, and 20 years respectively. An operating life of less than four years yields a negative NPV.

<u>Expenses – Moderate Sensitivity</u>. The sensitivity of expenses was analyzed by adjusting all expenses from equipment costs, to engineer salary, to amount of time the engineer works on equipment by an increase of 25% for a worst case, and decreasing by 25% for a best case. The best case and worst case result in 55% and 28% IRR respectively.

Combinations – High Sensitivity. Table 12 provides worst and best case combinations for our baseline ship/route pair, a ten-year life cycle, and an assumed discount rate of 10%. The worst case assumes that fuel price escalation averages only 2%, and that expenses are generally 25% higher than expected. The best case assumes a fuel price escalation on average of 11% with expenses lower by 25%. The resulting IRR ranges from 6% to 62%, with the worst case indicating a negative NPV.

Table 12. Life Cycle Cost Sensitivity, Combinations for Worst/Best Cases

	Ship/Route Pair	Containership Alaska to Puget Sound	Containership Alaska to Puget Sound	Containership Alaska to Puget Sound	Containership Alaska to Puget Sound
	Scrubber Type	**Open Loop**	**Open Loop**	**Open Loop**	**Open Loop**
Sensitivity Analysis	**Expenses**	**Low**	**Predicted**	**High**	**V. High**
Combination of Variables	**Fuel/CPI-PPI**	**11/5**	**8/3**	**5/2**	**2/1**
VARIABLES - CONTROLLED					
Investment Terms					
Life Cycle	*(# of Years)*	10	10	10	10
Analysis Date (Today)	*(Year)*	2011	2011	2011	2011
Scrubber Installation Date	*(Year)*	2014	2014	2014	2014
Discount Rate	*(%)*	10.0%	10.0%	10.0%	10.0%
Capital Expense for Scrubber					
Equipment (Today)	*(USD/One Time)*	$3,795,000	$5,060,000	$5,566,000	$6,325,000
Engineering/Design	*(% Equip Cost)*	5.0%	7.0%	9.0%	11.0%
Training/Documents	*(% Equip Cost)*	2.0%	2.0%	2.0%	2.0%
Install/Commission	*(% Equip Cost)*	40.0%	50.0%	60.0%	65.0%
Operating Expense - Annual					
ECA Fuel Consumption	*(MT/Annual)*	9,636	9,636	9,636	9,636
Chemical Consumption	*(% of Fuel Cost)*	0.0%	0.0%	0.0%	0.0%
Scrubber Parasitic Loads	*(% of Fuel Cost)*	2.0%	2.0%	2.0%	2.0%
Distillate Calorie Correction	*(% of Fuel Cost)*	4.0%	4.0%	4.0%	4.0%
HFO Process and Heating	*(% of Fuel Cost)*	0.8%	0.8%	0.8%	0.8%
Operating Engineer (Today)	*(USD/Annual)*	$200,000	$292,000	$350,000	$400,000
Operating Engineer	*(% of Position)*	25.0%	50.0%	75.0%	100.0%
M&R Equipment	*(% Equip Cost/Annual)*	2.0%	4.0%	6.0%	8.0%
Variables - Uncertain					
Fuel Differential (Today)	*(USD/MT)*	$255.50	$255.50	$255.50	$255.50
Fuel/Chemical Escalation Rate	*(% - Annual for Op Period)*	11.0%	8.0%	5.0%	2.0%
Personnel Inflation Rate	*(% - Annual for Op Period)*	5.0%	3.0%	2.0%	1.0%
Equipment Inflation Rate	*(% - Annual for Op Period)*	5.0%	3.3%	2.0%	1.0%
Analysis Results - Overview (Nearest $1,000)					
Capital Cost	*(USD - Year Zero Dollars)*	(6,458,000)	(8,868,000)	(10,100,000)	(12,405,000)
Expenses - Year One	*(USD - Year One Dollars)*	(407,000)	(623,000)	(849,000)	(1,124,000)
Fuel Savings - Year One	*(USD - Year One Dollars)*	3,737,000	3,350,000	2,993,000	2,665,000
Net Present Value	*(USD - Present Dollars)*	25,397,000	14,562,000	6,372,000	(1,964,000)
Internal Rate of Return	*(%)*	62%	36%	22%	6%

Section 4 Scrubbing Technology Options

"Which EGCS technology will work for my fleet?"

Scrubbing technologies are generally categorized as either *wet* or *dry* systems. There is essentially one option for the dry system whereas the wet system has at least three variants. Each of the wet and dry options will be described in this section to provide a sense of their relative merits.

Appendix A of this Guide provides an extensive survey of the available scrubbers. Please use this survey to perform comparisons between systems in terms of technology approach and physical plant integration. This section discusses the various technologies in general terms.

4.1 Wet Systems

A wet scrubbing system is one which uses either untreated seawater or treated freshwater as the scrubbing agent to remove SOx and particulate matter from exhaust gas. The water undergoes some form of filtration or chemical treatment before being discharged overboard or re-circulated to the system. Wet systems may be categorized as open loop, closed loop, or hybrid. Specific functional differences between the three variants are outlined below.

4.1.1 Open Loop System

An open loop system relies exclusively on ambient seawater for exhaust gas scrubbing. The term 'open loop' is used because 100% of the water drawn in from the sea is discharged after passing through the system. The process relies on the natural alkalinity of seawater to facilitate scrubbing of the sulfur oxides.

In this process seawater is drawn from below the waterline and pumped to a scrubber located in the engine exhaust uptake. The scrubber is a passive device that puts the water in direct contact with the exhaust gas. Internal baffles divide the scrubber into several stages; each stage causing different interactions between the gas and water. Seawater is injected near the top through special nozzles and gravitates to the bottom passing through the various stages.

Upon leaving the scrubber the water (now termed wash water) must be processed before discharge to the sea. Wash water is either pumped or drained via gravity to a cyclonic separator; another passive device which relies on internal baffles to induce fluid rotation. This rotation causes centrifugal separation of the heavy suspended particulates from the water. The particles, mostly silt from the ambient seawater, are drained away as sludge while the water is allowed to continue through the process.

A secondary stream of seawater which has bypassed the entire scrubbing process is mixed in equal parts with the water leaving the cyclonic separator. This mixing effectively dilutes the wash water bringing the pH to a level that is acceptable for overboard discharge in most areas.

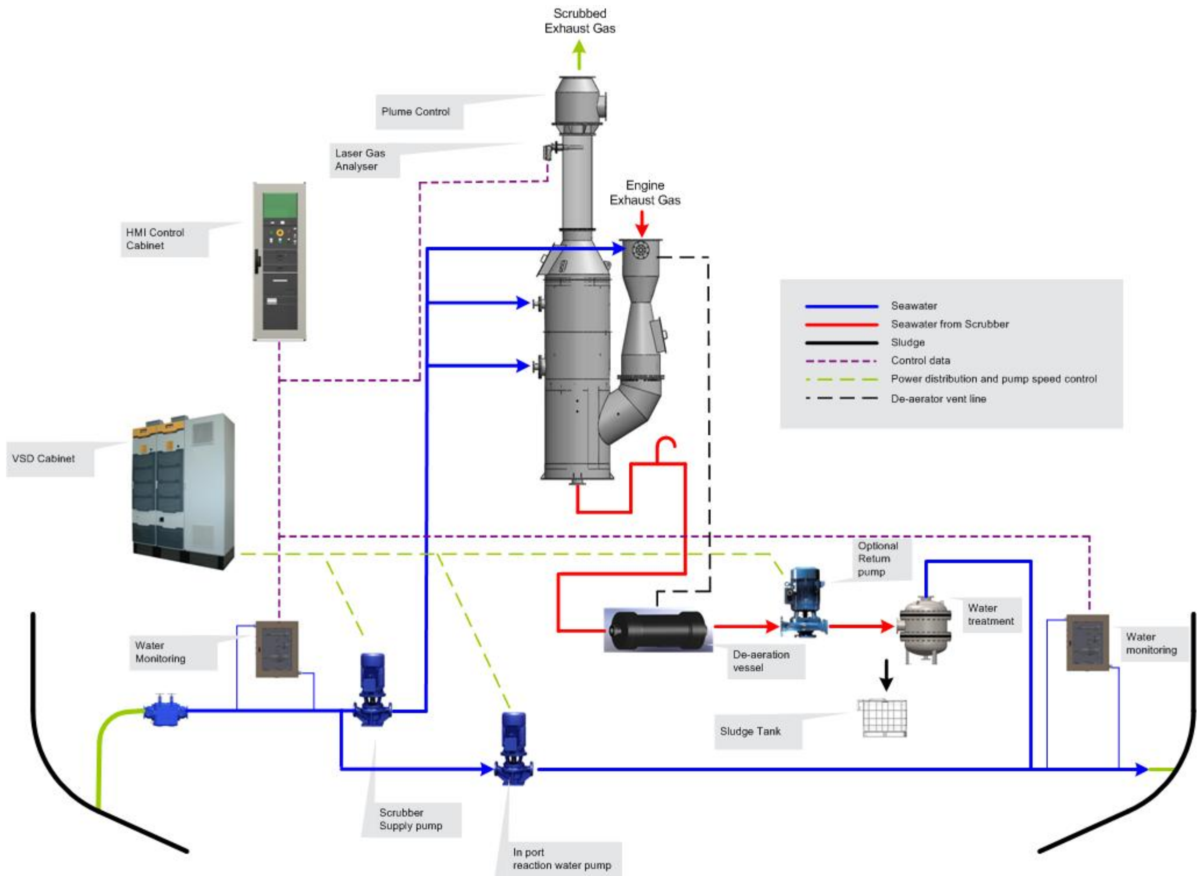

Figure 1. Open Loop System (Hamworthy Krystallon)

Advantages of the open loop system include the following:

- The process requires no hazardous chemicals; seawater is the only scrubbing agent.
- The system has fewer components than other wet systems.

Disadvantages of the open loop system include the following:

- Operation in brackish or fresh water or in high water temperatures can inhibit scrubbing of SOx.
- The discharge of effluent with acidic pH may be restricted in some regions, thereby requiring a switchover to low sulfur fuel or an alternative scrubbing system.

4.1.2 Closed Loop System

A closed loop system uses fresh water that is chemically treated to effect scrubbing. The term 'closed loop' is used because most of the scrubbing agent is re-circulated with only minimal water intake and effluent discharge. Chemical dosing is added at the rate needed to neutralize SOx in the exhaust gas.

Fresh water that has been dosed with sodium hydroxide solution is pumped from a holding reservoir to a scrubber. The scrubber operates in the same manner as that used in open loop systems; putting exhaust in direct contact with the fluid. After scrubbing the water is drained back to the reservoir. A seawater / freshwater heat exchanger extracts heat from the closed fresh water loop, the seawater being supplied by an independent SW pump.

As this process repeats the chemical reaction between the Sodium Hydroxide and the SOx depletes the reserves of NaOH in the solution. A dosing unit injects NaOH at the rate necessary to maintain a constant pH at the scrubber outlet. To purge the benign products of reaction (sulfates) a small flow of water is constantly drained from the reservoir. At the same time make-up water from the ship's fresh or potable water system is added to maintain the same volume in the reservoir. The drained water is sent to a treatment unit for processing.

The treatment unit is a mechanized centrifugal separator similar to those employed in fuel oil and lube oil systems. The separator extracts the heavy particulates and discharges clean water as effluent. The effluent is discharged in relatively small volumes (compared to open loop systems) and may be sent to a holding tank to avoid discharging in port.

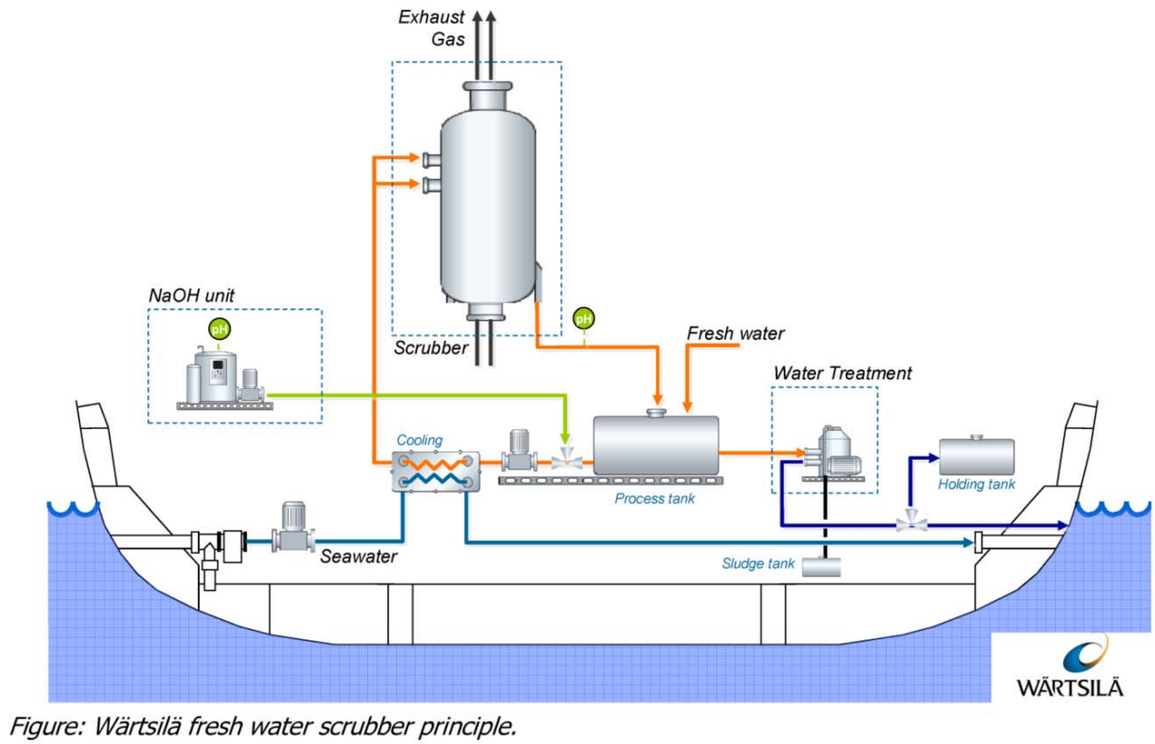

Figure 2. Closed Loop System (Wärtsilä)

Advantages of the closed loop system include the following:

- The system can operate in all regions regardless of seawater alkalinity or temperature.
- Effluent may be stored on board for whatever duration the tank volumes will permit.

Disadvantages of the open loop system include the following:

- The system has more components than an open loop system.

- The system requires a constant supply of sodium hydroxide solution, a hazardous substance requiring special handling, care, and cost. In addition, the use of caustic chemicals increases the effort to gain regulatory approval.

4.1.3 Hybrid System

A hybrid system capitalizes on the advantages of the open and closed loop systems. The system largely resembles a closed loop system but incorporates additional components which allow it to operate as either an open or closed loop system. The intent is that the system can operate as an open loop system at sea to conserve chemical agent or operate as a closed loop system in port to avoid issues stemming from water quality or port discharge regulations.

The hybrid system has all of the same components that are present in the closed loop system, with the primary distinction being the presence of two wash water treatment devices. Because the open loop mode of operation requires 100% of the water to undergo centrifugal separation it is therefore necessary to have a secondary device large enough for the higher flow rate.

To change from the closed loop mode to the open loop mode requires a change in the functions of certain components.

- The seawater pump used to provide cooling water to the heat exchanger in closed loop mode becomes the supplier of dilution water in the open loop mode. The heat exchanger is bypassed in open loop mode.
- The pump used to circulate fresh water in closed loop mode becomes the source of seawater for the scrubber in open loop mode.

The change in modes requires change-over from the small volume centrifuge to the large volume cyclone separator. Otherwise, system operation is the same as described in the above sections.

The same advantages and disadvantages described above are applicable to this system. There is an additional disadvantage in that the system requires the most components of any wet option.

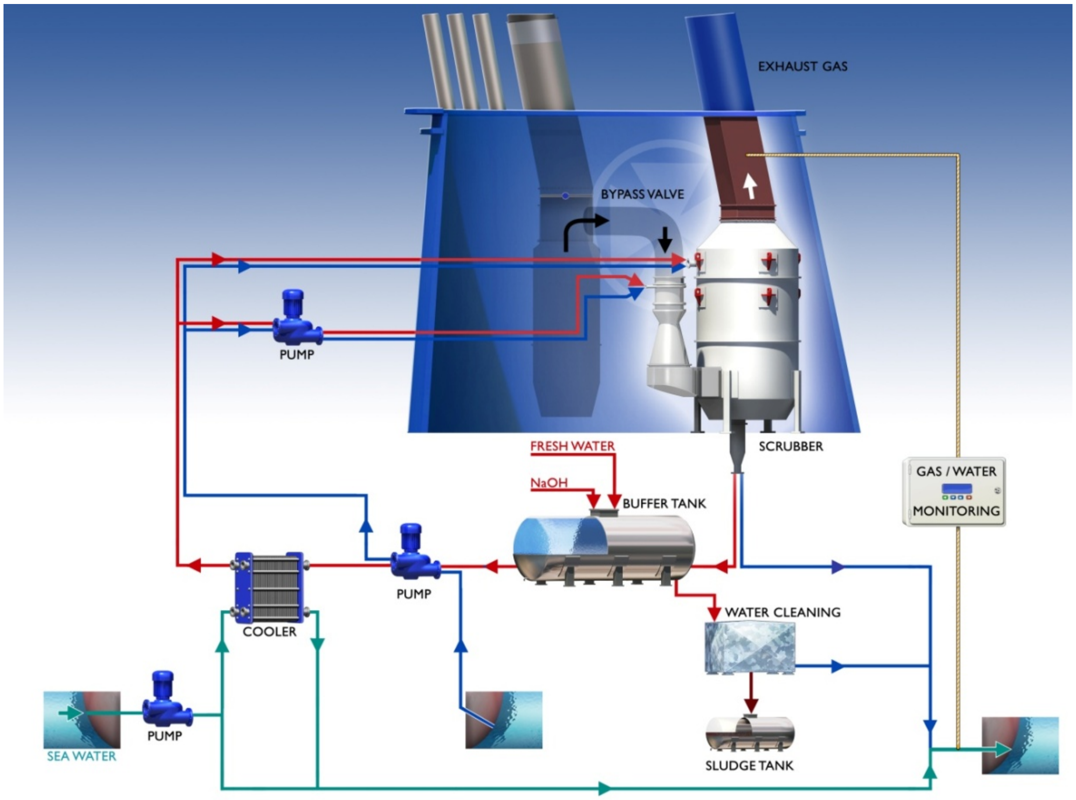

Figure 3. Hybrid System (Aalborg Industries)

4.1.4 Wet Systems Claiming NOx and CO2 Reductions

New variants of the wet scrubber system have begun to emerge with claims of significant NOx and CO2 reductions. Ecospec Marine of Singapore is claiming significant reductions in NOx and CO2 emissions with their CSNOx system while Simulation Tech, Inc. (STI) of South Korea is claiming significant reductions in CO2 emissions in their wet scrubber units.

The CSNOx system claims: "Meet 0.1 % low sulfur fuel emission criteria. No need to use distillate or modify the fuel system to accommodate the use of distillate. Meet NOx Tier 1, 2 and 3 requirements. Surpass all present international GHG mitigation targets." (MEPC 60 Presentation.) Compliance with IMO wash water requirements is also claimed.

The CSNOx first stage scrubber is effectively an open loop wet scrubber with similar wash water handling techniques. A second stage scrubber uses seawater that has been specially conditioned by "ultra low frequency" waves that results in alkaline seawater that reportedly absorbs the remaining SOx as well as NOx and CO2. The NOx is reported by Ecospec to convert to nitrogen gas, relieving concern of exceeding nitrogen limits in the seawater. The CO2 is reported to permanently convert into bicarbonate

The CSNOx is continuing to undergo verification testing on the motor tanker *White Star*. ABS has confirmed measurements taken validating reductions under some load conditions in the first of three planned pilot project tests. If full scale testing proves to be as effective as the initial claims this would truly be a remarkable technology. Without further empirical evidence, it would be premature for Owners to commit to this solution.

Figure 4. Pilot Scale Ecospec Installation

4.2 Dry Systems

Dry exhaust scrubbing systems are so described because they rely primarily on dry bulk reactants for treatment of the exhaust gas. The process utilizes calcium hydroxide in the form of spherical pellets. The pellets are loaded on the ship and stored in bulk. When the system is in use the pellets are fed via belt conveyor to a dry reactor or 'absorber' through which the engine exhaust passes. The SOx react chemically with the pellets to produce gypsum ($CaSO_4$) and water. The gypsum is removed from the bottom of the absorber by a discharge conveyor and captured for storage and subsequent offloading.

The gas travels from the absorber to an SCR reactor where NOx is chemically removed from the gas with the injection of ammonia or urea. A large volume blower on the outlet of the SCR reactor pulls the gas through the system, thereby reducing the back pressure at the engine exhaust outlet.

Advantages of the dry system include the following:

- The system does not produce any liquid effluent for overboard discharge.
- The system can reduce NOx emissions.

Disadvantages of the dry system include the following:

- The ship must have suitable storage and handling arrangements to accommodate the dry bulk reactants and products, as well as a reliable supply of materials.
- Increased costs from use of urea for NOx abatement, and calcium hydroxide for SOx abatement.

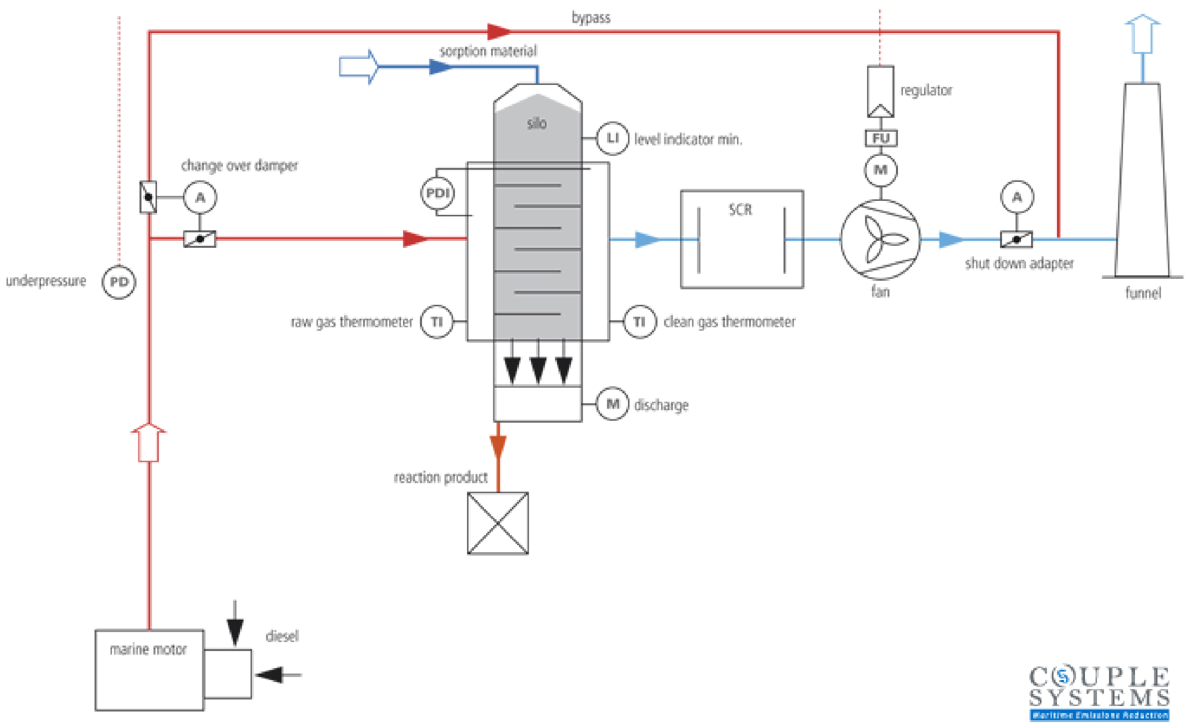

Figure 5. Dry System (Couple Systems)

4.3 Fuel Switching

Fuel switching to low sulfur fuel oil distillates when entering port has been practiced for decades by vessels calling in California waters. When the ship reaches a specified distance from an emissions control area (ECA), it initiates the process of switching from burning high sulfur fuel oil to burning low sulfur fuel oil. The duration of the switchover typically takes about one hour, depending on system component size and fuel burn rate. *Technical Considerations of Fuel Switching Practices* was published on 3 June 2009, by the API Technical Issues Workgroup and the ABS *Fuel Switching Advisory Notice*, both of which provide guidance on the below topics related to propulsion shutdown issues such as:

- Sticking/scuffing of fuel injection components as a result of the
  - thermal shock or reduced viscosity and lubricity, and
  - incompatibility of fuels being switched (complete fuel pump seizure).
- Mismatched crankcase or cylinder lubrication oil resulting in accelerated piston/liner wear.
- Liner lacquering resulting in difficulties maintaining oil film thickness.

These risks can be mitigated by a combination of the installation of special equipment and the modification of operational procedures. The extent and nature of conversion required for a vessel will be determined by the type of equipment installed on the vessel, and the arrangement of the affected systems. For vessels not already outfitted with special fuel switching equipment, modification costs will generally range from $15K to $80K. This assumes that the vessel has the appropriate tank capacity to carry the two fuel types.

Section 5 Integration, Operations, and Maintenance Practicality

"Can an EGCS be practically integrated with ship operations?"

Installation of an EGCS will place additional demands on those responsible for plant operation and maintenance. The decision to install an EGCS should consider the additional manpower required to sustain operation. Depending on a ship's current operations and maintenance profile, installation of an EGCS may require additional crew. This section will outline the major sources of additional labor associated with each type of system.

At this time there is insufficient empirical data from which to derive actual operating and maintenance data. In order to quantify the manpower requirements of an EGCS system a comparison shall be drawn between each major EGCS component and more common (existing) shipboard equipment of similar complexity.

What follows are discussions (grouped by system) identifying the general complexity and manpower requirements of each component.

5.1 Physical Integration Challenges – All Systems

The installation of exhaust gas cleaning systems (EGCS) present integration challenges to new builds and retrofits alike. Appendix A provides summary information of several EGCS including footprints, weights, and backpressures. This will provide each operator a baseline on which to begin discussions with suppliers on integration. Key considerations include:

- Weight and stability. Weights will vary significantly by scrubber rating and type. The primary weights of concern are the scrubbers themselves as they are positioned high and even a 20 ton wet weight could be of significant concern for ships that have limited remaining stability margin.
- Water handling systems. These systems can be significant for any of the wet systems, but particularly for open loop and hybrid systems. For example, a 50 megawatt plant with an open loop scrubber will require 4,500 cubic meters an hour of wash water. This wash water would require about 0.5 megawatts of power to run, and a 760 mm pipe (30 inch diameter).
- Machinery and stack arrangements. In the case of new builds, the EGCS will become a primary component for arrangements and weight allowances. For retrofits, fitting this equipment into existing spaces will be a significant challenge and in some cases may require installation of the scrubber unit in the weather or new above the main deck enclosure.
- Exhaust backpressure. Most engines can tolerate ~3.0 kPa of backpressure (12 inches of water) without significant degradation of power or adverse affects. Exceeding the allowance will degrade performance by ~ one percent for each additional 3 kPa of backpressure. It should be noted that exhaust piping and silencers may required, depending on the scrubber design. If one is required, then backpressure allowances should be included.
- Electrical power. The demands of these systems can be significant reaching 2% of nominal power, potentially requiring additional generating capacity.

- Failure modes. Being integral to diesel engine operations, a *failure modes and effects* or other analysis should be conducted to assure that a scrubber failure will not result in loss of ships service or propulsion power.

5.2 Open Loop Seawater System

Scrubber: The scrubber is a passive device that relies on the hydraulic pressure of an external supply pump for proper operation. Internally the scrubber is divided into multiple sections for processing of the exhaust gas. There are few, if any, moving parts although internal bypass dampers may be included. Regular inspection, de-fouling, and operational checks are required. Internal filtration elements in the scrubber will require periodic replacement. The scrubbers are similar in size and service profile to exhaust gas economizers. The Owner should anticipate a maintenance profile similar to inert gas system scrubbers commonly found on tank ships.

Pumps and Strainers: Strainers and centrifugal pumps are ubiquitous in shipboard plants. The service demands of the external scrubber pumps are essentially the same as those used for other auxiliary services such as seawater cooling with the addition of a variable speed control drive. The pumping demand is significant with two pumps, each requiring approximately 50 m3/hr per engine megawatt. This service profile makes for a predictable operation and maintenance schedule.

Wash Water Treatment Filter: The wash water treatment filter is generally a passive filtration assembly relying on fluid velocity and cyclonic baffles to effect centrifugal separation of sludge. With no moving parts or consumable elements the device would only require periodic inspection and de-fouling.

Sludge Handling: Sludge that is separated out in the Wash Water Treatment Filter must be retained on board and periodically discharged to a shoreside reception facility. The sludge may be retained in existing shipboard sludge tanks, but the pump-out interval will decrease requiring more frequent sludge transfers. Existing reports on scrubber sludge indicates that it is not hazardous, and therefore does not need to meet IMO Annex I handling requirements. However, Annex VI does not allow incineration of EGCS sludge.

Effluent Monitoring: Instrumentation used to monitor effluent conditions will require periodic calibration, inspection, and possible element replacement. The monitoring of turbidity is a common function of oil content monitors used in shipboard oily water separators. It is reasonable to expect that the degree of intervention required will be similar for the scrubber effluent instrumentation. Scrubber monitoring will however be continuous and requires monitoring of at least three parameters, in comparison to oil content monitor of a single parameter performed only periodically.

Exhaust Gas Monitoring: The instrumentation used for monitoring of scrubbed exhaust gas is not unlike that used in tank vessel inert gas monitoring. Scrubber monitoring however will be continuous as per regulation, and requires monitoring of more difficult parameters such as SO2. The Owner should anticipate the need for periodic calibration, servicing of calibration gases, inspection, and possible element replacement. Type Approval processes for this equipment will be required for Scheme B, including third party calibrations and maintenance, are anticipated.

Controls: The controls for an open loop system should not impose any significant operational or maintenance costs. Modern PLC/microprocessor controls are robust and generally do not require any attention beyond periodic inspection and testing of the power supplies.

5.3 Closed Loop Freshwater System

Buffer Tank: The buffer tank is a passive device, acting simply as a reservoir where the solution is allowed to stabilize. The tank has no internal moving parts and, besides periodic inspection, would require little or no operator intervention.

SW/FW Heat Exchanger: The SW/FW heat exchanger is required to remove heat that is absorbed by the solution as it passes through the scrubber. Although this is a passive device the Owner should anticipate the need for regular disassembly and cleaning of both FW and SW sides of the heat transfer surfaces.

Pumps and Strainers: The SW and FW circulation pumps will experience the same operational demands as those present in the open loop system. Again, this represents a predictable addition to the ship's maintenance workload.

Sodium Hydroxide Unit: The NaOH unit is used for storage and dosing. Generally it is a passive device and should require little operator intervention. However, the loading of the alkaline solution is a critical operation that requires diligence and strict adherence to safety procedures. Due to the hazardous nature of the chemical Owners should plan for a tightly controlled evolution requiring several crew members to remain present and fully attentive during a transfer. This procedure would take place at regular intervals during port stops and is a significant addition to the list of duties assumed by the ship's crew.

Water Treatment Device: The water treatment device is a mechanized centrifugal separator similar to those commonly used for fuel oil or lube oil processing. An owner should expect at least the same degree of operator intervention; regular operational checks and moderate to frequent disassembly and cleaning.

The system contains additional elements which are substantially similar to those found in the open loop system. These components include

- Scrubber
- Effluent Monitoring Devices
- Exhaust Gas Monitoring Devices
- Controls
- Sludge Handling

5.4 Hybrid System

The hybrid system has the ability to operate as an open loop system at sea and operate as a closed loop system in port. The system make-up is virtually the same as the closed loop system. Through the use of isolation valves, the circulation pumps can serve different roles depending on which mode the system is being used in.

One substantial deviation from the closed loop system is that the hybrid system must have two separate wash water treatment devices; one for each mode of operation. The open loop mode requires a large device capable of processing 100% of the system flow rate, whereas the closed loop treatment device only processes a fraction of the system flow rate.

5.5 Dry System

Absorber: The absorber (sometimes called the reactor) is the primary component involved in the dry scrubbing process. It is a large assembly mounted in the exhaust uptake which funnels the hot exhaust gas through a bed of calcium hydroxide pellets. The gas comes in direct contact with the pellets causing a chemical reaction which removes entrained SOx. The device is passive relying on external conveyors to feed unspent pellets and remove spent pellets. The absence of moving parts makes the device relatively easy to maintain, but periodic inspections of the internals should be conducted.

Conveyors: Conveyance of the dry chemical reactants and by-products to and from the absorber is accomplished with mechanical conveyor belts. These would be similar to those used in bulk ship cargo handling and would require frequent inspection and planned maintenance of the rotating elements and belts.

SCR Reactor: The selective catalytic reduction (SCR) reactor is the component where NOx are removed from the exhaust gas via chemical reaction with an injected chemical. A liquid reactant such as ammonia or urea is injected and mixed into the exhaust stream thereby reacting with the NOx and precipitating benign by-products. The reactor itself has no moving parts but it is reliant on external pumping and chemical storage devices.

Exhaust Gas Blower: A large volume blower is used to pull treated exhaust gas from the outlet of the absorber. As with similar large blowers (e.g. IG system blowers, forced draft fans) the device will require regular operational checks and moderate maintenance tasks.

Isolation and Bypass Dampers: The dampers used to divert the flow of exhaust gas through or around the absorber are essentially large butterfly valves designed for service in high temperature applications. Such dampers prevail in tankship IG systems for gas isolation. Periodic maintenance of seals and damper actuators will be required.

Calcium Hydroxide Storage: A closed, dry storage hopper is used as a reservoir for the unspent calcium hydroxide pellets. The hopper itself requires little or no attention from the ship's crew, but regular dry bulk loading operations must be carried out and supervised. It is improbable that all shoreside terminals will have the necessary handling equipment for loading the product in bulk. Therefore the Owner should plan for the contingency that the bulk products may need to be loaded in packaged form and transferred (internally) by the ship's crew to the hopper. Depending on the intervals between loading and the volumes being loaded this evolution could require significant manpower if performed as described. Hydraulic cranes or similar means must be added to the vessel if they are not already installed.

Gypsum Storage: As with the calcium hydroxide pellets, the reaction byproduct gypsum must be retained on board and discharged at regular intervals. A similar challenge is faced in the respect that not all shoreside terminals will have equipment or reception facilities that can easily remove the spent pellets en masse. Possible ship-based solutions include the following:

- Compressed air ‘blow tanks’ similar to those used for transferring bulk drilling mud in offshore supply vessel applications. This requires a large pressure vessel tank and dedicated air compressor(s) to effect dry bulk transfer. It also requires a shore side facility that can accept large flow rates of dry bulk material through a pipeline.
- Manual option; essentially the reverse of the loading option described above. This would require that the vessel have on-board portable containers which can be filled by the crew at the base of the gypsum storage hopper. Portable containers then removed by crane or hoist.

The system contains additional elements which are substantially similar to those found in the wet systems. These components include

- Exhaust Gas Monitoring Devices
- Controls

5.6 Summary

The following tables compare the components for each type of system to the conventional or existing shipboard equipment items.

The addition of any type of EGCS will increase the workload for shipboard engineering personnel. The ability of a ship’s crew to absorb this increase in workload is dependent on the current manning levels and utilization. These factors are in many ways linked to the ship type.

For instance, the engineering plant on board an ocean-going containership is less complex than the plant on board a tank vessel. A tank vessel carrying oil or chemicals has on-board cargo pumping and inert gas systems which do not exist on dry cargo ships, and which require constant supervision during cargo operations. Therefore, it is possible that the engineering department on a dry cargo ship may be capable of absorbing the additional workload without an increase in manning.

The ship type also carries with it certain regulatory barriers which may further limit a crew’s ability to carry the additional workload. Crews on board U.S. registered tank ships are limited by OPA 90 regulations to work no more than 12 hours in a 24 hour period. It would not be possible for an Owner to simply make the crew work longer days to compensate for the increase in workload.

In summary, the table and discussions are intended to give the reader a general sense of how much burden an EGCS will introduce. Ultimately, the Owner must weigh this information against known variables such as ship type, crew utilization, and watch-keeping regulations. A prudent approach may be to start operations with an additional crew member specifically trained to operate the EGCS, and subsequently shift these burdens to other crew members as possible.

Table 15. Comparison Chart for Open Loop, Closed Loop, and Hybrid Wet Systems

	Conventional or Existing Shipboard Equipment							
	Inert Gas Scrubber	SW Service Pump	Centrifugal Separator	OWS Oil Content Monitor	IG Monitoring Instrumentation	PLC / Microprocessor	Passive Tank (Haz Chemicals)	Plate Type Heat Exchanger
Open Loop System Components								
Scrubber	✓							
Scrubber Supply Pump		✓						
In-Port Reaction Water Pump		✓						
Wash Water Treatment			✓					
Effluent Monitoring Instrumentation				✓				
Exhaust Monitoring Instrumentation					✓			
Control Module						✓		
Closed Loop System Components								
Scrubber	✓							
Buffer Tank							✓	
SW/FW Heat Exchanger								✓
SW Circulation Pump		✓						
FW Circulation Pump		✓						
Wash Water Treatment			✓					
Sodium Hydroxide Unit							✓	
Effluent Monitoring Instrumentation				✓				
Exhaust Monitoring Instrumentation					✓			
Control Module						✓		
Hybrid System Components								
Scrubber	✓							
Buffer Tank							✓	
SW/FW Heat Exchanger								✓
SW Circulation / Reaction Water Pump		✓						
FW Circulation / Scrubber Supply Pump		✓						
Open Loop Wash Water Treatment			✓					
Closed Loop Wash Water Treatment			✓					
Sodium Hydroxide Unit							✓	
Effluent Monitoring Instrumentation				✓				
Exhaust Monitoring Instrumentation					✓			
Control Module						✓		

Table 16. Comparison Chart for Dry Systems

	Conventional or Existing Shipboard Equipment							
	No Marine Comparison	Dry Bulk Conveyor	No Marine Comparison	Inert Gas System Blower	Inert Gas System Damper	IG Monitoring Instrumentation	PLC / Microprocessor	Dry Bulk Hopper
Dry System Components								
Absorber	✓							
Feed Conveyor		✓						
Extraction Conveyor		✓						
SCR Reactor			✓					
Exhaust Gas Blower				✓				
Bypass Damper					✓			
Inlet Isolation Damper					✓			
Outlet Isolation Damper					✓			
Exhaust Monitoring Instrumentation						✓		
Control Module							✓	
Calcium Hydroxide Storage								✓
Gypsum Storage								✓

Section 6 Discussion

The ship operator considering an exhaust gas cleaning system (EGCS) faces a conflicting pair of recommendations. On the one hand, the fuel cost savings for those operating within an emissions control area (ECA) is so substantial that an EGCS may be a competitive necessity. On the other hand, installations are discouraged because the technology is not yet fully mature, places a significant burden on ship arrangements and operations, and raises some environmental impact concerns. This section provides a discussion on these considerations.

6.1 Cost Advantage

The cost advantage for EGCS is a combination of quantity of fuel burned within an ECA and the cost differential between the high-sulfur and low-sulfur fuel. The analysis in this Guide indicates that starting in 2015, ships that burn at least 4,000 metric tons of fuel oil annually within an ECA should consider an EGCS.

A key break point in fuel cost differentials is when sulfur limits become so low, that they cannot be practically or cost-effectively achieved by removing sulfur from residual fuel. Such limits, generally 0.5% sulfur or lower, require high-cost distillate fuel oil or alternatives such as EGCS or natural gas. The potential cost savings for an EGCS is then the differential between the high-cost distillate and the low-cost residual fuel oil.

Such differentials are currently in effect in EU ports and California coast waters that limit fuel sulfur concentrations to 0.1% sulfur. The cost advantage becomes widespread in 2015 when IMO enacted ECAs will require the 0.1% sulfur emissions. When worldwide sulfur limits reach 0.5% in either 2020 or 2025 the cost savings opportunity extends to ships regardless of their operating area.

Over the last eight years residual fuel has cost roughly 50% less than distillate fuel. On 10 January 2011, the cost differential between MGO and IFO380 in Los Angeles was about $250 per metric ton (bunkerworld.com). It is difficult to predict how this differential will change over time. The cases analyzed in this Guide assume that the percentage differential will remain constant, and that fuel cost escalation will average 8% annually over the assumed ten-year life-cycle period. Based on these assumptions, net present values between $4.8M and $20M, and internal rates of return between 20% and 53% are calculated. Ship operators are encouraged to utilize their own fuel cost differential predictions, as the analysis is very sensitive to fuel cost escalations.

6.2 Ship Impacts

The impact of an EGCS on ship arrangements, operations, and logistics is both broad and pervasive. The machinery is very large, impacts key mechanical, electrical, and control systems, and in the case of chemical based systems requires impacts logistics for bunkering and safety response.

In spite of these challenges, the cost savings potential remains significantly high. The ship operator installing an EGCS will need to return some of that cost savings to ensure success operations. An EGCS will require a significant investment to ensure adequate installation and commissioning, ongoing technical support, initial and ongoing training, and most likely an increase in shipboard engineering staff. Without this commitment of resources, installation of an EGCS is not recommended.

6.3 Applicability to non-Ocean Going Vessels

Exhaust gas cleaning systems offer significant benefits to non-ocean going vessels in terms of abating PM, NOx, and hydrocarbons. Equipment focused on these pollutants may be significantly smaller than sulfur focused scrubbers, and therefore may more readily fit onto smaller vessels. However, this Guide focuses on the removal of sulfur from residual fuel.

The employment of exhaust gas cleaning systems for sulfur abatement on smaller marine vessels, non-Ocean Going Vessels, faces several challenges: machinery spaces may be too restricted to fit the large scrubber plants; many already burn high cost marine diesel oil (MDO) or marine gas oil (MGO) eliminating much of the potential fuel cost savings; those that burn residual fuel oil may not burn enough to gain adequate pay-back on the capital investment.

Many smaller marine vessels, such as ocean going tugs or supply boats, have large propulsion plants tightly fit into relatively small machinery spaces. These service vessels are often designed around the propulsion plant, and therefore often have no additional space for even moderate increases in equipment. One solution for some vessels will be to locate the scrubbing equipment in the weather or in a new deck house. For small vessels, often all exterior spaces are working areas essential to the vessel's mission. A review of the available area in comparison to the machinery footprints provided in the appendix of this Guide will assist the operator with an initial evaluation.

The cost advantages of sulfur focused EGCS are dependent on the fuel cost differential between high-sulfur residual fuel oil and low-sulfur distillate fuel oil. In general, this means ocean going vessels that run slow speed diesel engines. There are classes of marine vessels, such as anchor handling tugs or larger ferries, that burn residual fuel oil in medium speed diesel engines. In these cases, the fuel has a high fuel cost differential but may not be in significant quantity to justify the equipment expenses. This Guide suggests 4,000 metric tons of fuel oil burned annually within an ECA as a point where an operator should develop an economic analysis.

There are many vessels that burn MDO, a blend of mostly distillate with some residual fuel oil. MDO may be burned out of convenience to avoid heavy fuel oil handling efforts, or because the associated engine is not capable of handling the residual fuel oil. However, the fuel cost differential between the MDO and 0.1% distillate fuel oil does not provide adequate increase in cost to shift the advantage to EGCS installation. For example, the Houston price for marine gas oil (most similar to 0.1% sulfur distillate) was only $47.50 more per metric ton than the cost of MDO at $823.50 (bunkerworld.com 11 February 2011).

6.4 Environmental Regulations

EGCS supplied data indicates that the wash water from open-loop style scrubbers is acceptable for discharge into ambient waters in accordance with international wash water guidelines, as well as the United States EPA Vessel General Permit requirements. However, ship operators should be cautioned that the regulation of ship discharges, particularly in the

United States, is subject to uncertainty. For example, several U.S. states have developed ballast water discharge requirements that conflict with international and federal requirements.

Sulfur regulations were initially developed as fuel standards, as the sulfur is not consumed in the combustion process, but rather passes into the air emissions. The EGCS alternative was accepted under the assumption that it would provide a similar level of emissions reductions. However, the sulfur-based fuel standard included an expectation that a significant reduction in particulate matter emissions would also occur. This expectation is not part of either the fuel standards, or the EGCS requirements. This creates uncertainty, as requirements for particulate matter reductions may be included in future EGCS requirements.

It is not clear whether a ship with an EGCS failure will be permitted to continue operations. This will require further analysis and discussion with regulatory authorities as the system installations become more widely implemented. One strategy for the ship operator would be to include an ability to switch-over the low-sulfur diesel fuel in these instances. Alternatively, the ship operator might consider installation approaches that prevent single point failures from impacting propulsion and/or generating capacities.

6.5 Experience Matters

As with any new or developing technology, the ship operator should proceed with caution. The most experienced EGCS suppliers have only a handful of shipboard installations, and most only have a single pilot project. Successful selection, integration design, installation, and commissioning of an EGCS will require careful consideration and significant effort.

The ship operator should expect that an EGCS installation will require ongoing support, and potential upgrades, particularly for early installations. As such, the relationship with the supplier and confidence in continued support are important factors when selecting a system.

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Reference 47 "Prevention of Air Pollution from Ships, Proposed draft changes to resolution MEPC.130(53)," IMO, Marine Environment Protection Committee, 56/4/4, 56th Session, Agenda item 4, 3 May 2007.

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Appendix A Exhaust Scrubber Technology Survey

This Appendix summarizes the Ship Operations Cooperative Program (SOCP) marine exhaust gas cleaning system (EGCS) supplier survey results.

The following information was provided by equipment suppliers, and comprises self-certified data on their system particulars and performance. The purpose of this data is to allow SOCP members to indentify one or more technologies that may be suitable for their ship(s). Members may then contact suppliers directly for detailed integration and commercial discussions.

Response	Description
None	Confirms a zero quantity.
DNA	Inquiry does not apply to technology.
TBD	Inquiry either not answered or unclear.

Vendor Summary

Systems are compared at a high level in the following table. System details are provided on the following pages.

**	Vendor Name	Unit Size* Range (MW)	Claimed Reductions	Land-Based Installs	Shipboard Installs	System Type	System Details
1	Aalborg Industries	1 to 80	99% SO_x 30-80% PM	One: 1 MW	One: 21 MW	Open/Closed Loop Hybrid	p A-2
2	BELCO Clean Air Technologies (Dupont)	2 to 200	>97% SO_x	Multiple: 2 to 200 MW	None	Open Loop & Closed Loop	p A-7
3	Cleanmarine, aka The Torrald Klaveness Group	No response from vendor.					
4	Couple Systems	1 to 60	99% SO_2 60% HC	Multiple: 3 to 100 MW	One: 3.6 MW	Dry EGCS	p A-10
5	Ecospec/CSNOx		99% SO_2 66% NO_x 77% CO_2	One: TBD	One: 5 MW	Open Loop System	p A-13
6	Hamworthy Krystallon	0.5 to 60	99% SO_x 60% PM	Three: 0.4, 1.0 & 2.2 MW	Three: 1.0, 8.5 & 10 MW	Open Loop System	p A-17
7	Marine Exhaust Solutions	0.3 to 5.6	74-80% SO_x	DNA	Nine: Eight at 23 MW, One 15 MW	Open Loop System	p A-21
8.	Wärtsilä Finland Oy	0.68	>99% SO_x	DNA	One: 0.68 MW	Closed Loop System	p A-24

** Unit size refers to diesel engine size served. Boiler units are not considered in this survey.*
*** Vendors are listed alphabetically and not by price or efficiency.*

Aalborg Industries Exhaust Gas Cleaning B.V., 1 of 5 pages

Contact	René Diks, +3 (0)24 352 3100, rdk@aalborg-industries.com Website: www.aalborg-industries.com		
Technology Type(s)	EGC system, Combined Open Loop (Salt Water) and Closed Loop (Fresh Water) No Dry Chemical	**Other Products**	The EGC system can incorporate a venturi system (non standard) to capture PM up to 80%
Exhaust Monitoring IMO Scheme	Scheme B	**Vessel Install Contact**	Olav Knudsen Aalborg Industries
System Availability	1 MW to 50 MW	**Size, Land Based Install**	1 MW, in 2008
Development Phase	Prototype	**Size, Shipboard Install**	21 MW, in 2009
Failure Modes	If an interruption occurs, the bypass valves open and the exhaust gas flow will bypass the EGC system.	**Failure Recovery**	The problem must be solved after which the system will return to normal operation automatically. The EGC can be remotely checked on trouble shooting by Aalborg Industries.

Unit Size* (MW)	Commercially Available (Yes/No)	Land-based Trial (Year/Units)	Shipboard Trial (Year/Units)	Efficiency Results Available (Yes/No)	How Many Hours of Operation?	Notes
1MW	Yes	2008	DNA	Yes	150	Landbased test (in cooperation w/MAN)
21MW	Yes	DNA	2009	Yes	1000	System in test since April 2010 (on *DFDS Tor Ficaria*)

** Unit size refers to diesel engine size served. Boiler units are not considered in this survey.*

System Efficiency Trial Results

Land-Based or Shipboard Trial	Landbased at Holeby (Fresh Water)	**Test Date**	Oct 2008 – Jan 2009
Engine Make/Model	MAN 5L21/31 50Hz	**Rated Power (MW)**	1MW
Fuel Grade (RMG35, RME25, DMB, DMA)	2, 4% S	**Trial Load (MW)**	25-50-75-100%

Fuel Sulfur	SO2	CO2	CO2	PM 2.5	PM	HC	NOx	CO	Back Press
(%)	(ppm)	(%)	(g/kWhr)						(kPa)
Scrubber OFF	431ppm	5.5%	TBD	1	TBD	TBD	1050 PPM	TBD	0
Scrubber ON	4ppm for Closed Loop	5.3%	TBD	0.3-0.8	TBD	TBD	950 PPM	TBD	1-3
Reduction (%)	99%	3-8%	TBD	30-80%	TBD	TBD	5-10%	TBD	TBD

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Land-Based or Shipboard Trial	Shipboard test results will be released Oct 2010	Test Date	TBD
Engine Make/Model	TBD	Rated Power (MW)	TBD
Fuel Grade (RMG35, RME25, DMB, DMA)	TBD	Trial Load (MW)	TBD

	Fuel Sulfur	SO2	CO2	CO2	PM 2.5	PM	HC	NOx	CO	Back Press
	(%)	(ppm)	(%)	(g/kWhr)						(kPa)
Scrubber OFF	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	
Scrubber ON	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	
Reduction (%)	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	

Waste Streams

Wash Water Overboard Discharge	Open Loop System 50 Tons/MW-hr, for Closed Loop 0.1 Tons/MW-hr
Must discharge in port?	No, in closed loop zero discharge
Meets IMO Wash Water Standards?	Yes
Meets EPA Vessel General Permit?	Yes
Meets California Ocean Plan Standards?	TBD
Sludge Residue Quantity	<0.5Kg/MW-hr
Hazardous waste as per EPA?	DNA
Disposal method?	Can be treated as normal sludge.
Solid Waste Quantity	DNA
Hazardous waste as per EPA?	DNA
Disposal method?	DNA

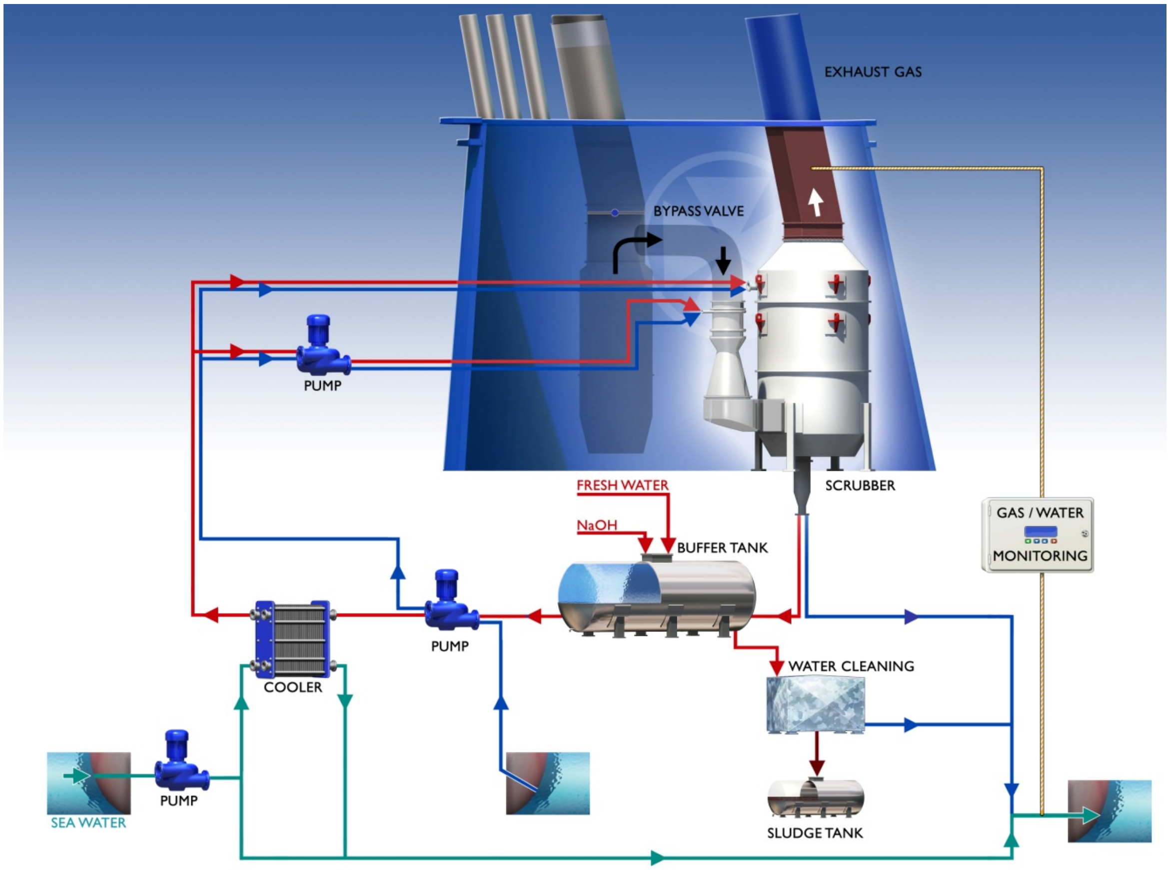
System Details

Unit Size (MW of Engine Served)	**4 MW**
Electrical Load (In Port/In ECA/At Sea) (kW)	In Port 20kW, Open Sea 40kW
Chemical Usage (In Port/In ECA/At Sea)	NaOH (caustic soda), 50% concentration, 27.5Kg/MW-hr (3.5%HFO)
Exhaust Handling: Pressure drop at full load (kPa)	0.5-1Kpa/50-100 mmwc
Does unit serve as silencer/spark arrestor?	Yes
System failure block free flow of exhaust?	No
Multiple engine inlet capable?	Yes
Seawater Supply Quantity (m^3/hr)	270m^3/h
Fresh Water Consumption (m^3/hr)	T=20C, 370 l/h
Steam Supply (kg/hr, kPa)	DNA
Air Supply (kg/hr, kPa)	DNA
Other necessary utilities?	DNA
Component #1 Name	EGC 36
Weight in kilograms (Dry/Wet)	Dry 11T/Wet 13T
Size in meters (Width/Depth/Height)	Diameter = 2.0m/W=3.5m/H=5.6m
Access required in meters (Front/Side/Top)	TBD

Unit Size (MW of Engine Served)	**8 MW**
Electrical Load (In Port/In ECA/At Sea) (kW)	In Port 40kW, Open Sea 80kW
Chemical Usage (In Port/In ECA/At Sea)	NaOH (caustic soda), 50% concentration, 27.5Kg/MW-hr (3.5%HFO)
Exhaust Handling: Pressure drop at full load (kPa)	0.5-1Kpa/50-100 mmwc
Does unit serve as silencer/spark arrestor?	Yes
System failure block free flow of exhaust?	No
Multiple engine inlet capable?	Yes
Seawater Supply Quantity (m^3/hr)	540m^3/h
Fresh Water Consumption (m^3/hr)	T=20C, 740 l/h
Steam Supply (kg/hr, kPa)	DNA
Air Supply (kg/hr, kPa)	DNA
Other necessary utilities?	DNA
Component #1 Name	EGC 73
Weight in kilograms (Dry/Wet)	Dry 15T/Wet 18T
Size in meters (Width/Depth/Height)	Diameter = 2.9m/W=4.9m/H=7.0m
Access required in meters (Front/Side/Top)	TBD

Unit Size (MW of Engine Served)	**16 MW**
Electrical Load (In Port/In ECA/At Sea) (kW)	In Port 80kW, Open Sea 160kW
Chemical Usage (In Port/In ECA/At Sea)	NaOH (caustic soda), 50% concentration, 27.5Kg/MW-hr (3.5%HFO)
Exhaust Handling: Pressure drop at full load (kPa)	0.5-1 Kpa / 50-100 mmwc
Does unit serve as silencer/spark arrestor?	Yes
System failure block free flow of exhaust?	No
Multiple engine inlet capable?	Yes
Seawater Supply Quantity (m^3/hr)	1080 m^3/h
Fresh Water Consumption (m^3/hr)	T=20C, 1480 l/h
Steam Supply (kg/hr, kPa)	DNA
Air Supply (kg/hr, kPa)	DNA
Other necessary utilities?	DNA
Component #1 Name	EGC 146
Weight in kilograms (Dry/Wet)	Dry 23T/Wet 29T
Size in meters (Width/Depth/Height)	Diameter = 4m/W=6.7m/H=9m
Access required in meters (Front/Side/Top)	TBD

Unit Size (MW of Engine Served)	**32 MW**
Electrical Load (In Port/In ECA/At Sea) (kW)	In Port 160kW, Open Sea 320kW
Chemical Usage (In Port/In ECA/At Sea)	NaOH (caustic soda), 50% concentration, 27.5Kg/MW-hr (3.5%HFO)
Exhaust Handling: Pressure drop at full load (kPa)	0.5-1 Kpa / 50-100 mmwc
Does unit serve as silencer/spark arrestor?	Yes
System failure block free flow of exhaust?	No
Multiple engine inlet capable?	Yes
Seawater Supply Quantity (m^3/hr)	2160 m^3/h
Fresh Water Consumption (m^3/hr)	T=20C, 2960 l/h
Steam Supply (kg/hr, kPa)	DNA
Air Supply (kg/hr, kPa)	DNA
Other necessary utilities?	DNA
Component #1 Name	EGC 292
Weight in kilograms (Dry/Wet)	Dry 38T/Wet 52T
Size in meters (Width/Depth/Height)	Diameter = 5.9m/W=10.6m/H=11.6m
Access required in meters (Front/Side/Top)	TBD



System Description *(Provided by Supplier)*

Aalborg Industries has more than 30 years of experience of supplying scrubbers as an integrated part of Inert Gas Systems (IGS) onboard ships. During 2008, our experiences from these systems in combination with our experiences from supplying exhaust gas boilers after large marine diesel engines were used to design a scrubber test rig to cool and clean the exhaust from a test engine at MAN Diesel test facility in Denmark. The knowledge and experience from these tests were successively used to design an entire exhaust gas cleaning system (EGS) onboard DFDS' Ro-Ro vessel "Tor Ficaria." Installed after the 21 MW MAN engine, it is by far the world's largest exhaust gas cleaning system installed onboard a ship. The design work has been carried out in close co-operation with the marine engineers from DFDS and MAN Diesel.

The EGC system is a combined wet scrubbing system being able to operate in ***sea water (open loop)*** and ***fresh water (closed*** loop). At open sea, the system operates with sea water and saves the use of NaOH and fresh water. In harbours and estuaries with strict discharge criteria, the system can operate on fresh water in a closed loop system. The combined EGC system offers therefore maximum flexibility combined with the lowest operational costs. In addition, our Exhaust Gas Scrubber is:

- A cost-saving solution (able to operate on HFO instead of expensive low sulphur MDO/MGO)
- In compliance with MARPOL Annex VI – MEPC 58 and 59
- Provides a sulphur removal rate >98% (exceeding the IMO requirements)
- Traps up to 80% of Particulate Matter (PM)

BELCO Technologies, 1 of 3 pages

Plus 1 Attachment: BELCO Installation List

Contact	Garrett Billemeyer, (973) 515-8902, billemeyer@belcotech.com Website: http://belcotech.dupont.com		
Technology Type(s)	EDV, Open Loop and Closed Loop No Dry Chemical	**Other Products**	Wet Electrostatic Precipitators, Dry Electrostatic Precipitators, Semi-dry Scrubbers, TSS and FSS, SCR Syssterms, LoTOx Systems, LABSORB Regenerative SO_2 Scrubbing Systems.
Exhaust Monitoring IMO Scheme	TBD	**Vessel Install Contact**	TBD
System Availability	2 MW to 200 MW	**Size, Land Based Install**	TBD
Development Phase	Commercial	**Size, Shipboard Install**	TBD
Failure Modes	The Scrubber is designed to run dry and continuously for plus five years. Interrupted operations are not an issue.	**Failure Recovery**	NA

Unit Size* (MW)	Commercially Available (Yes/No)	Land-based Trial (Year/Units)	Shipboard Trial (Year/Units)	Efficiency Results Available (Yes/No)	How Many Hours of Operation?	Notes
List of land-based industrial applications available upon request.						

** Unit size refers to diesel engine size served. Boiler units are not considered in this survey.*

System Efficiency Trial Results

Land-Based or Shipboard Trial	Shipboard	**Test Date**	TBD
Engine Make/Model	11,349 kW Engine	**Rated Power (MW)**	TBD
Fuel Grade (RMG35, RME25, DMB, DMA)	3% Sulfur Diesel	**Trial Load (MW)**	514 RPM

Fuel Sulfur	SO2	CO2	CO2	PM 2.5	PM	HC	NOx	CO	Back Press
(%)	(ppm)	(%)	(g/kWhr)						(kPa)
Scrubber OFF	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	0.6
Scrubber ON	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	0
Reduction (%)	> 97%	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD

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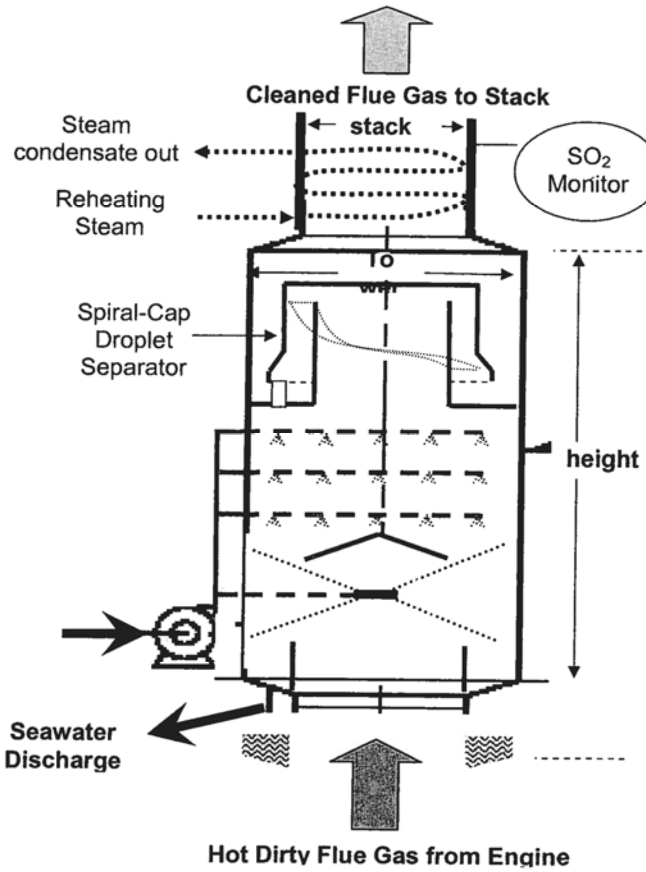
Waste Streams

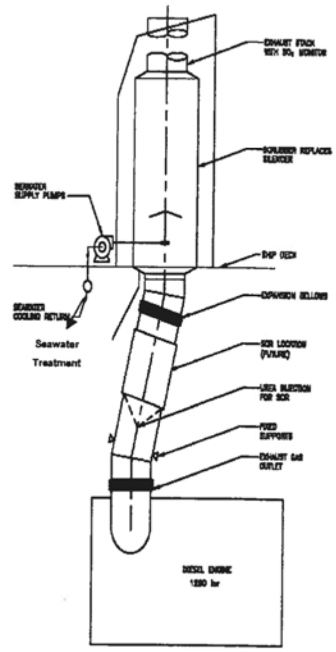
Wash Water Overboard Discharge	Dependant on Inlet SOx/Fuel
Must discharge in port?	No overboard discharge
Meets IMO Wash Water Standards?	Yes
Meets EPA Vessel General Permit?	Yes
Meets California Ocean Plan Standards?	Yes
Sludge Residue Quantity	Dependant on engine operation and fuel usage
Hazardous waste as per EPA?	Dependant on fuel source – no solid waste generated
Disposal method?	Occasionally offloaded to waste hauler
Solid Waste Quantity	0
Hazardous waste as per EPA?	We comply with all IMO regulations on waste streams
Disposal method?	None generated

System Details

All system details are based on specific design conditions.

Unit Size (MW of Engine Served)	TBD
Electrical Load (In Port/In ECA/At Sea) (kW)	TBD
Chemical Usage (In Port/In ECA/At Sea)	TBD
Exhaust Handling: Pressure drop at full load (kPa)	TBD
Does unit serve as silencer/spark arrestor?	TBD
System failure block free flow of exhaust?	TBD
Multiple engine inlet capable?	TBD
Seawater Supply Quantity (m^3/hr)	TBD
Fresh Water Consumption (m^3/hr)	TBD
Steam Supply (kg/hr, kPa)	TBD
Air Supply (kg/hr, kPa)	TBD
Other necessary utilities?	TBD
Component #1 Name	TBD
Weight in kilograms (Dry/Wet)	TBD
Size in meters (Width/Depth/Height)	TBD
Access required in meters (Front/Side/Top)	TBD





SHIP POLLUTION CONTROL SCRUBBER

08P084–03–A–01

System Description *(Provided by Supplier)*

The Benefits of BELCO® Marine Scrubbing Systems include:

- Reliable and cost effective design — designed specifically for your vessels in conjunction with your engineering staff
- Open tower design. Able to operate uninterrupted for many years concurrent with required dry dockings. No concern with plugging or maintenance shutdowns while at sea
- No hot by-pass required
- High efficiency of pollutant removal
- Helps meet all IMO, SECA, EPA regulations, even when using high sulfur fuels • Designed to withstand upset conditions and temperature excursions
- Designed to operate without shutdowns for periods in excess of 5 years
- Able to use various reagents and regenerative buffers
- Low pressure drop design
- High reliability and durability
- High efficiency

Aftermarket Services and Spare Parts include:

- Proprietary components
- Replacement parts
- Start-up support
- Troubleshooting
- Construction advisors

Couple Systems GmbH, 1 of 3 pages

Contact	Ralf Jürgens, +49 40 526000921, rj@couple-systems.com Website: www.couple-systems.com

Technology Type(s)	DryEGCS	**Other Products**	DryEGCS can easily be combined with SCR technology offered by Couple Systems. It does not require any additional reheating. Also, PM app. 80 %, HC app. 60 %
Exhaust Monitoring IMO Scheme	B	**Vessel Install Contact**	Shipowner Braren www.reedereibraren.de
System Availability	1MW up to 60MW	**Size, Land Based Install**	3MW up to 100MW
Development Phase	Commercial	**Size, Shipboard Install**	3.6MW
Failure Modes	Close exhaust gas dampers	**Failure Recovery**	Close exhaust gas dampers

Unit Size* (MW)	Commercially Available (Yes/No)	Land-based Trial (Year/Units)	Shipboard Trial (Year/Units)	Efficiency Results Available (Yes/No)	How Many Hours of Operation?	Notes
3.6	Yes	DNA	2009/1	99%	3500	TBD

** Unit size refers to diesel engine size served. Boiler units are not considered in this survey.*

System Efficiency Trial Results

Land-Based or Shipboard Trial	Shipboard	**Test Date**	2009/12/1
Engine Make/Model	MaK8M32	**Rated Power (MW)**	3.6
Fuel Grade (RMG35, RME25, DMB, DMA)	HFO 0.9%S	**Trial Load (MW)**	1.2

Fuel Sulfur	SO2	CO2	CO2	PM 2.5	PM	HC	NOx	CO	Back Press
(%)	(ppm)	(%)	(g/kWhr)						(kPa)
Scrubber OFF	258	6.44	TBD	TBD	TBD	113	1065	98	DNA
Scrubber ON	1	6.31	TBD	TBD	TBD	45	1054	153	0.8 across Scrubber
Reduction (%)	99%	DNA	TBD	TBD	TBD	60	DNA	DNA	TBD

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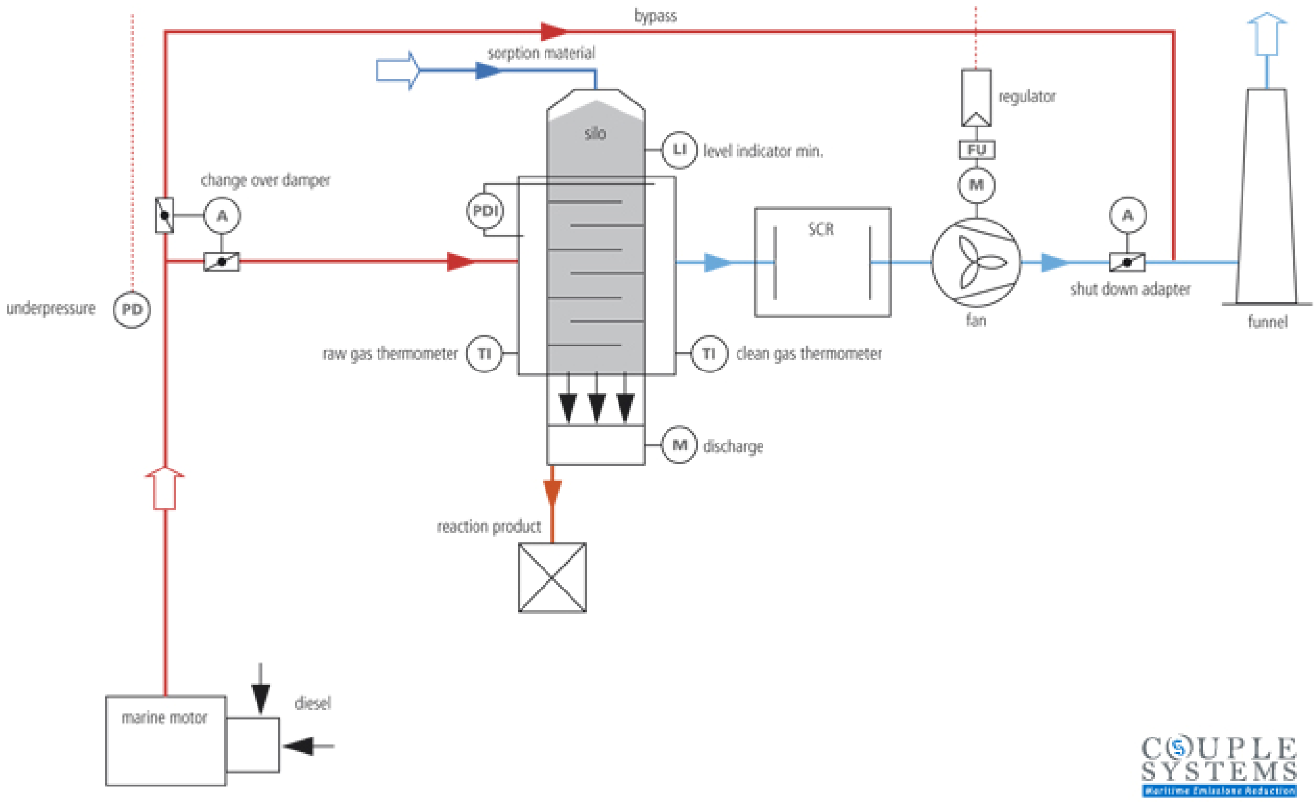
Waste Streams

Wash Water Overboard Discharge	DNA
Must discharge in port?	DNA
Meets IMO Wash Water Standards?	DNA
Meets EPA Vessel General Permit?	DNA
Meets California Ocean Plan Standards?	DNA
Sludge Residue Quantity	DNA
Hazardous waste as per EPA?	DNA
Disposal method?	DNA
Solid Waste Quantity	DNA
Hazardous waste as per EPA?	DNA
Disposal method?	DNA

System Details

Unit Size (MW of Engine Served)	**4MW**
Electrical Load (In Port/In ECA/At Sea) (kW)	12/12/12
Chemical Usage (In Port/In ECA/At Sea)	Calcium Hydroxide, 99%, .05 Tons/MW-hr, 50 Kg/h, 50 Kg/h, 0
Exhaust Handling: Pressure drop at full load (kPa)	1
Does unit serve as silencer/spark arrestor?	Yes
System failure block free flow of exhaust?	No
Multiple engine inlet capable?	Yes
Seawater Supply Quantity (m^3/hr)	DNA
Fresh Water Consumption (m^3/hr)	DNA
Steam Supply (kg/hr, kPa)	DNA
Air Supply (kg/hr, kPa)	DNA
Other necessary utilities?	DNA
Component #1 Name	DryEGCS Absorber
Weight in kilograms (Dry/Wet)	57,000
Size in meters (Width/Depth/Height)	3.85/5.60/7.80
Access required in meters (Front/Side/Top)	0.6/0.6/0.5
Component #2 Name	Supply and Discharge System
Weight in kilograms (Dry/Wet)	24,000
Size in meters (Width/Depth/Height)	2.40/2.40/6.0
Access required in meters (Front/Side/Top)	0.6/0.6/0.5



System Description *(Provided by Supplier)*

Couple Systems GmbH, Bardowick, Germany, brought the worldwide first and only dry system for the desulphurisation of exhaust gases of commercial vessels successfully into service on *MS Timbus*. Motorenwerke Bremerhaven (MWB AG) was able to install the system in less than a week's time with high precision and impeccable workmanship on the cellulose freighter MS Timbus (MaK 8M32, 3.6 MW) of the shipowning company Reederei Braren, Kollmar, Germany. Germanischer Lloyd (GL) has now taken outstanding test readings on the system. This clearly proves the feasibility of the DryEGCS ® on board ships and the full compliance of the system with the requirements with of Marpol Annex VI. Couple Systems GmbH provides a technical solution, proven and readily available to shipping. A continuation of the HFO-era is ecologically possible. A Return-on-Invest when purchasing a DryEGCS® in the light of today's fuel prices, for ships that mainly navigate in the ECA North- and Baltic-Sea, is possible in one year.

The 240° to 350°C hot exhaust gas, which contains SO2 and SO3, is fed through a packed-bed absorber filled with lime (calcium hydroxide Ca(OH)2) in the form of granulate pellets. The reaction product is CaSO4 i.e. gypsum. The spherical form of the granulate is retained. The ship's ballast chambers, cargo space, and other open, storage areas on the ship provide storage for recyclables. DryEGCS® is dimensioned conservatively so that the collection efficiency is reliably achieved. The loading limit for the calcium hydroxide granulate is about 60%. Thus the absorbent material retains a considerable residual activity for desulphurisation. Alternatively, the residues can be used as mine filling. In this case, costs of approximately US-$ 100 per metric ton can be expected.

Ecospec, 1 of 4 pages

Contact	Tany Tay, +65 6602 9600, tany@ecospec.com Website: www.ecospec.com		
Technology Type(s)	CSNOx, an Ultra-Low Frequency Electrolysis System	**Other Products**	TBD
Exhaust Monitoring IMO Scheme	TBD	**Vessel Install Contact**	TBD
System Availability	TBD	**Size, Land Based Install**	TBD
Development Phase	TBD	**Size, Shipboard Install**	11MW
Failure Modes	TBD	**Failure Recovery**	TBD

Unit Size* (MW)	Commercially Available (Yes/No)	Land-based Trial (Year/Units)	Shipboard Trial (Year/Units)	Efficiency Results Available (Yes/No)	How Many Hours of Operation?	Notes
TBD	TBD	2009/1	DNA	Yes	TBD	
5MW	TBD	DNA	2010	Yes	TBD	

** Unit size refers to diesel engine size served. Boiler units are not considered in this survey.*

System Efficiency Trial Results

Land-Based or Shipboard Trial	Shore-Based Test Rig	**Test Date**	2009
Engine Make/Model	TBD	**Rated Power (MW)**	TBD
Fuel Grade (RMG35, RME25, DMB, DMA)	TBD	**Trial Load (MW)**	TBD

Fuel Sulfur	SO2	CO2	CO2	PM 2.5	PM	HC	NOx	CO	Back Press
(%)	(ppm)	(%)	(g/kWhr)						(kPa)
Scrubber OFF	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Scrubber ON	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Reduction (%)	99%	30-55%	TBD	TBD	TBD	TBD	50-80%	TBD	TBD

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Land-Based or Shipboard Trial	Shipboard, Aframax Tanker	**Test Date**	2010
Engine Make/Model	Main Engine, 100,000-Tonne Oil Tanker	**Rated Power (MW)**	11MW
Fuel Grade (RMG35, RME25, DMB, DMA)	380 cSt, 3.64% Sulfur	**Trial Load (MW)**	5MW

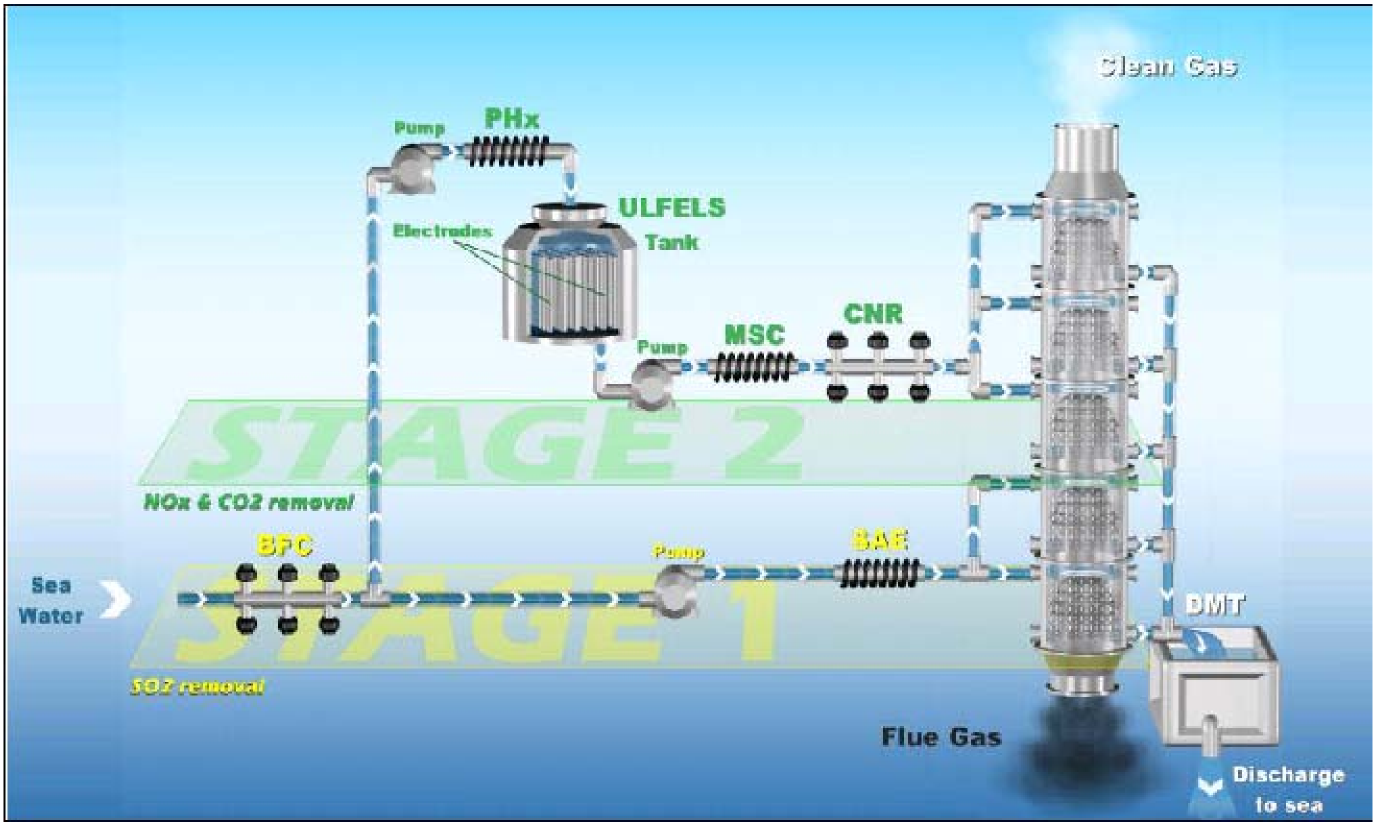
Fuel Sulfur	SO2	CO2	CO2	PM 2.5	PM	HC	NOx	CO	Back Press
(%)	(ppm)	(%)	(g/kWhr)						(kPa)
Scrubber OFF	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Scrubber ON	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Reduction (%)	98.6-98.9%	76.5-77.1%	TBD	TBD	TBD	TBD	64.5-66.2%	TBD	TBD

Waste Streams

Wash Water Overboard Discharge	Yes
Must discharge in port?	TBD
Meets IMO Wash Water Standards?	Yes
Meets EPA Vessel General Permit?	Yes
Meets California Ocean Plan Standards?	Yes
Sludge Residue Quantity	pH 6.7, PAH <1 ppb, Nitrates <0.066mg/l (ppm), Turbidity Δ8.7 NTU
Hazardous waste as per EPA?	TBD
Disposal method?	TBD
Solid Waste Quantity	TBD
Hazardous waste as per EPA?	TBD
Disposal method?	TBD

System Details

Unit Size (MW of Engine Served)	**5MW**
Electrical Load (In Port/In ECA/At Sea) (kW)	TBD
Chemical Usage (In Port/In ECA/At Sea)	None
Exhaust Handling: Pressure drop at full load (kPa)	TBD
Does unit serve as silencer/spark arrestor?	TBD
System failure block free flow of exhaust?	TBD
Multiple engine inlet capable?	TBD
Seawater Supply Quantity (m^3/hr)	TBD
Fresh Water Consumption (m^3/hr)	TBD
Steam Supply (kg/hr, kPa)	TBD
Air Supply (kg/hr, kPa)	TBD
Other necessary utilities?	TBD
Component #1 Name	TBD
Weight in kilograms (Dry/Wet)	TBD
Size in meters (Width/Depth/Height)	TBD
Access required in meters (Front/Side/Top)	TBD



System Description *(Provided by Supplier)*

ABS, one of the world's leading classification societies, has issued a statement on 8 February 2010 verifying the results of sulphur dioxide (SO2), carbon dioxide (CO2), nitrogen oxide (NOx) removal from the emissions of a trading 100,000-tonne Aframax tanker installed with the CSNOx gas abatement system. In the first load point verifications, part of the ongoing IMO Type Approval certification process, conducted during the last week of January 2010 onboard this 100,000-tonne oil tanker, at 50% gas load (equivalent to approximately 5 MW engine output), ABS issued a Statement of Fact on the performance of CSNOx system with the following results:

Fuel: Type Temperature Sulfur Content
380 cSt 50°C 3.64%

Removal SO2 CO2 NOx: efficiencies: 98.6% - 98.9% 76.5% - 77.1% 64.5% - 66.2%

Exhaust gas: Inlet Outlet: 212.3°C 33.5°C

Wash water pH PAH Nitrates Temperature Turbidity Quality: 6.7 <1 ppb <0.066mg/l (ppm) 32°C Δ8.7 NTU

This 100,000-tonne Singapore-registered oil tanker, which is owned and managed by leading shipping company Tanker Pacific, set sail from Singapore, travelling to the Middle East via Sri Lanka. Significantly, the removal efficiencies of the CSNOx system allows vessels installed with CSNOx to continue using normal heavy fuel and yet meet the 0.1% sulfur content as required by the EU Directive effective from 1 January 2010. The removal efficiency for NOx is the absolute reduction percentage. After translating this removal efficiency into the NOx emission requirement as per the Tier 1, 2 or 3 requirements, the CSNOx system is able to remove NOx to such levels that vessels installed with it are able to meet even the strictest Tier 3 requirement. CSNOx truly is a cost-effective and efficient solution for solving the emission issues faced by the ship owners. In addition, the results also affirm CSNOx scalability and suitability for a normal ship's operations.

Hamworthy Krystallon Ltd /Hamworthy Moss, 1 of 4 pages

Contact	Heidi Marie Johannessen, +47 6927 9900, hkjohannessen@hamworthy.com Website: http://www.hamworthy.com/en/Products-Systems/Hamworthy-Marine/Emissions-Reduction/Exhaust-Gas-Cleaning/		
Technology Type(s)	Open Loop (Closed Loop under Development) No Dry Chemical Hybrid Wet Solution Available	**Other Products**	The Hamworthy Krystallon SOx scrubber also acts as a Particulates scrubber. Stand alone PM scrubbers also available
Exhaust Monitoring IMO Scheme	Scheme B	**Vessel Install Contact**	TBD
System Availability	0.5 MW to 60 MW	**Size, Land Based Install**	0.4MW, 1MW, 2.2MW
Development Phase	Commercial	**Size, Shipboard Install**	1MW, 6MW, 8.5MW,
Failure Modes	Power loss, multiple supply pump failure, leakage (return pipes or scrubber), clogging of the wet filter.	**Failure Recovery**	If the issue is with the supply or return pump, then the system can be restarted as soon as the pump is repaired.

Unit Size* (MW)	Commercially Available (Yes/No)	Land-based Trial (Year/Units)	Shipboard Trial (Year/Units)	Efficiency Results Available (Yes/No)	How Many Hours of Operation?	Notes
0.5	Yes	2005/1		Yes	500	Test Unit
1	Yes	2008/1	2005/1	Yes	30,000	
2	Yes	2008/1		No	0	Power Plant installation not yet finished
6	No		1993/1	Yes	8000	Initial Hamworthy design
8	Yes		2007/1	Yes	4000	

** Unit size refers to diesel engine size served. Boiler units are not considered in this survey.*

System Efficiency Trial Results

Land-Based or Shipboard Trial	Land Based	**Test Date**	2009
Engine Make/Model	DM "MTE40"	**Rated Power (MW)**	0.9MW
Fuel Grade (RMG35, RME25, DMB, DMA)	TBD	**Trial Load (MW)**	Various

Fuel Sulfur	SO2	CO2	CO2	PM 2.5	PM	HC	NOx	CO	Back Press
(%)	(ppm)	(%)	(g/kWhr)						(kPa)
Scrubber OFF	340 ppm	DNA	DNA	TBD	TBD	TBD	TBD	TBD	TBD
Scrubber ON	4 ppm	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Reduction (%)	99%	TBD	TBD	DNA	60%	DNA	DNA	DNA	25

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Land-Based or Shipboard Trial	Shipboard	Test Date	2009
Engine Make/Model	Sulzer 6ATL25H	Rated Power (MW)	0.8MW
Fuel Grade (RMG35, RME25, DMB, DMA)	IF380	Trial Load (MW)	TBD

Fuel Sulfur	SO2	CO2	CO2	PM 2.5	PM	HC	NOx	CO	Back Press
(%)	(ppm)	(%)	(g/kWhr)						(kPa)
Scrubber OFF	330 ppm	DNA	DNA	TBD	TBD	TBD	TBD	TBD	TBD
Scrubber ON	12 ppm	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Reduction (%)	96.5%	TBD	TBD	DNA	60%	DNA	DNA	DNA	25

Land-Based or Shipboard Trial	Shipboard	Test Date	2010
Engine Make/Model	Sulzer 12VZA40S	Rated Power (MW)	0.8MW
Fuel Grade (RMG35, RME25, DMB, DMA)	IF380	Trial Load (MW)	7.4

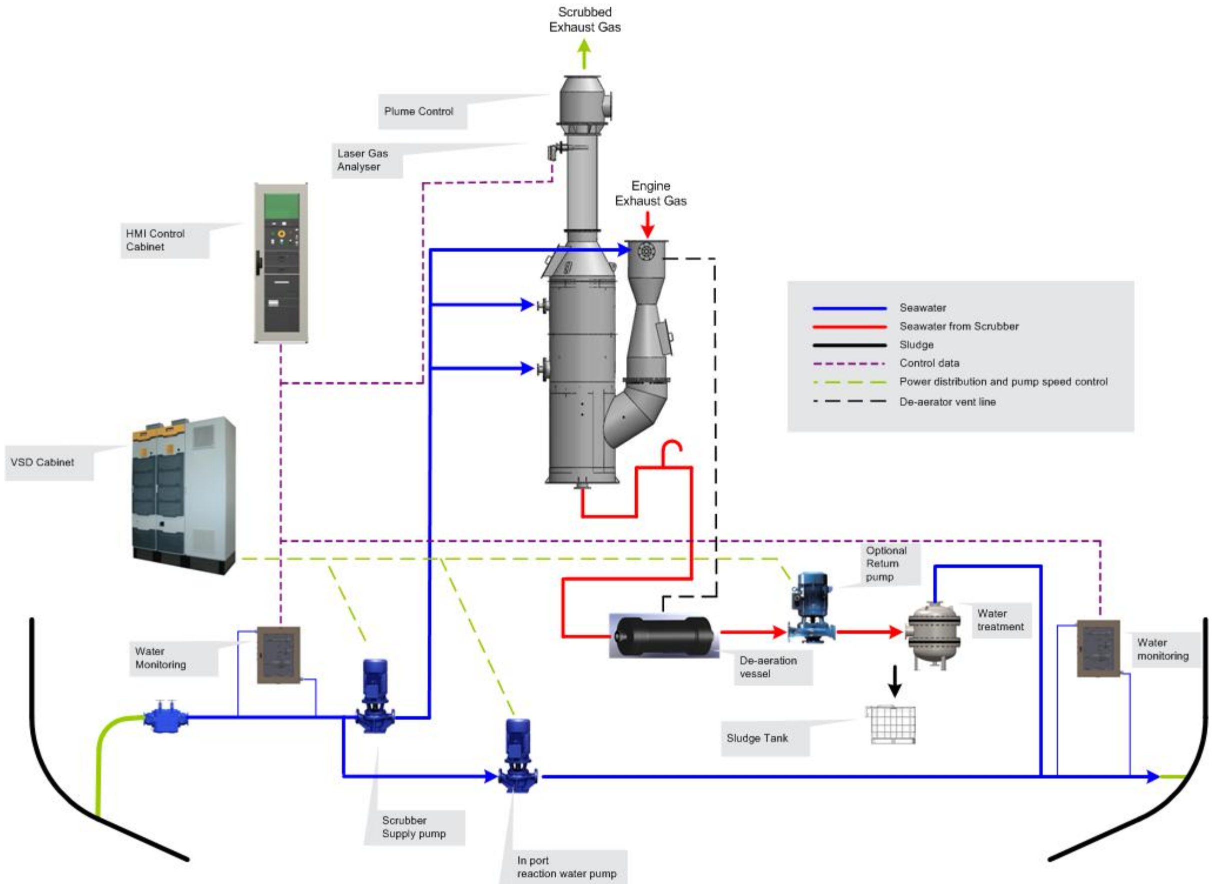
Fuel Sulfur	SO2	CO2	CO2	PM 2.5	PM	HC	NOx	CO	Back Press
(%)	(ppm)	(%)	(g/kWhr)						(kPa)
Scrubber OFF	340ppm	DNA	DNA	TBD	TBD	TBD	TBD	TBD	TBD
Scrubber ON	4ppm	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Reduction (%)	99%	TBD	TBD	DNA	60%	DNA	DNA	DNA	25

Waste Streams

Wash Water Overboard Discharge	45 Tons/MW-hr
Must discharge in port?	Yes
Meets IMO Wash Water Standards?	Yes
Meets EPA Vessel General Permit?	Yes
Meets California Ocean Plan Standards?	Meets MARPOL Annex VI
Sludge Residue Quantity	<0.1kg/MW.hr
Hazardous waste as per EPA?	No
Disposal method?	1) With ships waste oil, and 2) In portable containers
Solid Waste Quantity	0
Hazardous waste as per EPA?	DNA
Disposal method?	DNA

System Details

Unit Size (MW of Engine Served)	**8 MW**
Electrical Load (In Port/In ECA/At Sea) (kW)	75/120/120
Chemical Usage (In Port/In ECA/At Sea)	0
Exhaust Handling: Pressure drop at full load (kPa)	20 kPa
Does unit serve as silencer/spark arrestor?	Yes
System failure block free flow of exhaust?	Yes
Multiple engine inlet capable?	Yes
Seawater Supply Quantity (m^3/hr)	360 m^3/hr @ 600kPa
Fresh Water Consumption (m^3/hr)	0
Steam Supply (kg/hr, kPa)	450 kg/hr(deplume)@100kPa
Air Supply (kg/hr, kPa)	For instruments only
Other necessary utilities?	DNA
Component #1 Name	2MW
Weight in kilograms (Dry/Wet)	3500/4750 kg
Size in meters (Width/Depth/Height)	1.4/1.4/5
Access required in meters (Front/Side/Top)	600 mm
Exhaust Handling: Pressure drop at full load (kPa)	8 MW
Does unit serve as silencer/spark arrestor?	Yes
System failure block free flow of exhaust?	No
Multiple engine inlet capable?	Yes



System Description *(Provided by Supplier)*

The Hamworthy Krystallon sea water scrubbing technology will remove more than 98% of sulphur along with the majority of particulate matter from a 3.5% sulphur residual fuel. The technology is suitable for both new build and retrofit applications, and will deliver ease of operation and low maintenance costs. The technology is available for a wide range of vessel and engine configurations. Hamworthy Krystallon can offer;

1. Pre-installation design support and shipyard supervision
2. A full post-installation commissioning service
3. After sales and service support through Hamworthy's extensive service network worldwide
4. Access to innovative project financing and fuels supply risk management

The Sea Water Scrubber unit is manufactured from high nickel chrome alloy steels ensuring long lifetime and reliable operation. It can fit into the funnel space being both lightweight and self supporting. Whilst the Scrubber is designed to run cool, operating on a constant supply of sea water, under emergency conditions it can be operated at temperatures of up to 450°C. It also provides for silencing of the engine exhaust noise, and may therefore replace a typical exhaust gas silencer. The main sea water intake pipe work is manufactured from glass reinforced epoxy. This provides high corrosion resistance, low flow losses, light weight, and ease of installation. Water is transferred around the system via Hamworthy's own trusted centrifugal pumps.

The wash water treatment system will handle the full Scrubber Unit water flow. It is designed to remove both solid particulate matter and liquid hydrocarbon waste products. All exposed materials and wash water transfer pipe work are also manufactured from corrosion proof glass reinforced epoxy. The high efficiency design complies with the requirements of MARPOL Annex VI Regulation 14 Sea Water Scrubbing Wash Water Criteria.

Hamworthy has over 25 years experience of sea water scrubbing through its Inert Gas operation in Moss. Our knowledge and detailed engineering capability allied with Hamworthy Krystallon technology is unique in the marine market place.

Marine Exhaust Solutions, 1 of 3 pages

Contact	Robert Clarke, (506) 214-0535, rclarke@marineexhaustsolutions.com Website: www.marineexhaustsolutions.com		
Technology Type(s)	Seawater Scrubbing System	**Other Products**	J series for PM reduction on diesel fuel engines, NOx reduction unit for MAN Diesel.
Exhaust Monitoring IMO Scheme	TBD	**Vessel Install Contact**	TBD
System Availability	TBD	**Size, Land Based Install**	DNA
Development Phase	TBD	**Size, Shipboard Install**	1.2 to 5.6MW
Failure Modes	Water carryover prevented full time running during tests.	**Failure Recovery**	Run in dry mode until fixed.

Unit Size* (MW)	Commercially Available (Yes/No)	Land-based Trial (Year/Units)	Shipboard Trial (Year/Units)	Efficiency Results Available (Yes/No)	How Many Hours of Operation?	Notes
22.7	No	DNA	2003/8	Yes	11,680	
15.0	TBD	DNA	2001	Yes	TBD	Trials spanned 6 mos.

** Unit size refers to diesel engine size served. Boiler units are not considered in this survey.*

System Efficiency Trial Results

Land-Based or Shipboard Trial	Shipboard, RORO ferry	**Test Date**	March 2003
Engine Make/Model	Two engine packages, type TBD	**Rated Power (MW)**	Four 5.6MW mains and four 1.2MW auxiliary engines
Fuel Grade (RMG35, RME25, DMB, DMA)	Heavy Fuel 2.4% Sulfur	**Trial Load (MW)**	22.7

Fuel Sulfur	SO2	CO2	CO2	PM 2.5	PM	HC	NOx	CO	Back Press
(%)	(ppm)	(%)	(g/kWhr)						(kPa)
Scrubber OFF	235T/yr	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Scrubber ON	59T/yr	TBD	TBD	TBD	TBD	TBD	TBD	TBD	In Limits
Reduction (%)	74-80%	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD

Land-Based or Shipboard Trial	Shipboard, Ferry	**Test Date**	2001
Engine Make/Model	TBD	**Rated Power (MW)**	1.5MW
Fuel Grade (RMG35, RME25, DMB, DMA)	Heavy Fuel 2.4% Sulfur	**Trial Load (MW)**	TBD

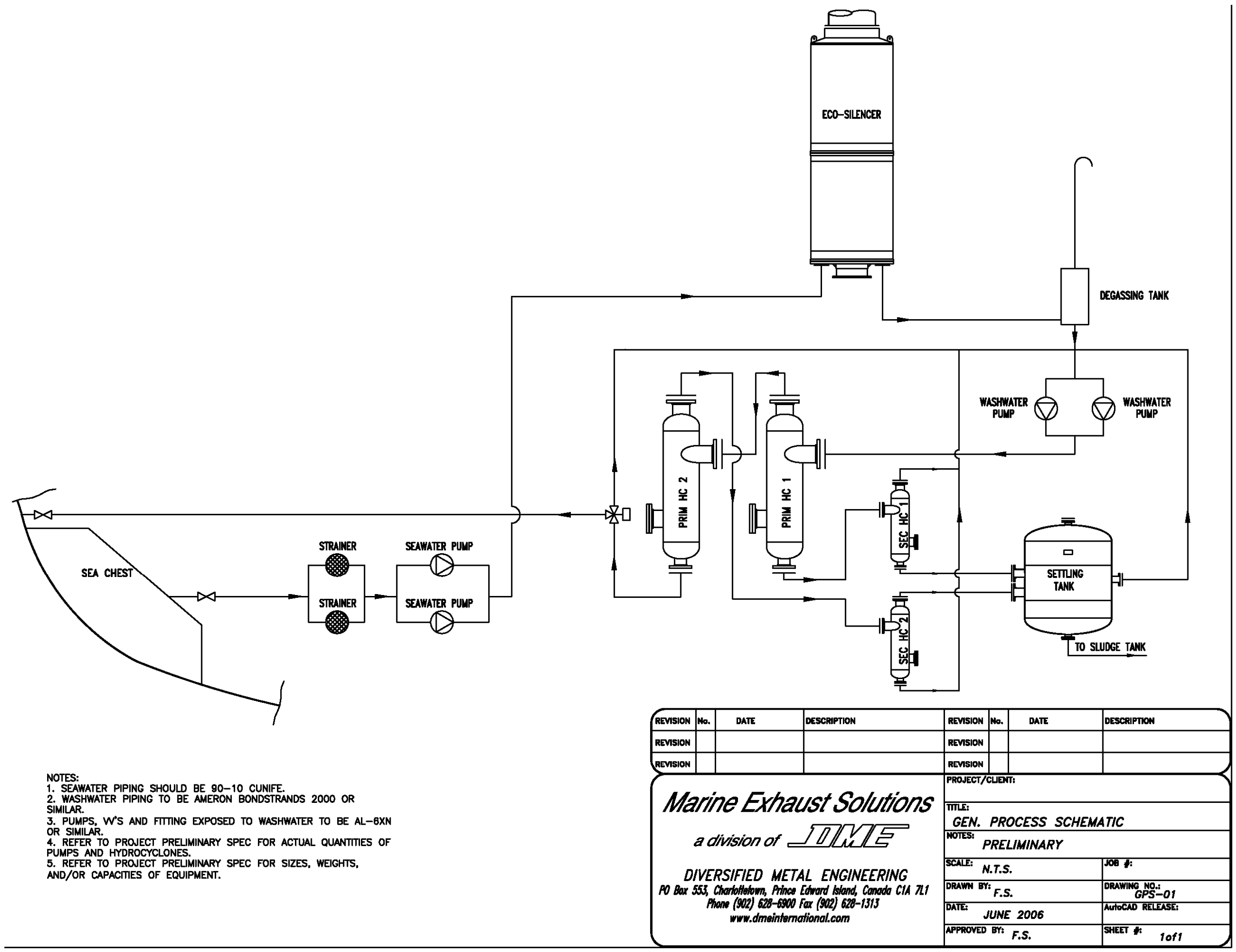
Fuel Sulfur	SO2	CO2	CO2	PM 2.5	PM	HC	NOx	CO	Back Press
(%)	(ppm)	(%)	(g/kWhr)						(kPa)
Scrubber OFF	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Scrubber ON	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Reduction (%)	90%	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD

Waste Streams

Wash Water Overboard Discharge	Yes
Must discharge in port?	No
Meets IMO Wash Water Standards?	Yes
Meets EPA Vessel General Permit?	Yes
Meets California Ocean Plan Standards?	TBD
Sludge Residue Quantity	0.6T/week
Hazardous waste as per EPA?	TBD
Disposal method?	Onshore
Solid Waste Quantity	0.6T/week
Hazardous waste as per EPA?	TBD
Disposal method?	Onshore

System Details

Unit Size (MW of Engine Served)	**TBD**
Electrical Load (In Port/In ECA/At Sea) (kW)	TBD
Chemical Usage (In Port/In ECA/At Sea)	TBD
Exhaust Handling: Pressure drop at full load (kPa)	TBD
Does unit serve as silencer/spark arrestor?	TBD
System failure block free flow of exhaust?	TBD
Multiple engine inlet capable?	TBD
Seawater Supply Quantity (m^3/hr)	TBD
Fresh Water Consumption (m^3/hr)	TBD
Steam Supply (kg/hr, kPa)	TBD
Air Supply (kg/hr, kPa)	TBD
Other necessary utilities?	TBD
Component #1 Name	TBD
Weight in kilograms (Dry/Wet)	TBD
Size in meters (Width/Depth/Height)	TBD
Access required in meters (Front/Side/Top)	TBD



System Description *(Provided by Supplier)*

Throughout the 16-month trials onboard the RORO passenger ferry, the auxiliary engines were operational for approximately 11680 hours and consumed 6272 tonnes of fuel. During this time, based on a reduction rate of 75%, the EcoSilencer® removed 235.5 of the 314 Tonnes of SO2. In particular:

- A sustainable SO2 removal level of 74% – 80% was obtained with a maximum/minimum range of 94% to 68%.
- The target removal of 90% was only achievable by overcharging the existing water circulation system. Proposed modifications to the circulating water system are expected to result in higher SO2 removal without the necessity of overcharging.
- Tests showed the overboard water discharge complies with USA EPA test criteria.
- Engine performance was not compromised. System backpressures remained within the engines' accepted limits.
- No indication of an increase in engine fuel consumption was noted.
- Soot sludge removal amounted to approximately 0.6 T/week and was easily handled as part of the ships regular onshore waste disposal.
- Minimal system maintenance was required. Routine maintenance consisted of, periodical boroscope type inspections, water circulation pump maintenance and periodical cleaning of the level measuring probes.
- Further trials are needed to confirm the design modifications that will achieve the targeted 90% SO2 removal rates for the main engines. The challenge of scaling the system design from a single unit at 1500 kW to eight units at 22700 kW as well as manufacturing, shipping and installation within the four months available proved to be greater than anticipated. A lack of time to properly model the design for the main engine units resulted in installing a system that required additional modifications to become operational.

The final result demonstrates that the EcoSilencer® is a reliable, low maintenance sea water scrubbing system that achieves reductions in SO2 emissions that far exceed those mandated by MARPOL Annex VI.

Wärtsilä Finland Oy, 1 of 4 pages

Contact

Technology Type(s)	Closed Loop, High Sulfur SCR	**Other Products**	Wärsilä NOx Reducer
Exhaust Monitoring IMO Scheme	A and B	**Vessel Install Contact**	TBD
System Availability	TBD	**Size, Land Based Install**	TBD
Development Phase	Commercial	**Size, Shipboard Install**	0.68MW
Failure Modes	TBD	**Failure Recovery**	TBD

Unit Size* (MW)	Commercially Available (Yes/No)	Land-based Trial (Year/Units)	Shipboard Trial (Year/Units)	Efficiency Results Available (Yes/No)	How Many Hours of Operation?	Notes
.68MW	Yes	TBD	2008/2	Yes	TBD	IMO Certification

** Unit size refers to diesel engine size served. Boiler units are not considered in this survey.*

System Efficiency Trial Results

Land-Based or Shipboard Trial	Shipboard	**Test Date**	2008-2010
Engine Make/Model	Wärtsilä 4L20	**Rated Power (MW)**	0.68MW
Fuel Grade (RMG35, RME25, DMB, DMA)	HFO 1.5% and 3.4%S	**Trial Load (MW)**	8, 40, 70, and 100% Load

Fuel Sulfur	SO2	CO2	CO2	PM 2.5	PM	HC	NOx	CO	Back Press
(%)	(ppm)	(%)	(g/kWhr)						(kPa)
Scrubber OFF	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Scrubber ON	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Reduction (%)	>99%	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD

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Land-Based or Shipboard Trial		Test Date	
Engine Make/Model		Rated Power (MW)	MW
Fuel Grade (RMG35, RME25, DMB, DMA)		Trial Load (MW)	MW

Fuel Sulfur	SO2	CO2	CO2	PM 2.5	PM	HC	NOx	CO	Back Press
(%)	(ppm)	(%)	(g/kWhr)						(kPa)
Scrubber OFF	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Scrubber ON	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Reduction (%)			TBD	TBD	TBD	TBD		TBD	TBD

Waste Streams

Wash Water Overboard Discharge	0.1
Must discharge in port?	No
Meets IMO Wash Water Standards?	Yes
Meets EPA Vessel General Permit?	TBD
Meets California Ocean Plan Standards?	TBD
Sludge Residue Quantity	0.0013 Tons/MW-hr
Hazardous waste as per EPA?	No
Disposal method?	Same as Engine Room sludge.
Solid Waste Quantity	0
Hazardous waste as per EPA?	DNA
Disposal method?	DNA

System Details

Unit Size (MW of Engine Served)	**8MW (main stream scrubber)**
Electrical Load (In Port/In ECA/At Sea) (kW)	24 kW
Chemical Usage (In Port/In ECA/At Sea)	Case dependent, 50% concentration NaOH
Exhaust Handling: Pressure drop at full load (kPa)	800 kPa
Does unit serve as silencer/spark arrestor?	Partly
System failure block free flow of exhaust?	No
Multiple engine inlet capable?	Yes
Seawater Supply Quantity (m^3/hr)	TBD
Fresh Water Consumption (m^3/hr)	0.8 m^3/hr
Steam Supply (kg/hr, kPa)	DNA
Air Supply (kg/hr, kPa)	TBD
Other necessary utilities?	TBD
Component #1 Name	Scrubber Unit
Weight in kilograms (Dry/Wet)	6000/8000
Size in meters (Width/Depth/Height)	2.8/2.8/6
Access required in meters (Front/Side/Top)	TBD

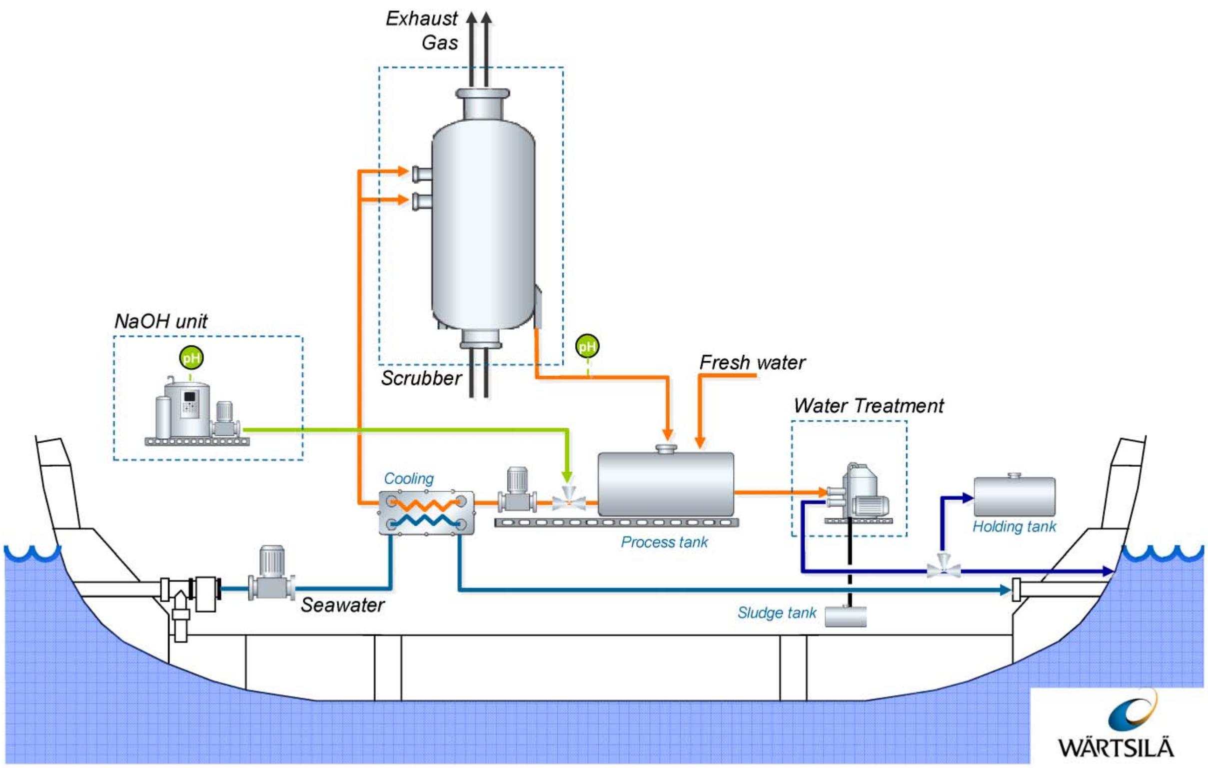

Figure: Wärtsilä fresh water scrubber principle.

System Description *(Provided by Supplier)*

Wärtsilä has developed a feasible scrubber solution, both for new installations and as a retrofit to existing ships. Combustion units can be diesel engines of any make, type, or application, 2-stroke or 4-stroke. In the case of Integrated Scrubber, also flue gases of oil-fired boilers can be cleaned. The SOx removal efficiency of Wärtsilä scrubber system is over 97%, making possible to operate with 3.5% sulphur fuel and still comply with 0.1% sulphur fuel limit. There are different scrubber configurations available. The scrubber system is equipped with an automation system for operation, monitoring, and safety control. Wärtsilä scrubber system has been approved by classification societies.

The Wärtsilä fresh water scrubber is based on closed loop system. Within this process, sulphur oxides in the exhaust gas stream are captured and neutralized by scrubbing water. The scrubbing water is based on fresh water boosted with alkali, typically sodium hydroxide (NaOH). The chemical process sulphur oxides resulting from the exhaust gas are neutralized to sulphates in the scrubbing water. The scrubber system is entirely built of highly corrosion resistant materials. Scrubbing water circulation flow rate is related to the actual dimensions of the scrubber module and design performance of the system. Scrubbing water is buffered in a process tank or wet sump for controlling the quality of the solution. This water is circulated with circulation pump from process tank or wet sump via the cooling heat exchanger to scrubber and back. A small bleed-off is extracted from the scrubbing water circulation to remove the accumulated impurities and led to treatment unit. Clean effluent from the treatment unit is monitored full-filling IMO quality requirements and can be discharged overboard. If operation in zero discharge mode is requested, the effluent can be led to a holding tank for scheduled and periodical discharge.

Appendix B Life Cycle Cost Tables

This Appendix provides the tables that were developed to support the life cycle cost analysis performed for the Ship Operations Cooperative Program (SOCP) marine exhaust gas cleaning system (EGCS) selection guide.

		Containership Transpacific	Containership Alaska to Puget Sound	Tankship US West Coast
Ship Speed	***(knots)***	**23**	**20**	**14.5**
Port Name		**Shanghai**	**Tacoma**	**Anacortes**
Distance from Last	*(n.miles)*	5345	1453	1117
non-ECA	*(n.miles)*	4584	726.5	0
ECA	*(n.miles)*	761	726.5	1117
Transit Time				
non-ECA	*(days)*	8.30	1.51	0.00
ECA	*(days)*	1.38	1.51	3.21
Port Time	*(days)*	2.00	0.25	0.75
Port Name		**Los Angeles**	**Anchorage**	**Long Beach**
Distance from Last	*(n.miles)*	5643	1453	1117
non-ECA	*(n.miles)*	4882	726.5	0
ECA	*(n.miles)*	761	726.5	1117
Transit Time				
non-ECA	*(days)*	8.84	1.51	0.00
ECA	*(days)*	1.38	1.51	3.21
Port Time	*(days)*	1.00	0.42	0.75
Port Name		**Oakland**		
Distance from Last	*(n.miles)*	374		
non-ECA	*(n.miles)*	0		
ECA	*(n.miles)*	374		
Transit Time				
non-ECA	*(days)*	0.0		
ECA	*(days)*	0.7		
Port Time	*(days)*	1.0		
Trip Total	*(days)*	24.6	6.7	7.9
Transit Time				
non-ECA	*(days)*	17.1	3.0	0.0
ECA	***(days)***	**3.4**	**3.0**	**6.4**
Port Time (ECA)	***(days)***	**4.0**	**0.7**	**1.5**

Notes:
1. Containership route and speed based on simplified Horizon Lines Eastern run.
2. Trailership route and speed based on TOTE Alaskan service run.
3. Tankship route based on product trade on West Coast. Speeds are typical.
4. Ocean transits assume Great Circle route.
5. U.S. port to port uses NOAA estimated distances.
6. ECA entry from Ocean assumes a run at 45 degrees to account for maneuvering.
7. ECA from AK to Puget Sound is rough estimate of 50% based on geography.

		Containership Transpacific	Containership Alaska to Puget Sound	Tankship US West Coast
Installed Equipment				
Propulsion	*(kW)*	1 x 36,000	1 x 16,000	1 x 10,100
	(gr/kW-hr)	170	175	175
Auxiliary	*(kW)*	3 x 1,000	4 x 1500	3 x 1,000
	(gr/kW-hr)	185	185	185
Annual Ops	*(days)*	320	320	320
Transit	***(kW)***	**30,200**	**14,700**	**9,000**
Non-ECA	*(hours/yr)*	5,357	3,459	0
	Fuel (MT/yr)	27,502	8,899	0
ECA	*(hours/yr)*	1,074	3,459	6,225
	Fuel (MT/yr)	5,512	8,899	9,805
Ships Service	***(kW)***	**1200**	**800**	**350**
Non-ECA	*(hours/yr)*	5,357	3,459	0
	Fuel (MT/yr)	1,189	512	0
ECA	*(hours/yr)*	2,323	4,221	7,680
	Fuel (MT/yr)	516	625	497
Cargo Support	***(kW)***	**800**	**800**	**2000**
ECA	*(hours/yr)*	1,250	762	1,455
	Fuel (MT/yr)	185	113	538
Fuel Total	*Fuel (MT/yr)*	34,903	19,046	10,840
Non-ECA	*Fuel (MT/yr)*	28,691	9,410	0
ECA	***Fuel (MT/yr)***	**6,212**	**9,636**	**10,840**

Notes:

1. Container Transpacific propulsion power based on 4000 TEU ship, MAN Containerships Trends 2008.
2. Container Alaska propulsion power based on 2000 TEU ship, MAN Containerships Trends 2008.
3. Tankship propulsion power based on 60,000 DWT, MAN Tankship Trends 2008.
4. Cargo and Ship Service loads are rough estimates.
5. Engine fuel consumptions based on 2 stroke diesels for propulsion, and 4 stroke for generators. Using rough estimates from Wartsila.

	Open Loop	Closed Loop	Hybrid	Dry
Scrubber Ratings (by Engine Size)	(USD)	(USD)	(USD)	(USD)
36MW	3,100,000	3,850,000	3,600,000	6,050,000
16MW	2,900,000	3,600,000	3,120,000	3,200,000
12MW	2,000,000	2,500,000	2,220,000	1,900,000
10MW	1,800,000	2,150,000	1,920,000	1,600,000
3MW	1,300,000	1,850,000	1,560,000	1,250,000
1MW	1,000,000	1,750,000	1,260,000	930,000
Containership Transpacific	5,260,000	6,430,000	5,904,000	7,970,000
Containership Alaska to Puget Sound	5,060,000	6,180,000	5,424,000	5,120,000
Tankship US West Coast	3,960,000	4,730,000	4,224,000	3,520,000

Notes:

1. Costs are for vendor supplied equipment and support only.
2. Costs based on ROMs from vendors (+/- 20%) plus adjustments to level scope.
3. Vessel estimates based on propulsion plants.
4. Assume - auxiliary engines combined into one large scrubber.

	Ship/Route Pair	Containership Transpacific	Containership Alaska to Puget Sound	Tankship US West Coast
	Scrubber Type	Open Loop	Open Loop	Open Loop
VARIABLES - CONTROLLED				
Investment Terms				
Life Cycle	*(# of Years)*	10	10	10
Analysis Date (Today)	*(Year)*	2011	2011	2011
Scrubber Installation Date	*(Year)*	2014	2014	2014
Discount Rate	*(%)*	10.0%	10.0%	10.0%
Capital Expense for Scrubber				
Equipment (Today)	*(USD/One Time)*	$5,260,000	$5,060,000	$3,960,000
Engineering/Design	*(% Equip Cost)*	7.0%	7.0%	7.0%
Training/Documents	*(% Equip Cost)*	2.0%	2.0%	2.0%
Install/Commission	*(% Equip Cost)*	50.0%	50.0%	50.0%
Operating Expense - Annual				
ECA Fuel Consumption	*(MT/Annual)*	6,212	9,636	10,840
Chemical Consumption	*(% of Fuel Cost)*	0.0%	0.0%	0.0%
Scrubber Parasitic Loads	*(% of Fuel Cost)*	2.0%	2.0%	2.0%
Distillate Calorie Correction	*(% of Fuel Cost)*	4.0%	4.0%	4.0%
HFO Process and Heating	*(% of Fuel Cost)*	0.8%	0.8%	0.8%
Operating Engineer (Today)	*(USD/Annual)*	$292,000	$292,000	$292,000
Operating Engineer	*(% of Position)*	50.0%	50.0%	50.0%
M&R Equipment	*(% Equip Cost/Annual)*	4.0%	4.0%	4.0%
Variables - Uncertain				
Fuel Differential (Today)	*(USD/MT)*	$255.50	$255.50	$255.50
Fuel/Chemical Escalation Rate	*(% - Annual for Op Period)*	8.0%	8.0%	8.0%
Personnel Inflation Rate	*(% - Annual for Op Period)*	3.0%	3.0%	3.0%
Equipment Inflation Rate	*(% - Annual for Op Period)*	3.3%	3.3%	3.3%

Analysis Results - Overview (Nearest $1,000)				
Capital Cost	*(USD - Year Zero Dollars)*	(9,219,000)	(8,868,000)	(6,941,000)
Expenses - Year One	*(USD - Year One Dollars)*	(551,000)	(623,000)	(601,000)
Fuel Savings - Year One	*(USD - Year One Dollars)*	2,159,000	3,350,000	3,768,000
Net Present Value	*(USD - 2011 Dollars)*	4,851,000	14,562,000	20,110,000
Internal Rate of Return	*(%)*	20%	36%	53%

Inflation Baseline	Year					
Expenses Baseline	0	1	2	3	4	5
Capital Cost - Total	**(9,219,000)**					
Equipment	(5,798,113)					
Acquisition	(3,420,887)					
Expenses - Total		**(550,743)**	**(575,326)**	**(601,257)**	**(628,626)**	**(657,525)**
Distillate Correction		(86,377)	(93,287)	(100,750)	(108,810)	(117,514)
HFO Process & Heating		(17,275)	(18,657)	(20,150)	(21,762)	(23,503)
Operating Engineer		(164,324)	(169,254)	(174,332)	(179,562)	(184,948)
Chemical Consumption		0	0	0	0	0
Scrubber Loads		(43,188)	(46,643)	(50,375)	(54,405)	(58,757)
M&R Equip & Labor		(239,578)	(247,484)	(255,651)	(264,088)	(272,802)
Savings - Fuel Differential		**2,159,415**	**2,332,168**	**2,518,742**	**2,720,241**	**2,937,860**
NPV & IRR						
Cash Flow	(9,219,000)	1,608,673	1,756,843	1,917,485	2,091,616	2,280,335
Discount Factor	1.0000	0.9091	0.8264	0.7513	0.6830	0.6209
Present Value	(9,219,000)	1,462,430	1,451,936	1,440,635	1,428,602	1,415,909
Net Present Value (at Year 0)	**4,850,970**					
Internal Rate of Return	**19.54%**					

Inflation Baseline	Year				
Expenses Baseline	6	7	8	9	10
Capital Cost - Total					
Equipment					
Acquisition					
Expenses - Total	**(688,058)**	**(720,333)**	**(754,467)**	**(790,587)**	**(828,826)**
Distillate Correction	(126,916)	(137,069)	(148,034)	(159,877)	(172,667)
HFO Process & Heating	(25,383)	(27,414)	(29,607)	(31,975)	(34,533)
Operating Engineer	(190,497)	(196,212)	(202,098)	(208,161)	(214,406)
Chemical Consumption	0	0	0	0	0
Scrubber Loads	(63,458)	(68,534)	(74,017)	(79,939)	(86,334)
M&R Equip & Labor	(281,805)	(291,105)	(300,711)	(310,634)	(320,885)
Savings - Fuel Differential	**3,172,889**	**3,426,720**	**3,700,858**	**3,996,927**	**4,316,681**
NPV & IRR					
Cash Flow	2,484,831	2,706,387	2,946,391	3,206,340	3,487,855
Discount Factor	0.5645	0.5132	0.4665	0.4241	0.3855
Present Value	1,402,622	1,388,805	1,374,513	1,359,801	1,344,719
Net Present Value (at Year 0)					
Internal Rate of Return					

Inflation Baseline	Year					
Expenses Baseline	0	1	2	3	4	5
Capital Cost - Total	**(8,868,468)**					
Equipment	(5,577,653)					
Acquisition	(3,290,815)					
Expenses - Total		**(622,559)**	**(653,316)**	**(685,929)**	**(720,528)**	**(757,252)**
Distillate Correction		(133,980)	(144,699)	(156,275)	(168,777)	(182,279)
HFO Process & Heating		(26,796)	(28,940)	(31,255)	(33,755)	(36,456)
Operating Engineer		(164,324)	(169,254)	(174,332)	(179,562)	(184,948)
Chemical Consumption		0	0	0	0	0
Scrubber Loads		(66,990)	(72,349)	(78,137)	(84,388)	(91,139)
M&R Equip & Labor		(230,469)	(238,074)	(245,931)	(254,046)	(262,430)
Savings - Fuel Differential		**3,349,508**	**3,617,469**	**3,906,867**	**4,219,416**	**4,556,969**
NPV & IRR						
Cash Flow	(8,868,468)	2,726,949	2,964,153	3,220,937	3,498,888	3,799,717
Discount Factor	1.0000	0.9091	0.8264	0.7513	0.6830	0.6209
Present Value	(8,868,468)	2,479,044	2,449,713	2,419,938	2,389,787	2,359,325
Net Present Value	**14,562,028**					
Internal Rate of Return	**36.17%**					

Inflation Baseline	Year				
Expenses Baseline	6	7	8	9	10
Capital Cost - Total					
Equipment					
Acquisition					
Expenses - Total	**(796,251)**	**(837,685)**	**(881,727)**	**(928,564)**	**(978,397)**
Distillate Correction	(196,861)	(212,610)	(229,619)	(247,988)	(267,827)
HFO Process & Heating	(39,372)	(42,522)	(45,924)	(49,598)	(53,565)
Operating Engineer	(190,497)	(196,212)	(202,098)	(208,161)	(214,406)
Chemical Consumption	0	0	0	0	0
Scrubber Loads	(98,431)	(106,305)	(114,809)	(123,994)	(133,914)
M&R Equip & Labor	(271,090)	(280,036)	(289,277)	(298,823)	(308,684)
Savings - Fuel Differential	**4,921,527**	**5,315,249**	**5,740,469**	**6,199,706**	**6,695,683**
NPV & IRR					
Cash Flow	4,125,276	4,477,564	4,858,742	5,271,142	5,717,286
Discount Factor	0.5645	0.5132	0.4665	0.4241	0.3855
Present Value	2,328,611	2,297,698	2,266,639	2,235,479	2,204,261
Net Present Value					
Internal Rate of Return					

Inflation Baseline	**Year**					
Expenses Baseline	0	1	2	3	4	5
Capital Cost - Total	**(6,940,540)**					
Equipment	(4,365,120)					
Acquisition	(2,575,421)					
Expenses - Total		**(600,928)**	**(632,309)**	**(665,674)**	**(701,165)**	**(738,936)**
Distillate Correction		(150,728)	(162,786)	(175,809)	(189,874)	(205,063)
HFO Process & Heating		(30,146)	(32,557)	(35,162)	(37,975)	(41,013)
Operating Engineer		(164,324)	(169,254)	(174,332)	(179,562)	(184,948)
Chemical Consumption		0	0	0	0	0
Scrubber Loads		(75,364)	(81,393)	(87,904)	(94,937)	(102,532)
M&R Equip & Labor		(180,367)	(186,319)	(192,467)	(198,819)	(205,380)
Savings - Fuel Differential		**3,768,194**	**4,069,650**	**4,395,222**	**4,746,839**	**5,126,587**
NPV & IRR						
Cash Flow	(6,940,540)	3,167,266	3,437,341	3,729,548	4,045,674	4,387,650
Discount Factor	1.0000	0.9091	0.8264	0.7513	0.6830	0.6209
Present Value	(6,940,540)	2,879,333	2,840,777	2,802,064	2,763,250	2,724,386
Net Present Value	**20,109,656**					
Internal Rate of Return	**52.62%**					

Inflation Baseline	Year				
Expenses Baseline	6	7	8	9	10
Capital Cost - Total					
Equipment					
Acquisition					
Expenses - Total	**(779,151)**	**(821,987)**	**(867,634)**	**(916,300)**	**(968,204)**
Distillate Correction	(221,469)	(239,186)	(258,321)	(278,987)	(301,306)
HFO Process & Heating	(44,294)	(47,837)	(51,664)	(55,797)	(60,261)
Operating Engineer	(190,497)	(196,212)	(202,098)	(208,161)	(214,406)
Chemical Consumption	0	0	0	0	0
Scrubber Loads	(110,734)	(119,593)	(129,160)	(139,493)	(150,653)
M&R Equip & Labor	(212,157)	(219,159)	(226,391)	(233,862)	(241,579)
Savings - Fuel Differential	**5,536,714**	**5,979,651**	**6,458,023**	**6,974,664**	**7,532,638**
NPV & IRR					
Cash Flow	4,757,563	5,157,664	5,590,388	6,058,365	6,564,433
Discount Factor	0.5645	0.5132	0.4665	0.4241	0.3855
Present Value	2,685,520	2,646,697	2,607,957	2,569,338	2,530,873
Net Present Value					
Internal Rate of Return					

Inflation	Year					
Expenses	0	1	2	3	4	5
Capital Cost - Total	**0**					
Equipment	0					
Acquisition	0					
Expenses - Total		**(169,254)**	**(174,332)**	**(179,562)**	**(184,948)**	**(190,497)**
Distillate Correction		0	0	0	0	0
HFO Process & Heating		0	0	0	0	0
Operating Engineer		(169,254)	(174,332)	(179,562)	(184,948)	(190,497)
Chemical Consumption		0	0	0	0	0
Scrubber Loads		0	0	0	0	0
M&R Equip & Labor		0	0	0	0	0
Savings - Fuel Differential		**0**	**0**	**0**	**0**	**0**
NPV & IRR						
Cash Flow	0	(169,254)	(174,332)	(179,562)	(184,948)	(190,497)
Discount Factor	1.0000	0.9091	0.8264	0.7513	0.6830	0.6209
Present Value	0	(153,867)	(144,076)	(134,907)	(126,322)	(118,284)
Net Present Value	**(1,165,101)**					
Internal Rate of Return	**NONE**					

Inflation	Year				
Expenses	6	7	8	9	10
Capital Cost - Total					
Equipment					
Acquisition					
Expenses - Total	**(196,212)**	**(202,098)**	**(208,161)**	**(214,406)**	**(220,838)**
Distillate Correction	0	0	0	0	0
HFO Process & Heating	0	0	0	0	0
Operating Engineer	(196,212)	(202,098)	(208,161)	(214,406)	(220,838)
Chemical Consumption	0	0	0	0	0
Scrubber Loads	0	0	0	0	0
M&R Equip & Labor	0	0	0	0	0
Savings - Fuel Differential	**0**	**0**	**0**	**0**	**0**
NPV & IRR					
Cash Flow	(196,212)	(202,098)	(208,161)	(214,406)	(220,838)
Discount Factor	0.5645	0.5132	0.4665	0.4241	0.3855
Present Value	(110,756)	(103,708)	(97,109)	(90,929)	(85,143)
Net Present Value					
Internal Rate of Return					

	Ship/Route Pair	Containership Alaska to Puget Sound	Containership Alaska to Puget Sound	Containership Alaska to Puget Sound	Containership Alaska to Puget Sound
	Scrubber Type	**Open Loop**	**Closed Loop**	**Hybrid**	**Dry**
Sensitivity Analysis	**Scrubber Types**	**Open Loop**	**Closed Loop**	**Hybrid**	**Dry**
VARIABLES - CONTROLLED					
Investment Terms					
Life Cycle	*(# of Years)*	10	10	10	10
Analysis Date (Today)	*(Year)*	2011	2011	2011	2011
Scrubber Installation Date	*(Year)*	2014	2014	2014	2014
Discount Rate	*(%)*	10.0%	10.0%	10.0%	10.0%
Capital Expense for Scrubber					
Equipment (Today)	*(USD/One Time)*	$5,060,000	$6,180,000	$5,424,000	$5,120,000
Engineering/Design	*(% Equip Cost)*	7.0%	9.0%	9.0%	11.0%
Training/Documents	*(% Equip Cost)*	2.0%	2.0%	2.0%	2.0%
Install/Commission	*(% Equip Cost)*	50.0%	65.0%	75.0%	85.0%
Operating Expense - Annual					
ECA Fuel Consumption	*(MT/Annual)*	9,636	9,636	9,636	9,636
Chemical Consumption	*(% of Fuel Cost)*	0.0%	3.0%	1.5%	3.0%
Scrubber Parasitic Loads	*(% of Fuel Cost)*	2.0%	1.0%	1.5%	1.0%
Distillate Calorie Correction	*(% of Fuel Cost)*	4.0%	4.0%	4.0%	4.0%
HFO Process and Heating	*(% of Fuel Cost)*	0.8%	0.8%	0.8%	0.8%
Operating Engineer (Today)	*(USD/Annual)*	$292,000	$292,000	$292,000	$292,000
Operating Engineer	*(% of Position)*	50.0%	65.0%	65.0%	65.0%
M&R Equipment	*(% Equip Cost/Annual)*	4.0%	4.0%	4.0%	4.0%
Variables - Uncertain					
Fuel Differential (Today)	*(USD/MT)*	$255.50	$255.50	$255.50	$255.50
Fuel/Chemical Escalation Rate	*(% - Annual for Op Period)*	8.0%	8.0%	8.0%	8.0%
Personnel Inflation Rate	*(% - Annual for Op Period)*	3.0%	3.0%	3.0%	3.0%
Equipment Inflation Rate	*(% - Annual for Op Period)*	3.3%	3.3%	3.3%	3.3%

Analysis Results - Overview (Nearest $1,000)					
Capital Cost	*(USD - Year Zero Dollars)*	(8,868,000)	(11,990,000)	(11,121,000)	(11,175,000)
Expenses - Year One	*(USD - Year One Dollars)*	(623,000)	(790,000)	(722,000)	(742,000)
Fuel Savings - Year One	*(USD - Year One Dollars)*	3,350,000	3,350,000	3,350,000	3,350,000
Net Present Value	*(USD - Present Dollars)*	14,562,000	10,185,000	11,574,000	11,336,000
Internal Rate of Return	*(%)*	36%	25%	28%	27%

Scrubber Types Open Loop	Year					
-	0	1	2	3	4	5
Capital Cost - Total	**(8,868,468)**					
Equipment	(5,577,653)					
Acquisition	(3,290,815)					
Expenses - Total		**(622,559)**	**(653,316)**	**(685,929)**	**(720,528)**	**(757,252)**
Distillate Correction		(133,980)	(144,699)	(156,275)	(168,777)	(182,279)
HFO Process & Heating		(26,796)	(28,940)	(31,255)	(33,755)	(36,456)
Operating Engineer		(164,324)	(169,254)	(174,332)	(179,562)	(184,948)
Chemical Consumption		0	0	0	0	0
Scrubber Loads		(66,990)	(72,349)	(78,137)	(84,388)	(91,139)
M&R Equip & Labor		(230,469)	(238,074)	(245,931)	(254,046)	(262,430)
Savings - Fuel Differential		**3,349,508**	**3,617,469**	**3,906,867**	**4,219,416**	**4,556,969**
NPV & IRR						
Cash Flow	(8,868,468)	2,726,949	2,964,153	3,220,937	3,498,888	3,799,717
Discount Factor	1.0000	0.9091	0.8264	0.7513	0.6830	0.6209
Present Value	(8,868,468)	2,479,044	2,449,713	2,419,938	2,389,787	2,359,325
Net Present Value (at Year 0)	**14,562,028**					
Internal Rate of Return	**36.17%**					

Scrubber Types Open Loop	Year				
-	6	7	8	9	10
Capital Cost - Total					
Equipment					
Acquisition					
Expenses - Total	**(796,251)**	**(837,685)**	**(881,727)**	**(928,564)**	**(978,397)**
Distillate Correction	(196,861)	(212,610)	(229,619)	(247,988)	(267,827)
HFO Process & Heating	(39,372)	(42,522)	(45,924)	(49,598)	(53,565)
Operating Engineer	(190,497)	(196,212)	(202,098)	(208,161)	(214,406)
Chemical Consumption	0	0	0	0	0
Scrubber Loads	(98,431)	(106,305)	(114,809)	(123,994)	(133,914)
M&R Equip & Labor	(271,090)	(280,036)	(289,277)	(298,823)	(308,684)
Savings - Fuel Differential	**4,921,527**	**5,315,249**	**5,740,469**	**6,199,706**	**6,695,683**
NPV & IRR					
Cash Flow	4,125,276	4,477,564	4,858,742	5,271,142	5,717,286
Discount Factor	0.5645	0.5132	0.4665	0.4241	0.3855
Present Value	2,328,611	2,297,698	2,266,639	2,235,479	2,204,261
Net Present Value (at Year 0)					
Internal Rate of Return					

Scrubber Types Closed Loop	Year					
-	0	1	2	3	4	5
Capital Cost - Total	**(11,989,529)**					
Equipment	(6,812,232)					
Acquisition	(5,177,296)					
Expenses - Total		**(789,860)**	**(829,138)**	**(870,801)**	**(915,016)**	**(961,963)**
Distillate Correction		(133,980)	(144,699)	(156,275)	(168,777)	(182,279)
HFO Process & Heating		(26,796)	(28,940)	(31,255)	(33,755)	(36,456)
Operating Engineer		(213,622)	(220,030)	(226,631)	(233,430)	(240,433)
Chemical Consumption		(100,485)	(108,524)	(117,206)	(126,582)	(136,709)
Scrubber Loads		(33,495)	(36,175)	(39,069)	(42,194)	(45,570)
M&R Equip & Labor		(281,481)	(290,770)	(300,366)	(310,278)	(320,517)
Savings - Fuel Differential		**3,349,508**	**3,617,469**	**3,906,867**	**4,219,416**	**4,556,969**
NPV & IRR						
Cash Flow	(11,989,529)	2,559,649	2,788,331	3,036,065	3,304,399	3,595,006
Discount Factor	1.0000	0.9091	0.8264	0.7513	0.6830	0.6209
Present Value	(11,989,529)	2,326,953	2,304,406	2,281,041	2,256,949	2,232,216
Net Present Value	**10,184,863**					
Internal Rate of Return	**24.71%**					

Scrubber Types Closed Loop	Year				
-	6	7	8	9	10
Capital Cost - Total					
Equipment					
Acquisition					
Expenses - Total	**(1,011,834)**	**(1,064,837)**	**(1,121,196)**	**(1,181,149)**	**(1,244,958)**
Distillate Correction	(196,861)	(212,610)	(229,619)	(247,988)	(267,827)
HFO Process & Heating	(39,372)	(42,522)	(45,924)	(49,598)	(53,565)
Operating Engineer	(247,646)	(255,075)	(262,728)	(270,609)	(278,728)
Chemical Consumption	(147,646)	(159,457)	(172,214)	(185,991)	(200,870)
Scrubber Loads	(49,215)	(53,152)	(57,405)	(61,997)	(66,957)
M&R Equip & Labor	(331,094)	(342,020)	(353,307)	(364,966)	(377,010)
Savings - Fuel Differential	**4,921,527**	**5,315,249**	**5,740,469**	**6,199,706**	**6,695,683**
NPV & IRR					
Cash Flow	3,909,692	4,250,411	4,619,273	5,018,557	5,450,725
Discount Factor	0.5645	0.5132	0.4665	0.4241	0.3855
Present Value	2,206,919	2,181,133	2,154,925	2,128,358	2,101,491
Net Present Value					
Internal Rate of Return					

Scrubber Types Hybrid	Year					
-	0	1	2	3	4	5
Capital Cost - Total	**(11,120,738)**					
Equipment	(5,978,891)					
Acquisition	(5,141,846)					
Expenses - Total		**(721,931)**	**(757,393)**	**(794,989)**	**(834,866)**	**(877,185)**
Distillate Correction		(133,980)	(144,699)	(156,275)	(168,777)	(182,279)
HFO Process & Heating		(26,796)	(28,940)	(31,255)	(33,755)	(36,456)
Operating Engineer		(213,622)	(220,030)	(226,631)	(233,430)	(240,433)
Chemical Consumption		(50,243)	(54,262)	(58,603)	(63,291)	(68,355)
Scrubber Loads		(50,243)	(54,262)	(58,603)	(63,291)	(68,355)
M&R Equip & Labor		(247,048)	(255,200)	(263,622)	(272,321)	(281,308)
Savings - Fuel Differential		**3,349,508**	**3,617,469**	**3,906,867**	**4,219,416**	**4,556,969**
NPV & IRR						
Cash Flow	(11,120,738)	2,627,577	2,860,076	3,111,878	3,384,550	3,679,785
Discount Factor	1.0000	0.9091	0.8264	0.7513	0.6830	0.6209
Present Value	(11,120,738)	2,388,707	2,363,699	2,338,000	2,311,693	2,284,857
Net Present Value	**11,574,199**					
Internal Rate of Return	**27.61%**					

Scrubber Types Hybrid	Year				
-	6	7	8	9	10
Capital Cost - Total					
Equipment					
Acquisition					
Expenses - Total	**(922,116)**	**(969,846)**	**(1,020,571)**	**(1,074,506)**	**(1,131,881)**
Distillate Correction	(196,861)	(212,610)	(229,619)	(247,988)	(267,827)
HFO Process & Heating	(39,372)	(42,522)	(45,924)	(49,598)	(53,565)
Operating Engineer	(247,646)	(255,075)	(262,728)	(270,609)	(278,728)
Chemical Consumption	(73,823)	(79,729)	(86,107)	(92,996)	(100,435)
Scrubber Loads	(73,823)	(79,729)	(86,107)	(92,996)	(100,435)
M&R Equip & Labor	(290,591)	(300,181)	(310,087)	(320,320)	(330,890)
Savings - Fuel Differential	**4,921,527**	**5,315,249**	**5,740,469**	**6,199,706**	**6,695,683**
NPV & IRR					
Cash Flow	3,999,410	4,345,403	4,719,898	5,125,200	5,563,802
Discount Factor	0.5645	0.5132	0.4665	0.4241	0.3855
Present Value	2,257,563	2,229,879	2,201,867	2,173,585	2,145,086
Net Present Value					
Internal Rate of Return					

Scrubber Types Dry	Year					
-	0	1	2	3	4	5
Capital Cost - Total	**(11,174,706)**					
Equipment	(5,643,791)					
Acquisition	(5,530,915)					
Expenses - Total		**(741,580)**	**(779,265)**	**(819,282)**	**(861,797)**	**(906,988)**
Distillate Correction		(133,980)	(144,699)	(156,275)	(168,777)	(182,279)
HFO Process & Heating		(26,796)	(28,940)	(31,255)	(33,755)	(36,456)
Operating Engineer		(213,622)	(220,030)	(226,631)	(233,430)	(240,433)
Chemical Consumption		(100,485)	(108,524)	(117,206)	(126,582)	(136,709)
Scrubber Loads		(33,495)	(36,175)	(39,069)	(42,194)	(45,570)
M&R Equip & Labor		(233,201)	(240,897)	(248,847)	(257,059)	(265,542)
Savings - Fuel Differential		**3,349,508**	**3,617,469**	**3,906,867**	**4,219,416**	**4,556,969**
NPV & IRR						
Cash Flow	(11,174,706)	2,607,929	2,838,204	3,087,584	3,357,619	3,649,981
Discount Factor	1.0000	0.9091	0.8264	0.7513	0.6830	0.6209
Present Value	(11,174,706)	2,370,844	2,345,624	2,319,748	2,293,299	2,266,351
Net Present Value	**11,335,895**					
Internal Rate of Return	**27.22%**					

Scrubber Types Dry	Year				
-	6	7	8	9	10
Capital Cost - Total					
Equipment					
Acquisition					
Expenses - Total	**(955,045)**	**(1,006,174)**	**(1,060,596)**	**(1,118,550)**	**(1,180,292)**
Distillate Correction	(196,861)	(212,610)	(229,619)	(247,988)	(267,827)
HFO Process & Heating	(39,372)	(42,522)	(45,924)	(49,598)	(53,565)
Operating Engineer	(247,646)	(255,075)	(262,728)	(270,609)	(278,728)
Chemical Consumption	(147,646)	(159,457)	(172,214)	(185,991)	(200,870)
Scrubber Loads	(49,215)	(53,152)	(57,405)	(61,997)	(66,957)
M&R Equip & Labor	(274,304)	(283,356)	(292,707)	(302,367)	(312,345)
Savings - Fuel Differential	**4,921,527**	**5,315,249**	**5,740,469**	**6,199,706**	**6,695,683**
NPV & IRR					
Cash Flow	3,966,482	4,309,075	4,679,873	5,081,156	5,515,390
Discount Factor	0.5645	0.5132	0.4665	0.4241	0.3855
Present Value	2,238,976	2,211,237	2,183,195	2,154,906	2,126,422
Net Present Value					
Internal Rate of Return					

	Ship/Route Pair	Containership Alaska to Puget Sound	Containership Alaska to Puget Sound	Containership Alaska to Puget Sound	Containership Alaska to Puget Sound
	Scrubber Type	**Open Loop**	**Open Loop**	**Open Loop**	**Open Loop**
Sensitivity Analysis	**Fuel Consumption**	**21%**	**50%**	**75%**	**100%**
VARIABLES - CONTROLLED					
Investment Terms					
Life Cycle	*(# of Years)*	10	10	10	10
Analysis Date (Today)	*(Year)*	2011	2011	2011	2011
Scrubber Installation Date	*(Year)*	2014	2014	2014	2014
Discount Rate	*(%)*	10.0%	10.0%	10.0%	10.0%
Capital Expense for Scrubber					
Equipment (Today)	*(USD/One Time)*	$5,060,000	$5,060,000	$5,060,000	$5,060,000
Engineering/Design	*(% Equip Cost)*	7.0%	7.0%	7.0%	7.0%
Training/Documents	*(% Equip Cost)*	2.0%	2.0%	2.0%	2.0%
Install/Commission	*(% Equip Cost)*	50.0%	50.0%	50.0%	50.0%
Operating Expense - Annual					
ECA Fuel Consumption	*(MT/Annual)*	4,000	9,523	14,285	19,046
Chemical Consumption	*(% of Fuel Cost)*	0.0%	0.0%	0.0%	0.0%
Scrubber Parasitic Loads	*(% of Fuel Cost)*	2.0%	2.0%	2.0%	2.0%
Distillate Calorie Correction	*(% of Fuel Cost)*	4.0%	4.0%	4.0%	4.0%
HFO Process and Heating	*(% of Fuel Cost)*	0.8%	0.8%	0.8%	0.8%
Operating Engineer (Today)	*(USD/Annual)*	$292,000	$292,000	$292,000	$292,000
Operating Engineer	*(% of Position)*	50.0%	50.0%	50.0%	50.0%
M&R Equipment	*(% Equip Cost/Annual)*	4.0%	4.0%	4.0%	4.0%
Variables - Uncertain					
Fuel Differential (Today)	*(USD/MT)*	$255.50	$255.50	$255.50	$255.50
Fuel/Chemical Escalation Rate	*(% - Annual for Op Period)*	8.0%	8.0%	8.0%	8.0%
Personnel Inflation Rate	*(% - Annual for Op Period)*	3.0%	3.0%	3.0%	3.0%
Equipment Inflation Rate	*(% - Annual for Op Period)*	3.3%	3.3%	3.3%	3.3%

Analysis Results - Overview (Nearest $1,000)					
Capital Cost	*(USD - Year Zero Dollars)*	(8,868,000)	(8,868,000)	(8,868,000)	(8,868,000)
Expenses - Year One	*(USD - Year One Dollars)*	(489,000)	(620,000)	(732,000)	(845,000)
Fuel Savings - Year One	*(USD - Year One Dollars)*	1,390,000	3,310,000	4,965,000	6,621,000
Net Present Value	*(USD - Present Dollars)*	(743,000)	14,256,000	27,186,000	40,116,000
Internal Rate of Return	*(%)*	8%	36%	55%	73%

Fuel Consumption 0.21	**Year**					
-	0	1	2	3	4	5
Capital Cost - Total	**(8,868,468)**					
Equipment	(5,577,653)					
Acquisition	(3,290,815)					
Expenses - Total		**(489,336)**	**(509,434)**	**(530,537)**	**(552,704)**	**(576,002)**
Distillate Correction		(55,613)	(60,062)	(64,867)	(70,057)	(75,661)
HFO Process & Heating		(11,123)	(12,012)	(12,973)	(14,011)	(15,132)
Operating Engineer		(164,324)	(169,254)	(174,332)	(179,562)	(184,948)
Chemical Consumption		0	0	0	0	0
Scrubber Loads		(27,807)	(30,031)	(32,434)	(35,028)	(37,831)
M&R Equip & Labor		(230,469)	(238,074)	(245,931)	(254,046)	(262,430)
Savings - Fuel Differential		**1,390,333**	**1,501,560**	**1,621,684**	**1,751,419**	**1,891,533**
NPV & IRR						
Cash Flow	(8,868,468)	900,997	992,125	1,091,148	1,198,715	1,315,530
Discount Factor	1.0000	0.9091	0.8264	0.7513	0.6830	0.6209
Present Value	(8,868,468)	819,089	819,938	819,795	818,738	816,841
Net Present Value (at Year 0)	**(743,184)**					
Internal Rate of Return	**8.28%**					

Fuel Consumption 0.21	**Year**				
-	6	7	8	9	10
Capital Cost - Total					
Equipment					
Acquisition					
Expenses - Total	**(600,501)**	**(626,275)**	**(653,405)**	**(681,976)**	**(712,082)**
Distillate Correction	(81,714)	(88,251)	(95,311)	(102,936)	(111,171)
HFO Process & Heating	(16,343)	(17,650)	(19,062)	(20,587)	(22,234)
Operating Engineer	(190,497)	(196,212)	(202,098)	(208,161)	(214,406)
Chemical Consumption	0	0	0	0	0
Scrubber Loads	(40,857)	(44,126)	(47,656)	(51,468)	(55,586)
M&R Equip & Labor	(271,090)	(280,036)	(289,277)	(298,823)	(308,684)
Savings - Fuel Differential	**2,042,855**	**2,206,284**	**2,382,786**	**2,573,409**	**2,779,282**
NPV & IRR					
Cash Flow	1,442,354	1,580,009	1,729,382	1,891,433	2,067,201
Discount Factor	0.5645	0.5132	0.4665	0.4241	0.3855
Present Value	814,171	810,794	806,769	802,152	796,995
Net Present Value (at Year 0)					
Internal Rate of Return					

Fuel Consumption 0.5	**Year**					
-	0	1	2	3	4	5
Capital Cost - Total	**(8,868,468)**					
Equipment	(5,577,653)					
Acquisition	(3,290,815)					
Expenses - Total		**(619,894)**	**(650,438)**	**(682,821)**	**(717,171)**	**(753,626)**
Distillate Correction		(132,413)	(143,006)	(154,446)	(166,802)	(180,146)
HFO Process & Heating		(26,483)	(28,601)	(30,889)	(33,360)	(36,029)
Operating Engineer		(164,324)	(169,254)	(174,332)	(179,562)	(184,948)
Chemical Consumption		0	0	0	0	0
Scrubber Loads		(66,206)	(71,503)	(77,223)	(83,401)	(90,073)
M&R Equip & Labor		(230,469)	(238,074)	(245,931)	(254,046)	(262,430)
Savings - Fuel Differential		**3,310,317**	**3,575,142**	**3,861,153**	**4,170,046**	**4,503,649**
NPV & IRR						
Cash Flow	(8,868,468)	2,690,422	2,924,704	3,178,333	3,452,875	3,750,023
Discount Factor	1.0000	0.9091	0.8264	0.7513	0.6830	0.6209
Present Value	(8,868,468)	2,445,838	2,417,111	2,387,928	2,358,360	2,328,469
Net Present Value	**14,255,860**					
Internal Rate of Return	**35.69%**					

Fuel Consumption 0.5	Year				
-	6	7	8	9	10
Capital Cost - Total					
Equipment					
Acquisition					
Expenses - Total	**(792,335)**	**(833,456)**	**(877,160)**	**(923,632)**	**(973,069)**
Distillate Correction	(194,558)	(210,122)	(226,932)	(245,087)	(264,694)
HFO Process & Heating	(38,912)	(42,024)	(45,386)	(49,017)	(52,939)
Operating Engineer	(190,497)	(196,212)	(202,098)	(208,161)	(214,406)
Chemical Consumption	0	0	0	0	0
Scrubber Loads	(97,279)	(105,061)	(113,466)	(122,543)	(132,347)
M&R Equip & Labor	(271,090)	(280,036)	(289,277)	(298,823)	(308,684)
Savings - Fuel Differential	**4,863,941**	**5,253,056**	**5,673,301**	**6,127,165**	**6,617,338**
NPV & IRR					
Cash Flow	4,071,606	4,419,601	4,796,141	5,203,534	5,644,269
Discount Factor	0.5645	0.5132	0.4665	0.4241	0.3855
Present Value	2,298,316	2,267,954	2,237,435	2,206,806	2,176,110
Net Present Value					
Internal Rate of Return					

Fuel Consumption 0.75	Year					
-	0	1	2	3	4	5
Capital Cost - Total	**(8,868,468)**					
Equipment	(5,577,653)					
Acquisition	(3,290,815)					
Expenses - Total		**(732,445)**	**(771,993)**	**(814,100)**	**(858,952)**	**(906,750)**
Distillate Correction		(198,619)	(214,509)	(231,669)	(250,203)	(270,219)
HFO Process & Heating		(39,724)	(42,902)	(46,334)	(50,041)	(54,044)
Operating Engineer		(164,324)	(169,254)	(174,332)	(179,562)	(184,948)
Chemical Consumption		0	0	0	0	0
Scrubber Loads		(99,309)	(107,254)	(115,835)	(125,101)	(135,109)
M&R Equip & Labor		(230,469)	(238,074)	(245,931)	(254,046)	(262,430)
Savings - Fuel Differential		**4,965,475**	**5,362,713**	**5,791,730**	**6,255,068**	**6,755,474**
NPV & IRR						
Cash Flow	(8,868,468)	4,233,030	4,590,720	4,977,630	5,396,116	5,848,723
Discount Factor	1.0000	0.9091	0.8264	0.7513	0.6830	0.6209
Present Value	(8,868,468)	3,848,209	3,793,984	3,739,767	3,685,620	3,631,597
Net Present Value	**27,186,070**					
Internal Rate of Return	**54.79%**					

Fuel Consumption 0.75	Year				
-	6	7	8	9	10
Capital Cost - Total					
Equipment					
Acquisition					
Expenses - Total	**(957,709)**	**(1,012,059)**	**(1,070,052)**	**(1,131,955)**	**(1,198,059)**
Distillate Correction	(291,836)	(315,183)	(340,398)	(367,630)	(397,040)
HFO Process & Heating	(58,367)	(63,037)	(68,080)	(73,526)	(79,408)
Operating Engineer	(190,497)	(196,212)	(202,098)	(208,161)	(214,406)
Chemical Consumption	0	0	0	0	0
Scrubber Loads	(145,918)	(157,592)	(170,199)	(183,815)	(198,520)
M&R Equip & Labor	(271,090)	(280,036)	(289,277)	(298,823)	(308,684)
Savings - Fuel Differential	**7,295,912**	**7,879,585**	**8,509,951**	**9,190,748**	**9,926,007**
NPV & IRR					
Cash Flow	6,338,203	6,867,525	7,439,900	8,058,792	8,727,949
Discount Factor	0.5645	0.5132	0.4665	0.4241	0.3855
Present Value	3,577,750	3,524,126	3,470,768	3,417,715	3,365,002
Net Present Value					
Internal Rate of Return					

Fuel Consumption 1	Year					
-	0	1	2	3	4	5
Capital Cost - Total	**(8,868,468)**					
Equipment	(5,577,653)					
Acquisition	(3,290,815)					
Expenses - Total		**(844,996)**	**(893,547)**	**(945,379)**	**(1,000,734)**	**(1,059,874)**
Distillate Correction		(264,825)	(286,011)	(308,892)	(333,604)	(360,292)
HFO Process & Heating		(52,965)	(57,202)	(61,778)	(66,721)	(72,058)
Operating Engineer		(164,324)	(169,254)	(174,332)	(179,562)	(184,948)
Chemical Consumption		0	0	0	0	0
Scrubber Loads		(132,413)	(143,006)	(154,446)	(166,802)	(180,146)
M&R Equip & Labor		(230,469)	(238,074)	(245,931)	(254,046)	(262,430)
Savings - Fuel Differential		**6,620,633**	**7,150,284**	**7,722,307**	**8,340,091**	**9,007,298**
NPV & IRR						
Cash Flow	(8,868,468)	5,775,637	6,256,737	6,776,928	7,339,357	7,947,424
Discount Factor	1.0000	0.9091	0.8264	0.7513	0.6830	0.6209
Present Value	(8,868,468)	5,250,579	5,170,857	5,091,606	5,012,880	4,934,725
Net Present Value	**40,116,280**					
Internal Rate of Return	**72.83%**					

Fuel Consumption 1	Year				
-	6	7	8	9	10
Capital Cost - Total					
Equipment					
Acquisition					
Expenses - Total	**(1,123,083)**	**(1,190,663)**	**(1,262,944)**	**(1,340,279)**	**(1,423,048)**
Distillate Correction	(389,115)	(420,245)	(453,864)	(490,173)	(529,387)
HFO Process & Heating	(77,823)	(84,049)	(90,773)	(98,035)	(105,877)
Operating Engineer	(190,497)	(196,212)	(202,098)	(208,161)	(214,406)
Chemical Consumption	0	0	0	0	0
Scrubber Loads	(194,558)	(210,122)	(226,932)	(245,087)	(264,694)
M&R Equip & Labor	(271,090)	(280,036)	(289,277)	(298,823)	(308,684)
Savings - Fuel Differential	**9,727,882**	**10,506,113**	**11,346,602**	**12,254,330**	**13,234,677**
NPV & IRR					
Cash Flow	8,604,800	9,315,450	10,083,658	10,914,051	11,811,628
Discount Factor	0.5645	0.5132	0.4665	0.4241	0.3855
Present Value	4,857,185	4,780,299	4,704,101	4,628,623	4,553,894
Net Present Value					
Internal Rate of Return					

	Ship/Route Pair	Containership Alaska to Puget Sound	Containership Alaska to Puget Sound	Containership Alaska to Puget Sound	Containership Alaska to Puget Sound
	Scrubber Type	Open Loop	Open Loop	Open Loop	Open Loop
Sensitivity Analysis	**Inflation**	**Low**	**Moderate**	**Predicted**	**High**
	Fuel Escalation	**Low**	**Moderate**	**Predicted**	**High**
VARIABLES - CONTROLLED					
Investment Terms					
Life Cycle	*(# of Years)*	10	10	10	10
Analysis Date (Today)	*(Year)*	2011	2011	2011	2011
Scrubber Installation Date	*(Year)*	2014	2014	2014	2014
Discount Rate	*(%)*	10.0%	10.0%	10.0%	10.0%
Capital Expense for Scrubber					
Equipment (Today)	*(USD/One Time)*	$5,060,000	$5,060,000	$5,060,000	$5,060,000
Engineering/Design	*(% Equip Cost)*	7.0%	7.0%	7.0%	7.0%
Training/Documents	*(% Equip Cost)*	2.0%	2.0%	2.0%	2.0%
Install/Commission	*(% Equip Cost)*	50.0%	50.0%	50.0%	50.0%
Operating Expense - Annual					
ECA Fuel Consumption	*(MT/Annual)*	9,636	9,636	9,636	9,636
Chemical Consumption	*(% of Fuel Cost)*	0.0%	0.0%	0.0%	0.0%
Scrubber Parasitic Loads	*(% of Fuel Cost)*	2.0%	2.0%	2.0%	2.0%
Distillate Calorie Correction	*(% of Fuel Cost)*	4.0%	4.0%	4.0%	4.0%
HFO Process and Heating	*(% of Fuel Cost)*	0.8%	0.8%	0.8%	0.8%
Operating Engineer (Today)	*(USD/Annual)*	$292,000	$292,000	$292,000	$292,000
Operating Engineer	*(% of Position)*	50.0%	50.0%	50.0%	50.0%
M&R Equipment	*(% Equip Cost/Annual)*	4.0%	4.0%	4.0%	4.0%
Variables - Uncertain					
Fuel Differential (Today)	*(USD/MT)*	$255.50	$255.50	$255.50	$255.50
Fuel/Chemical Escalation Rate	*(% - Annual for Op Period)*	2.0%	5.0%	8.0%	11.0%
Personnel Inflation Rate	*(% - Annual for Op Period)*	1.0%	2.0%	3.0%	5.0%
Equipment Inflation Rate	*(% - Annual for Op Period)*	1.0%	2.0%	3.3%	5.0%

Analysis Results - Overview (Nearest $1,000)					
Capital Cost	*(USD - Year Zero Dollars)*	(8,289,000)	(8,538,000)	(8,868,000)	(8,669,000)
Expenses - Year One	*(USD - Year One Dollars)*	(544,000)	(581,000)	(623,000)	(678,000)
Fuel Savings - Year One	*(USD - Year One Dollars)*	2,665,000	2,993,000	3,350,000	3,737,000
Net Present Value	*(USD - Present Dollars)*	5,854,000	9,714,000	14,562,000	21,174,000
Internal Rate of Return	*(%)*	24%	30%	36%	44%

11.52016187	14.46884962	17.36018386	0.346456441

Inflation Low	Year					
Fuel Escalation Low	0	1	2	3	4	5
Capital Cost - Total	**(8,289,184)**					
Equipment	(5,213,323)					
Acquisition	(3,075,861)					
Expenses - Total		**(543,762)**	**(551,012)**	**(558,370)**	**(565,839)**	**(573,421)**
Distillate Correction		(106,597)	(108,729)	(110,904)	(113,122)	(115,384)
HFO Process & Heating		(21,319)	(21,746)	(22,181)	(22,624)	(23,077)
Operating Engineer		(151,928)	(153,447)	(154,982)	(156,532)	(158,097)
Chemical Consumption		0	0	0	0	0
Scrubber Loads		(53,299)	(54,365)	(55,452)	(56,561)	(57,692)
M&R Equip & Labor		(210,618)	(212,724)	(214,852)	(217,000)	(219,170)
Savings - Fuel Differential		**2,664,936**	**2,718,234**	**2,772,599**	**2,828,051**	**2,884,612**
NPV & IRR						
Cash Flow	(8,289,184)	2,121,174	2,167,223	2,214,229	2,262,212	2,311,191
Discount Factor	1.0000	0.9091	0.8264	0.7513	0.6830	0.6209
Present Value	(8,289,184)	1,928,340	1,791,093	1,663,583	1,545,121	1,435,068
Net Present Value (at Year 0)	**5,853,509**					
Internal Rate of Return	**24.10%**					

Inflation Low	Year				
Fuel Escalation Low	6	7	8	9	10
Capital Cost - Total					
Equipment					
Acquisition					
Expenses - Total	**(581,117)**	**(588,929)**	**(596,859)**	**(604,909)**	**(613,081)**
Distillate Correction	(117,692)	(120,046)	(122,447)	(124,896)	(127,394)
HFO Process & Heating	(23,538)	(24,009)	(24,489)	(24,979)	(25,479)
Operating Engineer	(159,678)	(161,275)	(162,888)	(164,516)	(166,162)
Chemical Consumption	0	0	0	0	0
Scrubber Loads	(58,846)	(60,023)	(61,223)	(62,448)	(63,697)
M&R Equip & Labor	(221,362)	(223,576)	(225,811)	(228,069)	(230,350)
Savings - Fuel Differential	**2,942,304**	**3,001,150**	**3,061,173**	**3,122,397**	**3,184,845**
NPV & IRR					
Cash Flow	2,361,188	2,412,222	2,464,315	2,517,488	2,571,764
Discount Factor	0.5645	0.5132	0.4665	0.4241	0.3855
Present Value	1,332,829	1,237,851	1,149,621	1,067,661	991,526
Net Present Value (at Year 0)					
Internal Rate of Return					

Inflation Moderate	Year					
Fuel Escalation Moderate	0	1	2	3	4	5
Capital Cost - Total	**(8,537,843)**					
Equipment	(5,369,712)					
Acquisition	(3,168,130)					
Expenses - Total		**(580,614)**	**(598,331)**	**(616,707)**	**(635,772)**	**(655,555)**
Distillate Correction		(119,703)	(125,688)	(131,972)	(138,571)	(145,499)
HFO Process & Heating		(23,941)	(25,138)	(26,394)	(27,714)	(29,100)
Operating Engineer		(158,035)	(161,196)	(164,420)	(167,708)	(171,062)
Chemical Consumption		0	0	0	0	0
Scrubber Loads		(59,851)	(62,844)	(65,986)	(69,285)	(72,750)
M&R Equip & Labor		(219,084)	(223,466)	(227,935)	(232,494)	(237,144)
Savings - Fuel Differential		**2,992,563**	**3,142,191**	**3,299,300**	**3,464,265**	**3,637,479**
NPV & IRR						
Cash Flow	(8,537,843)	2,411,949	2,543,860	2,682,593	2,828,493	2,981,924
Discount Factor	1.0000	0.9091	0.8264	0.7513	0.6830	0.6209
Present Value	(8,537,843)	2,192,681	2,102,364	2,015,472	1,931,899	1,851,540
Net Present Value	**9,713,769**					
Internal Rate of Return	**30.28%**					

Inflation Moderate	Year				
Fuel Escalation Moderate	6	7	8	9	10
Capital Cost - Total					
Equipment					
Acquisition					
Expenses - Total	**(676,086)**	**(697,399)**	**(719,528)**	**(742,509)**	**(766,379)**
Distillate Correction	(152,774)	(160,413)	(168,433)	(176,855)	(185,698)
HFO Process & Heating	(30,555)	(32,083)	(33,687)	(35,371)	(37,140)
Operating Engineer	(174,484)	(177,973)	(181,533)	(185,163)	(188,867)
Chemical Consumption	0	0	0	0	0
Scrubber Loads	(76,387)	(80,206)	(84,217)	(88,428)	(92,849)
M&R Equip & Labor	(241,887)	(246,724)	(251,659)	(256,692)	(261,826)
Savings - Fuel Differential	**3,819,352**	**4,010,320**	**4,210,836**	**4,421,378**	**4,642,447**
NPV & IRR					
Cash Flow	3,143,266	3,312,921	3,491,308	3,678,869	3,876,068
Discount Factor	0.5645	0.5132	0.4665	0.4241	0.3855
Present Value	1,774,292	1,700,052	1,628,721	1,560,199	1,494,392
Net Present Value					
Internal Rate of Return					

Inflation Predicted	**Year**					
Fuel Escalation Predicted	0	1	2	3	4	5
Capital Cost - Total	**(8,868,468)**					
Equipment	(5,577,653)					
Acquisition	(3,290,815)					
Expenses - Total		**(622,559)**	**(653,316)**	**(685,929)**	**(720,528)**	**(757,252)**
Distillate Correction		(133,980)	(144,699)	(156,275)	(168,777)	(182,279)
HFO Process & Heating		(26,796)	(28,940)	(31,255)	(33,755)	(36,456)
Operating Engineer		(164,324)	(169,254)	(174,332)	(179,562)	(184,948)
Chemical Consumption		0	0	0	0	0
Scrubber Loads		(66,990)	(72,349)	(78,137)	(84,388)	(91,139)
M&R Equip & Labor		(230,469)	(238,074)	(245,931)	(254,046)	(262,430)
Savings - Fuel Differential		**3,349,508**	**3,617,469**	**3,906,867**	**4,219,416**	**4,556,969**
NPV & IRR						
Cash Flow	(8,868,468)	2,726,949	2,964,153	3,220,937	3,498,888	3,799,717
Discount Factor	1.0000	0.9091	0.8264	0.7513	0.6830	0.6209
Present Value	(8,868,468)	2,479,044	2,449,713	2,419,938	2,389,787	2,359,325
Net Present Value	**14,562,028**					
Internal Rate of Return	**36.17%**					

Inflation Predicted	Year				
Fuel Escalation Predicted	6	7	8	9	10
Capital Cost - Total					
Equipment					
Acquisition					
Expenses - Total	**(796,251)**	**(837,685)**	**(881,727)**	**(928,564)**	**(978,397)**
Distillate Correction	(196,861)	(212,610)	(229,619)	(247,988)	(267,827)
HFO Process & Heating	(39,372)	(42,522)	(45,924)	(49,598)	(53,565)
Operating Engineer	(190,497)	(196,212)	(202,098)	(208,161)	(214,406)
Chemical Consumption	0	0	0	0	0
Scrubber Loads	(98,431)	(106,305)	(114,809)	(123,994)	(133,914)
M&R Equip & Labor	(271,090)	(280,036)	(289,277)	(298,823)	(308,684)
Savings - Fuel Differential	**4,921,527**	**5,315,249**	**5,740,469**	**6,199,706**	**6,695,683**
NPV & IRR					
Cash Flow	4,125,276	4,477,564	4,858,742	5,271,142	5,717,286
Discount Factor	0.5645	0.5132	0.4665	0.4241	0.3855
Present Value	2,328,611	2,297,698	2,266,639	2,235,479	2,204,261
Net Present Value					
Internal Rate of Return					

Inflation High	**Year**					
Fuel Escalation High	0	1	2	3	4	5
Capital Cost - Total	**(8,669,297)**					
Equipment	(5,213,323)					
Acquisition	(3,455,974)					
Expenses - Total		**(677,630)**	**(726,761)**	**(780,025)**	**(837,815)**	**(900,560)**
Distillate Correction		(149,499)	(165,944)	(184,198)	(204,459)	(226,950)
HFO Process & Heating		(29,900)	(33,189)	(36,840)	(40,892)	(45,390)
Operating Engineer		(177,464)	(186,337)	(195,654)	(205,437)	(215,708)
Chemical Consumption		0	0	0	0	0
Scrubber Loads		(74,749)	(82,972)	(92,099)	(102,230)	(113,475)
M&R Equip & Labor		(246,018)	(258,319)	(271,235)	(284,797)	(299,037)
Savings - Fuel Differential		**3,737,472**	**4,148,594**	**4,604,939**	**5,111,483**	**5,673,746**
NPV & IRR						
Cash Flow	(8,669,297)	3,059,842	3,421,833	3,824,914	4,273,668	4,773,186
Discount Factor	1.0000	0.9091	0.8264	0.7513	0.6830	0.6209
Present Value	(8,669,297)	2,781,674	2,827,961	2,873,715	2,918,973	2,963,773
Net Present Value	**21,174,017**					
Internal Rate of Return	**44.30%**					

Inflation High	Year				
Fuel Escalation High	6	7	8	9	10
Capital Cost - Total					
Equipment					
Acquisition					
Expenses - Total	**(968,737)**	**(1,042,869)**	**(1,123,534)**	**(1,211,370)**	**(1,307,080)**
Distillate Correction	(251,914)	(279,625)	(310,384)	(344,526)	(382,424)
HFO Process & Heating	(50,383)	(55,925)	(62,077)	(68,905)	(76,485)
Operating Engineer	(226,494)	(237,819)	(249,710)	(262,195)	(275,305)
Chemical Consumption	0	0	0	0	0
Scrubber Loads	(125,957)	(139,812)	(155,192)	(172,263)	(191,212)
M&R Equip & Labor	(313,989)	(329,688)	(346,173)	(363,481)	(381,655)
Savings - Fuel Differential	**6,297,858**	**6,990,622**	**7,759,591**	**8,613,146**	**9,560,592**
NPV & IRR					
Cash Flow	5,329,121	5,947,753	6,636,056	7,401,775	8,253,511
Discount Factor	0.5645	0.5132	0.4665	0.4241	0.3855
Present Value	3,008,150	3,052,138	3,095,769	3,139,075	3,182,086
Net Present Value					
Internal Rate of Return					

	Ship/Route Pair	Containership Alaska to Puget Sound	Containership Alaska to Puget Sound	Containership Alaska to Puget Sound	Containership Alaska to Puget Sound
	Scrubber Type	**Open Loop**	**Open Loop**	**Open Loop**	**Open Loop**
Sensitivity Analysis	**Opeating Years**	**Minimum**	**10**	**15**	**20**
VARIABLES - CONTROLLED					
Investment Terms					
Life Cycle	*(# of Years)*	4	10	15	20
Analysis Date (Today)	*(Year)*	2011	2011	2011	2011
Scrubber Installation Date	*(Year)*	2014	2014	2014	2014
Discount Rate	*(%)*	10.0%	10.0%	10.0%	10.0%
Capital Expense for Scrubber					
Equipment (Today)	*(USD/One Time)*	$5,060,000	$5,060,000	$5,060,000	$5,060,000
Engineering/Design	*(% Equip Cost)*	7.0%	7.0%	7.0%	7.0%
Training/Documents	*(% Equip Cost)*	2.0%	2.0%	2.0%	2.0%
Install/Commission	*(% Equip Cost)*	50.0%	50.0%	50.0%	50.0%
Operating Expense - Annual					
ECA Fuel Consumption	*(MT/Annual)*	9,636	9,636	9,636	9,636
Chemical Consumption	*(% of Fuel Cost)*	0.0%	0.0%	0.0%	0.0%
Scrubber Parasitic Loads	*(% of Fuel Cost)*	2.0%	2.0%	2.0%	2.0%
Distillate Calorie Correction	*(% of Fuel Cost)*	4.0%	4.0%	4.0%	4.0%
HFO Process and Heating	*(% of Fuel Cost)*	0.8%	0.8%	0.8%	0.8%
Operating Engineer (Today)	*(USD/Annual)*	$292,000	$292,000	$292,000	$292,000
Operating Engineer	*(% of Position)*	50.0%	50.0%	50.0%	50.0%
M&R Equipment	*(% Equip Cost/Annual)*	4.0%	4.0%	4.0%	4.0%
Variables - Uncertain					
Fuel Differential (Today)	*(USD/MT)*	$255.50	$255.50	$255.50	$255.50
Fuel/Chemical Escalation Rate	*(% - Annual for Op Period)*	8.0%	8.0%	8.0%	8.0%
Personnel Inflation Rate	*(% - Annual for Op Period)*	3.0%	3.0%	3.0%	3.0%
Equipment Inflation Rate	*(% - Annual for Op Period)*	3.3%	3.3%	3.3%	3.3%

Analysis Results - Overview (Nearest $1,000)					
Capital Cost	*(USD - Year Zero Dollars)*	(8,868,000)	(8,868,000)	(8,868,000)	(8,868,000)
Expenses - Year One	*(USD - Year One Dollars)*	(623,000)	(623,000)	(623,000)	(623,000)
Fuel Savings - Year One	*(USD - Year One Dollars)*	3,350,000	3,350,000	3,350,000	3,350,000
Net Present Value	*(USD - Present Dollars)*	(1,520,000)	14,562,000	14,562,000	14,562,000
Internal Rate of Return	*(%)*	0%	36%	36%	36%

Opeating Years Minimum	Year					
-	0	1	2	3	4	5
Capital Cost - Total	**(8,868,468)**					
Equipment	(5,577,653)					
Acquisition	(3,290,815)					
Expenses - Total		**(622,559)**	**(653,316)**	**(685,929)**		
Distillate Correction		(133,980)	(144,699)	(156,275)		
HFO Process & Heating		(26,796)	(28,940)	(31,255)		
Operating Engineer		(164,324)	(169,254)	(174,332)		
Chemical Consumption		0	0	0		
Scrubber Loads		(66,990)	(72,349)	(78,137)		
M&R Equip & Labor		(230,469)	(238,074)	(245,931)		
Savings - Fuel Differential		**3,349,508**	**3,617,469**	**3,906,867**		
NPV & IRR						
Cash Flow	(8,868,468)	2,726,949	2,964,153	3,220,937		
Discount Factor	1.0000	0.9091	0.8264	0.7513		
Present Value	(8,868,468)	2,479,044	2,449,713	2,419,938		
Net Present Value (at Year 0)	**(1,519,772)**					
Internal Rate of Return	**0.24%**					

<u>**Opeating Years Minimum**</u>	**Year**				
-	6	7	8	9	10
Capital Cost - Total					
Equipment					
Acquisition					
Expenses - Total					
Distillate Correction					
HFO Process & Heating					
Operating Engineer					
Chemical Consumption					
Scrubber Loads					
M&R Equip & Labor					
Savings - Fuel Differential					
NPV & IRR					
Cash Flow					
Discount Factor					
Present Value					
Net Present Value (at Year 0)					
Internal Rate of Return					

Opeating Years 10	Year					
-	0	1	2	3	4	5
Capital Cost - Total	**(8,868,468)**					
Equipment	(5,577,653)					
Acquisition	(3,290,815)					
Expenses - Total		**(622,559)**	**(653,316)**	**(685,929)**	**(720,528)**	**(757,252)**
Distillate Correction		(133,980)	(144,699)	(156,275)	(168,777)	(182,279)
HFO Process & Heating		(26,796)	(28,940)	(31,255)	(33,755)	(36,456)
Operating Engineer		(164,324)	(169,254)	(174,332)	(179,562)	(184,948)
Chemical Consumption		0	0	0	0	0
Scrubber Loads		(66,990)	(72,349)	(78,137)	(84,388)	(91,139)
M&R Equip & Labor		(230,469)	(238,074)	(245,931)	(254,046)	(262,430)
Savings - Fuel Differential		**3,349,508**	**3,617,469**	**3,906,867**	**4,219,416**	**4,556,969**
NPV & IRR						
Cash Flow	(8,868,468)	2,726,949	2,964,153	3,220,937	3,498,888	3,799,717
Discount Factor	1.0000	0.9091	0.8264	0.7513	0.6830	0.6209
Present Value	(8,868,468)	2,479,044	2,449,713	2,419,938	2,389,787	2,359,325
Net Present Value	**14,562,028**					
Internal Rate of Return	**36.17%**					

<u>**Opeating Years 10**</u>	**Year**				
-	6	7	8	9	10
Capital Cost - Total					
Equipment					
Acquisition					
Expenses - Total	**(796,251)**	**(837,685)**	**(881,727)**	**(928,564)**	**(978,397)**
Distillate Correction	(196,861)	(212,610)	(229,619)	(247,988)	(267,827)
HFO Process & Heating	(39,372)	(42,522)	(45,924)	(49,598)	(53,565)
Operating Engineer	(190,497)	(196,212)	(202,098)	(208,161)	(214,406)
Chemical Consumption	0	0	0	0	0
Scrubber Loads	(98,431)	(106,305)	(114,809)	(123,994)	(133,914)
M&R Equip & Labor	(271,090)	(280,036)	(289,277)	(298,823)	(308,684)
Savings - Fuel Differential	**4,921,527**	**5,315,249**	**5,740,469**	**6,199,706**	**6,695,683**
NPV & IRR					
Cash Flow	4,125,276	4,477,564	4,858,742	5,271,142	5,717,286
Discount Factor	0.5645	0.5132	0.4665	0.4241	0.3855
Present Value	2,328,611	2,297,698	2,266,639	2,235,479	2,204,261
Net Present Value					
Internal Rate of Return					

Opeating Years 15	Year					
-	0	1	2	3	4	5
Capital Cost - Total	**(8,868,468)**					
Equipment	(5,577,653)					
Acquisition	(3,290,815)					
Expenses - Total		**(622,559)**	**(653,316)**	**(685,929)**	**(720,528)**	**(757,252)**
Distillate Correction		(133,980)	(144,699)	(156,275)	(168,777)	(182,279)
HFO Process & Heating		(26,796)	(28,940)	(31,255)	(33,755)	(36,456)
Operating Engineer		(164,324)	(169,254)	(174,332)	(179,562)	(184,948)
Chemical Consumption		0	0	0	0	0
Scrubber Loads		(66,990)	(72,349)	(78,137)	(84,388)	(91,139)
M&R Equip & Labor		(230,469)	(238,074)	(245,931)	(254,046)	(262,430)
Savings - Fuel Differential		**3,349,508**	**3,617,469**	**3,906,867**	**4,219,416**	**4,556,969**
NPV & IRR						
Cash Flow	(8,868,468)	2,726,949	2,964,153	3,220,937	3,498,888	3,799,717
Discount Factor	1.0000	0.9091	0.8264	0.7513	0.6830	0.6209
Present Value	(8,868,468)	2,479,044	2,449,713	2,419,938	2,389,787	2,359,325
Net Present Value	**14,562,028**					
Internal Rate of Return	**36.17%**					

Opeating Years 15	Year				
-	6	7	8	9	10
Capital Cost - Total					
Equipment					
Acquisition					
Expenses - Total	**(796,251)**	**(837,685)**	**(881,727)**	**(928,564)**	**(978,397)**
Distillate Correction	(196,861)	(212,610)	(229,619)	(247,988)	(267,827)
HFO Process & Heating	(39,372)	(42,522)	(45,924)	(49,598)	(53,565)
Operating Engineer	(190,497)	(196,212)	(202,098)	(208,161)	(214,406)
Chemical Consumption	0	0	0	0	0
Scrubber Loads	(98,431)	(106,305)	(114,809)	(123,994)	(133,914)
M&R Equip & Labor	(271,090)	(280,036)	(289,277)	(298,823)	(308,684)
Savings - Fuel Differential	**4,921,527**	**5,315,249**	**5,740,469**	**6,199,706**	**6,695,683**
NPV & IRR					
Cash Flow	4,125,276	4,477,564	4,858,742	5,271,142	5,717,286
Discount Factor	0.5645	0.5132	0.4665	0.4241	0.3855
Present Value	2,328,611	2,297,698	2,266,639	2,235,479	2,204,261
Net Present Value					
Internal Rate of Return					

Opeating Years 15					
-	11	12	13	14	15
Capital Cost - Total					
Equipment					
Acquisition					
Expenses - Total	**(1,031,440)**	**(1,087,926)**	**(1,148,106)**	**(1,212,248)**	**(1,280,641)**
Distillate Correction	(289,253)	(312,394)	(337,385)	(364,376)	(393,526)
HFO Process & Heating	(57,851)	(62,479)	(67,477)	(72,875)	(78,705)
Operating Engineer	(220,838)	(227,463)	(234,287)	(241,316)	(248,555)
Chemical Consumption	0	0	0	0	0
Scrubber Loads	(144,627)	(156,197)	(168,693)	(182,188)	(196,763)
M&R Equip & Labor	(318,871)	(329,394)	(340,264)	(351,492)	(363,092)
Savings - Fuel Differential	**7,231,337**	**7,809,844**	**8,434,632**	**9,109,402**	**9,838,155**
NPV & IRR					
Cash Flow	6,199,897	6,721,918	7,286,526	7,897,155	8,557,513
Discount Factor	0.3505	0.3186	0.2897	0.2633	0.2394
Present Value	2,173,026	2,141,810	2,110,647	2,079,568	2,048,601
Net Present Value					
Internal Rate of Return					

Opeating Years 15	Page Not Used
-	
Capital Cost - Total	
Equipment	
Acquisition	
Expenses - Total	
Distillate Correction	
HFO Process & Heating	
Operating Engineer	
Chemical Consumption	
Scrubber Loads	
M&R Equip & Labor	
Savings - Fuel Differential	
NPV & IRR	
Cash Flow	
Discount Factor	
Present Value	
Net Present Value	
Internal Rate of Return	

Opeating Years 20	Year					
-	0	1	2	3	4	5
Capital Cost - Total	**(8,868,468)**					
Equipment	(5,577,653)					
Acquisition	(3,290,815)					
Expenses - Total		**(622,559)**	**(653,316)**	**(685,929)**	**(720,528)**	**(757,252)**
Distillate Correction		(133,980)	(144,699)	(156,275)	(168,777)	(182,279)
HFO Process & Heating		(26,796)	(28,940)	(31,255)	(33,755)	(36,456)
Operating Engineer		(164,324)	(169,254)	(174,332)	(179,562)	(184,948)
Chemical Consumption		0	0	0	0	0
Scrubber Loads		(66,990)	(72,349)	(78,137)	(84,388)	(91,139)
M&R Equip & Labor		(230,469)	(238,074)	(245,931)	(254,046)	(262,430)
Savings - Fuel Differential		**3,349,508**	**3,617,469**	**3,906,867**	**4,219,416**	**4,556,969**
NPV & IRR						
Cash Flow	(8,868,468)	2,726,949	2,964,153	3,220,937	3,498,888	3,799,717
Discount Factor	1.0000	0.9091	0.8264	0.7513	0.6830	0.6209
Present Value	(8,868,468)	2,479,044	2,449,713	2,419,938	2,389,787	2,359,325
Net Present Value	**14,562,028**					
Internal Rate of Return	**36.17%**					

Opeating Years 20	**Year**				
-	6	7	8	9	10
Capital Cost - Total					
Equipment					
Acquisition					
Expenses - Total	**(796,251)**	**(837,685)**	**(881,727)**	**(928,564)**	**(978,397)**
Distillate Correction	(196,861)	(212,610)	(229,619)	(247,988)	(267,827)
HFO Process & Heating	(39,372)	(42,522)	(45,924)	(49,598)	(53,565)
Operating Engineer	(190,497)	(196,212)	(202,098)	(208,161)	(214,406)
Chemical Consumption	0	0	0	0	0
Scrubber Loads	(98,431)	(106,305)	(114,809)	(123,994)	(133,914)
M&R Equip & Labor	(271,090)	(280,036)	(289,277)	(298,823)	(308,684)
Savings - Fuel Differential	**4,921,527**	**5,315,249**	**5,740,469**	**6,199,706**	**6,695,683**
NPV & IRR					
Cash Flow	4,125,276	4,477,564	4,858,742	5,271,142	5,717,286
Discount Factor	0.5645	0.5132	0.4665	0.4241	0.3855
Present Value	2,328,611	2,297,698	2,266,639	2,235,479	2,204,261
Net Present Value					
Internal Rate of Return					

Opeating Years 20						
-	11	12	13	14	15	16
Capital Cost - Total						
Equipment						
Acquisition						
Expenses - Total	**(1,031,440)**	**(1,087,926)**	**(1,148,106)**	**(1,212,248)**	**(1,280,641)**	**(1,353,600)**
Distillate Correction	(289,253)	(312,394)	(337,385)	(364,376)	(393,526)	(425,008)
HFO Process & Heating	(57,851)	(62,479)	(67,477)	(72,875)	(78,705)	(85,002)
Operating Engineer	(220,838)	(227,463)	(234,287)	(241,316)	(248,555)	(256,012)
Chemical Consumption	0	0	0	0	0	0
Scrubber Loads	(144,627)	(156,197)	(168,693)	(182,188)	(196,763)	(212,504)
M&R Equip & Labor	(318,871)	(329,394)	(340,264)	(351,492)	(363,092)	(375,074)
Savings - Fuel Differential	**7,231,337**	**7,809,844**	**8,434,632**	**9,109,402**	**9,838,155**	**10,625,207**
NPV & IRR						
Cash Flow	6,199,897	6,721,918	7,286,526	7,897,155	8,557,513	9,271,607
Discount Factor	0.3505	0.3186	0.2897	0.2633	0.2394	0.2176
Present Value	2,173,026	2,141,810	2,110,647	2,079,568	2,048,601	2,017,772
Net Present Value						
Internal Rate of Return						

Opeating Years 20				
-	17	18	19	20
Capital Cost - Total				
Equipment				
Acquisition				
Expenses - Total	**(1,431,459)**	**(1,514,580)**	**(1,603,356)**	**(1,698,205)**
Distillate Correction	(459,009)	(495,730)	(535,388)	(578,219)
HFO Process & Heating	(91,802)	(99,146)	(107,078)	(115,644)
Operating Engineer	(263,692)	(271,603)	(279,751)	(288,144)
Chemical Consumption	0	0	0	0
Scrubber Loads	(229,504)	(247,865)	(267,694)	(289,110)
M&R Equip & Labor	(387,451)	(400,237)	(413,445)	(427,089)
Savings - Fuel Differential	**11,475,224**	**12,393,241**	**13,384,701**	**14,455,477**
NPV & IRR				
Cash Flow	10,043,765	10,878,661	11,781,345	12,757,272
Discount Factor	0.1978	0.1799	0.1635	0.1486
Present Value	1,987,105	1,956,623	1,926,344	1,896,287
Net Present Value				
Internal Rate of Return				

	Ship/Route Pair	Containership Alaska to Puget Sound	Containership Alaska to Puget Sound	Containership Alaska to Puget Sound	Containership Alaska to Puget Sound
	Scrubber Type	**Open Loop**	**Open Loop**	**Open Loop**	**Open Loop**
Sensitivity Analysis	**Expenses**	**Low**	**Predicted**	**High**	**V. High**
VARIABLES - CONTROLLED					
Investment Terms					
Life Cycle	*(# of Years)*	10	10	10	10
Analysis Date (Today)	*(Year)*	2011	2011	2011	2011
Scrubber Installation Date	*(Year)*	2014	2014	2014	2014
Discount Rate	*(%)*	10.0%	10.0%	10.0%	10.0%
Capital Expense for Scrubber					
Equipment (Today)	*(USD/One Time)*	$3,795,000	$5,060,000	$5,566,000	$6,325,000
Engineering/Design	*(% Equip Cost)*	5.3%	7.0%	8.8%	11.0%
Training/Documents	*(% Equip Cost)*	1.5%	2.0%	2.5%	2.0%
Install/Commission	*(% Equip Cost)*	37.5%	50.0%	62.5%	65.0%
Operating Expense - Annual					
ECA Fuel Consumption	*(MT/Annual)*	9,636	9,636	9,636	9,636
Chemical Consumption	*(% of Fuel Cost)*	0.0%	0.0%	0.0%	0.0%
Scrubber Parasitic Loads	*(% of Fuel Cost)*	2.0%	2.0%	2.0%	2.0%
Distillate Calorie Correction	*(% of Fuel Cost)*	4.0%	4.0%	4.0%	4.0%
HFO Process and Heating	*(% of Fuel Cost)*	0.8%	0.8%	0.8%	0.8%
Operating Engineer (Today)	*(USD/Annual)*	$219,000	$292,000	$365,000	$400,000
Operating Engineer	*(% of Position)*	37.5%	50.0%	62.5%	100.0%
M&R Equipment	*(% Equip Cost/Annual)*	3.0%	4.0%	5.0%	8.0%
Variables - Uncertain					
Fuel Differential (Today)	*(USD/MT)*	$255.50	$255.50	$255.50	$255.50
Fuel/Chemical Escalation Rate	*(% - Annual for Op Period)*	8.0%	8.0%	8.0%	8.0%
Personnel Inflation Rate	*(% - Annual for Op Period)*	3.0%	3.0%	3.0%	3.0%
Equipment Inflation Rate	*(% - Annual for Op Period)*	3.3%	3.3%	3.3%	3.3%

Analysis Results - Overview (Nearest $1,000)					
Capital Cost	*(USD - Year Zero Dollars)*	(6,034,000)	(8,868,000)	(10,660,000)	(12,410,000)
Expenses - Year One	*(USD - Year One Dollars)*	(450,000)	(623,000)	(801,000)	(1,254,000)
Fuel Savings - Year One	*(USD - Year One Dollars)*	3,350,000	3,350,000	3,350,000	3,350,000
Net Present Value	*(USD - Present Dollars)*	18,593,000	14,562,000	11,532,000	6,645,000
Internal Rate of Return	*(%)*	55%	36%	28%	20%

Expenses Low	Year					
-	0	1	2	3	4	5
Capital Cost - Total	**(6,034,323)**					
Equipment	(4,183,240)					
Acquisition	(1,851,084)					
Expenses - Total		**(449,838)**	**(475,110)**	**(502,064)**	**(530,825)**	**(561,524)**
Distillate Correction		(133,980)	(144,699)	(156,275)	(168,777)	(182,279)
HFO Process & Heating		(26,796)	(28,940)	(31,255)	(33,755)	(36,456)
Operating Engineer		(92,432)	(95,205)	(98,062)	(101,003)	(104,033)
Chemical Consumption		0	0	0	0	0
Scrubber Loads		(66,990)	(72,349)	(78,137)	(84,388)	(91,139)
M&R Equip & Labor		(129,639)	(133,917)	(138,336)	(142,901)	(147,617)
Savings - Fuel Differential		**3,349,508**	**3,617,469**	**3,906,867**	**4,219,416**	**4,556,969**
NPV & IRR						
Cash Flow	(6,034,323)	2,899,671	3,142,359	3,404,802	3,688,591	3,995,445
Discount Factor	1.0000	0.9091	0.8264	0.7513	0.6830	0.6209
Present Value	(6,034,323)	2,636,064	2,596,991	2,558,078	2,519,357	2,480,857
Net Present Value (at Year 0)	**18,593,214**					
Internal Rate of Return	**55.06%**					

Expenses Low	Year				
-	6	7	8	9	10
Capital Cost - Total					
Equipment					
Acquisition					
Expenses - Total	**(594,306)**	**(629,326)**	**(666,750)**	**(706,759)**	**(749,545)**
Distillate Correction	(196,861)	(212,610)	(229,619)	(247,988)	(267,827)
HFO Process & Heating	(39,372)	(42,522)	(45,924)	(49,598)	(53,565)
Operating Engineer	(107,154)	(110,369)	(113,680)	(117,091)	(120,603)
Chemical Consumption	0	0	0	0	0
Scrubber Loads	(98,431)	(106,305)	(114,809)	(123,994)	(133,914)
M&R Equip & Labor	(152,488)	(157,520)	(162,718)	(168,088)	(173,635)
Savings - Fuel Differential	**4,921,527**	**5,315,249**	**5,740,469**	**6,199,706**	**6,695,683**
NPV & IRR					
Cash Flow	4,327,220	4,685,923	5,073,718	5,492,948	5,946,138
Discount Factor	0.5645	0.5132	0.4665	0.4241	0.3855
Present Value	2,442,603	2,404,619	2,366,927	2,329,546	2,292,494
Net Present Value (at Year 0)					
Internal Rate of Return					

Expenses Predicted	**Year**					
-	0	1	2	3	4	5
Capital Cost - Total	**(8,868,468)**					
Equipment	(5,577,653)					
Acquisition	(3,290,815)					
Expenses - Total		**(622,559)**	**(653,316)**	**(685,929)**	**(720,528)**	**(757,252)**
Distillate Correction		(133,980)	(144,699)	(156,275)	(168,777)	(182,279)
HFO Process & Heating		(26,796)	(28,940)	(31,255)	(33,755)	(36,456)
Operating Engineer		(164,324)	(169,254)	(174,332)	(179,562)	(184,948)
Chemical Consumption		0	0	0	0	0
Scrubber Loads		(66,990)	(72,349)	(78,137)	(84,388)	(91,139)
M&R Equip & Labor		(230,469)	(238,074)	(245,931)	(254,046)	(262,430)
Savings - Fuel Differential		**3,349,508**	**3,617,469**	**3,906,867**	**4,219,416**	**4,556,969**
NPV & IRR						
Cash Flow	(8,868,468)	2,726,949	2,964,153	3,220,937	3,498,888	3,799,717
Discount Factor	1.0000	0.9091	0.8264	0.7513	0.6830	0.6209
Present Value	(8,868,468)	2,479,044	2,449,713	2,419,938	2,389,787	2,359,325
Net Present Value	**14,562,028**					
Internal Rate of Return	**36.17%**					

Expenses Predicted	**Year**				
-	6	7	8	9	10
Capital Cost - Total					
Equipment					
Acquisition					
Expenses - Total	**(796,251)**	**(837,685)**	**(881,727)**	**(928,564)**	**(978,397)**
Distillate Correction	(196,861)	(212,610)	(229,619)	(247,988)	(267,827)
HFO Process & Heating	(39,372)	(42,522)	(45,924)	(49,598)	(53,565)
Operating Engineer	(190,497)	(196,212)	(202,098)	(208,161)	(214,406)
Chemical Consumption	0	0	0	0	0
Scrubber Loads	(98,431)	(106,305)	(114,809)	(123,994)	(133,914)
M&R Equip & Labor	(271,090)	(280,036)	(289,277)	(298,823)	(308,684)
Savings - Fuel Differential	**4,921,527**	**5,315,249**	**5,740,469**	**6,199,706**	**6,695,683**
NPV & IRR					
Cash Flow	4,125,276	4,477,564	4,858,742	5,271,142	5,717,286
Discount Factor	0.5645	0.5132	0.4665	0.4241	0.3855
Present Value	2,328,611	2,297,698	2,266,639	2,235,479	2,204,261
Net Present Value					
Internal Rate of Return					

Expenses High	Year					
-	0	1	2	3	4	5
Capital Cost - Total	**(10,660,289)**					
Equipment	(6,135,418)					
Acquisition	(4,524,871)					
Expenses - Total		**(801,418)**	**(837,799)**	**(876,215)**	**(916,799)**	**(959,697)**
Distillate Correction		(133,980)	(144,699)	(156,275)	(168,777)	(182,279)
HFO Process & Heating		(26,796)	(28,940)	(31,255)	(33,755)	(36,456)
Operating Engineer		(256,757)	(264,459)	(272,393)	(280,565)	(288,982)
Chemical Consumption		0	0	0	0	0
Scrubber Loads		(66,990)	(72,349)	(78,137)	(84,388)	(91,139)
M&R Equip & Labor		(316,894)	(327,352)	(338,154)	(349,314)	(360,841)
Savings - Fuel Differential		**3,349,508**	**3,617,469**	**3,906,867**	**4,219,416**	**4,556,969**
NPV & IRR						
Cash Flow	(10,660,289)	2,548,091	2,779,670	3,030,652	3,302,617	3,597,272
Discount Factor	1.0000	0.9091	0.8264	0.7513	0.6830	0.6209
Present Value	(10,660,289)	2,316,446	2,297,248	2,276,974	2,255,732	2,233,623
Net Present Value	**11,532,079**					
Internal Rate of Return	**28.15%**					

Expenses High	Year				
-	6	7	8	9	10
Capital Cost - Total					
Equipment					
Acquisition					
Expenses - Total	**(1,005,064)**	**(1,053,067)**	**(1,103,886)**	**(1,157,714)**	**(1,214,757)**
Distillate Correction	(196,861)	(212,610)	(229,619)	(247,988)	(267,827)
HFO Process & Heating	(39,372)	(42,522)	(45,924)	(49,598)	(53,565)
Operating Engineer	(297,651)	(306,581)	(315,778)	(325,252)	(335,009)
Chemical Consumption	0	0	0	0	0
Scrubber Loads	(98,431)	(106,305)	(114,809)	(123,994)	(133,914)
M&R Equip & Labor	(372,749)	(385,049)	(397,756)	(410,882)	(424,441)
Savings - Fuel Differential	**4,921,527**	**5,315,249**	**5,740,469**	**6,199,706**	**6,695,683**
NPV & IRR					
Cash Flow	3,916,463	4,262,182	4,636,583	5,041,993	5,480,926
Discount Factor	0.5645	0.5132	0.4665	0.4241	0.3855
Present Value	2,210,741	2,187,173	2,163,000	2,138,297	2,113,134
Net Present Value					
Internal Rate of Return					

Expenses V. High	Year					
-	0	1	2	3	4	5
Capital Cost - Total	**(12,410,278)**					
Equipment	(6,972,066)					
Acquisition	(5,438,212)					
Expenses - Total		**(1,254,142)**	**(1,304,883)**	**(1,358,114)**	**(1,413,985)**	**(1,472,656)**
Distillate Correction		(133,980)	(144,699)	(156,275)	(168,777)	(182,279)
HFO Process & Heating		(26,796)	(28,940)	(31,255)	(33,755)	(36,456)
Operating Engineer		(450,204)	(463,710)	(477,621)	(491,950)	(506,708)
Chemical Consumption		0	0	0	0	0
Scrubber Loads		(66,990)	(72,349)	(78,137)	(84,388)	(91,139)
M&R Equip & Labor		(576,172)	(595,185)	(614,826)	(635,116)	(656,074)
Savings - Fuel Differential		**3,349,508**	**3,617,469**	**3,906,867**	**4,219,416**	**4,556,969**
NPV & IRR						
Cash Flow	(12,410,278)	2,095,367	2,312,586	2,548,752	2,805,430	3,084,313
Discount Factor	1.0000	0.9091	0.8264	0.7513	0.6830	0.6209
Present Value	(12,410,278)	1,904,879	1,911,228	1,914,915	1,916,147	1,915,116
Net Present Value	**6,644,910**					
Internal Rate of Return	**19.56%**					

Expenses V. High	Year				
-	6	7	8	9	10
Capital Cost - Total					
Equipment					
Acquisition					
Expenses - Total	**(1,534,298)**	**(1,599,093)**	**(1,667,238)**	**(1,738,942)**	**(1,814,431)**
Distillate Correction	(196,861)	(212,610)	(229,619)	(247,988)	(267,827)
HFO Process & Heating	(39,372)	(42,522)	(45,924)	(49,598)	(53,565)
Operating Engineer	(521,909)	(537,567)	(553,694)	(570,304)	(587,413)
Chemical Consumption	0	0	0	0	0
Scrubber Loads	(98,431)	(106,305)	(114,809)	(123,994)	(133,914)
M&R Equip & Labor	(677,725)	(700,090)	(723,193)	(747,058)	(771,711)
Savings - Fuel Differential	**4,921,527**	**5,315,249**	**5,740,469**	**6,199,706**	**6,695,683**
NPV & IRR					
Cash Flow	3,387,229	3,716,156	4,073,231	4,460,764	4,881,252
Discount Factor	0.5645	0.5132	0.4665	0.4241	0.3855
Present Value	1,912,002	1,906,975	1,900,192	1,891,799	1,881,934
Net Present Value					
Internal Rate of Return					

	Ship/Route Pair	Containership Alaska to Puget Sound	Containership Alaska to Puget Sound	Containership Alaska to Puget Sound	Containership Alaska to Puget Sound
	Scrubber Type	Open Loop	Open Loop	Open Loop	Open Loop
Sensitivity Analysis	**Expenses**	**Low**	**Predicted**	**High**	**V. High**
Combination of Variables	**Fuel/CPI-PPI**	**11/5**	**8/3**	**5/2**	**2/1**
VARIABLES - CONTROLLED					
Investment Terms					
Life Cycle	*(# of Years)*	10	10	10	10
Analysis Date (Today)	*(Year)*	2011	2011	2011	2011
Scrubber Installation Date	*(Year)*	2014	2014	2014	2014
Discount Rate	*(%)*	10.0%	10.0%	10.0%	10.0%
Capital Expense for Scrubber					
Equipment (Today)	*(USD/One Time)*	$3,795,000	$5,060,000	$5,566,000	$6,325,000
Engineering/Design	*(% Equip Cost)*	5.0%	7.0%	9.0%	11.0%
Training/Documents	*(% Equip Cost)*	2.0%	2.0%	2.0%	2.0%
Install/Commission	*(% Equip Cost)*	40.0%	50.0%	60.0%	65.0%
Operating Expense - Annual					
ECA Fuel Consumption	*(MT/Annual)*	9,636	9,636	9,636	9,636
Chemical Consumption	*(% of Fuel Cost)*	0.0%	0.0%	0.0%	0.0%
Scrubber Parasitic Loads	*(% of Fuel Cost)*	2.0%	2.0%	2.0%	2.0%
Distillate Calorie Correction	*(% of Fuel Cost)*	4.0%	4.0%	4.0%	4.0%
HFO Process and Heating	*(% of Fuel Cost)*	0.8%	0.8%	0.8%	0.8%
Operating Engineer (Today)	*(USD/Annual)*	$200,000	$292,000	$350,000	$400,000
Operating Engineer	*(% of Position)*	25.0%	50.0%	75.0%	100.0%
M&R Equipment	*(% Equip Cost/Annual)*	2.0%	4.0%	6.0%	8.0%
Variables - Uncertain					
Fuel Differential (Today)	*(USD/MT)*	$255.50	$255.50	$255.50	$255.50
Fuel/Chemical Escalation Rate	*(% - Annual for Op Period)*	11.0%	8.0%	5.0%	2.0%
Personnel Inflation Rate	*(% - Annual for Op Period)*	5.0%	3.0%	2.0%	1.0%
Equipment Inflation Rate	*(% - Annual for Op Period)*	5.0%	3.3%	2.0%	1.0%

Analysis Results - Overview (Nearest $1,000)					
Capital Cost	*(USD - Year Zero Dollars)*	(6,458,000)	(8,868,000)	(10,100,000)	(12,405,000)
Expenses - Year One	*(USD - Year One Dollars)*	(407,000)	(623,000)	(849,000)	(1,124,000)
Fuel Savings - Year One	*(USD - Year One Dollars)*	3,737,000	3,350,000	2,993,000	2,665,000
Net Present Value	*(USD - Present Dollars)*	25,397,000	14,562,000	6,372,000	(1,964,000)
Internal Rate of Return	*(%)*	62%	36%	22%	6%

Expenses Low	Year					
Fuel/CPI-PPI 11/5	0	1	2	3	4	5
Capital Cost - Total	**(6,457,985)**					
Equipment	(4,393,187)					
Acquisition	(2,064,798)					
Expenses - Total		**(407,180)**	**(442,788)**	**(481,854)**	**(524,735)**	**(571,826)**
Distillate Correction		(149,499)	(165,944)	(184,198)	(204,459)	(226,950)
HFO Process & Heating		(29,900)	(33,189)	(36,840)	(40,892)	(45,390)
Operating Engineer		(60,775)	(63,814)	(67,005)	(70,355)	(73,873)
Chemical Consumption		0	0	0	0	0
Scrubber Loads		(74,749)	(82,972)	(92,099)	(102,230)	(113,475)
M&R Equip & Labor		(92,257)	(96,870)	(101,713)	(106,799)	(112,139)
Savings - Fuel Differential		**3,737,472**	**4,148,594**	**4,604,939**	**5,111,483**	**5,673,746**
NPV & IRR						
Cash Flow	(6,457,985)	3,330,292	3,705,806	4,123,085	4,586,748	5,101,919
Discount Factor	1.0000	0.9091	0.8264	0.7513	0.6830	0.6209
Present Value	(6,457,985)	3,027,538	3,062,649	3,097,735	3,132,811	3,167,891
Net Present Value (at Year 0)	**25,397,427**					
Internal Rate of Return	**61.59%**					

Expenses Low	Year				
Fuel/CPI-PPI 11/5	6	7	8	9	10
Capital Cost - Total					
Equipment					
Acquisition					
Expenses - Total	**(623,567)**	**(680,440)**	**(742,984)**	**(811,792)**	**(887,523)**
Distillate Correction	(251,914)	(279,625)	(310,384)	(344,526)	(382,424)
HFO Process & Heating	(50,383)	(55,925)	(62,077)	(68,905)	(76,485)
Operating Engineer	(77,566)	(81,445)	(85,517)	(89,793)	(94,282)
Chemical Consumption	0	0	0	0	0
Scrubber Loads	(125,957)	(139,812)	(155,192)	(172,263)	(191,212)
M&R Equip & Labor	(117,746)	(123,633)	(129,815)	(136,305)	(143,121)
Savings - Fuel Differential	**6,297,858**	**6,990,622**	**7,759,591**	**8,613,146**	**9,560,592**
NPV & IRR					
Cash Flow	5,674,291	6,310,182	7,016,607	7,801,353	8,673,068
Discount Factor	0.5645	0.5132	0.4665	0.4241	0.3855
Present Value	3,202,990	3,238,121	3,273,299	3,308,535	3,343,843
Net Present Value (at Year 0)					
Internal Rate of Return					

Expenses Predicted	Year					
Fuel/CPI-PPI 8/3	0	1	2	3	4	5
Capital Cost - Total	**(8,868,468)**					
Equipment	(5,577,653)					
Acquisition	(3,290,815)					
Expenses - Total		**(622,559)**	**(653,316)**	**(685,929)**	**(720,528)**	**(757,252)**
Distillate Correction		(133,980)	(144,699)	(156,275)	(168,777)	(182,279)
HFO Process & Heating		(26,796)	(28,940)	(31,255)	(33,755)	(36,456)
Operating Engineer		(164,324)	(169,254)	(174,332)	(179,562)	(184,948)
Chemical Consumption		0	0	0	0	0
Scrubber Loads		(66,990)	(72,349)	(78,137)	(84,388)	(91,139)
M&R Equip & Labor		(230,469)	(238,074)	(245,931)	(254,046)	(262,430)
Savings - Fuel Differential		**3,349,508**	**3,617,469**	**3,906,867**	**4,219,416**	**4,556,969**
NPV & IRR						
Cash Flow	(8,868,468)	2,726,949	2,964,153	3,220,937	3,498,888	3,799,717
Discount Factor	1.0000	0.9091	0.8264	0.7513	0.6830	0.6209
Present Value	(8,868,468)	2,479,044	2,449,713	2,419,938	2,389,787	2,359,325
Net Present Value	**14,562,028**					
Internal Rate of Return	**36.17%**					

Expenses Predicted	Year				
Fuel/CPI-PPI 8/3	6	7	8	9	10
Capital Cost - Total					
Equipment					
Acquisition					
Expenses - Total	**(796,251)**	**(837,685)**	**(881,727)**	**(928,564)**	**(978,397)**
Distillate Correction	(196,861)	(212,610)	(229,619)	(247,988)	(267,827)
HFO Process & Heating	(39,372)	(42,522)	(45,924)	(49,598)	(53,565)
Operating Engineer	(190,497)	(196,212)	(202,098)	(208,161)	(214,406)
Chemical Consumption	0	0	0	0	0
Scrubber Loads	(98,431)	(106,305)	(114,809)	(123,994)	(133,914)
M&R Equip & Labor	(271,090)	(280,036)	(289,277)	(298,823)	(308,684)
Savings - Fuel Differential	**4,921,527**	**5,315,249**	**5,740,469**	**6,199,706**	**6,695,683**
NPV & IRR					
Cash Flow	4,125,276	4,477,564	4,858,742	5,271,142	5,717,286
Discount Factor	0.5645	0.5132	0.4665	0.4241	0.3855
Present Value	2,328,611	2,297,698	2,266,639	2,235,479	2,204,261
Net Present Value					
Internal Rate of Return					

Expenses High	Year					
Fuel/CPI-PPI 5/2	0	1	2	3	4	5
Capital Cost - Total	**(10,100,429)**					
Equipment	(5,906,684)					
Acquisition	(4,193,745)					
Expenses - Total		**(849,122)**	**(872,209)**	**(896,063)**	**(920,715)**	**(946,196)**
Distillate Correction		(119,703)	(125,688)	(131,972)	(138,571)	(145,499)
HFO Process & Heating		(23,941)	(25,138)	(26,394)	(27,714)	(29,100)
Operating Engineer		(284,138)	(289,821)	(295,618)	(301,530)	(307,561)
Chemical Consumption		0	0	0	0	0
Scrubber Loads		(59,851)	(62,844)	(65,986)	(69,285)	(72,750)
M&R Equip & Labor		(361,489)	(368,719)	(376,093)	(383,615)	(391,287)
Savings - Fuel Differential		**2,992,563**	**3,142,191**	**3,299,300**	**3,464,265**	**3,637,479**
NPV & IRR						
Cash Flow	(10,100,429)	2,143,441	2,269,982	2,403,237	2,543,550	2,691,282
Discount Factor	1.0000	0.9091	0.8264	0.7513	0.6830	0.6209
Present Value	(10,100,429)	1,948,583	1,876,018	1,805,588	1,737,279	1,671,074
Net Present Value	**6,372,232**					
Internal Rate of Return	**21.88%**					

Expenses High	Year				
Fuel/CPI-PPI 5/2	6	7	8	9	10
Capital Cost - Total					
Equipment					
Acquisition					
Expenses - Total	**(972,541)**	**(999,783)**	**(1,027,960)**	**(1,057,109)**	**(1,087,271)**
Distillate Correction	(152,774)	(160,413)	(168,433)	(176,855)	(185,698)
HFO Process & Heating	(30,555)	(32,083)	(33,687)	(35,371)	(37,140)
Operating Engineer	(313,712)	(319,986)	(326,386)	(332,913)	(339,572)
Chemical Consumption	0	0	0	0	0
Scrubber Loads	(76,387)	(80,206)	(84,217)	(88,428)	(92,849)
M&R Equip & Labor	(399,113)	(407,095)	(415,237)	(423,542)	(432,013)
Savings - Fuel Differential	**3,819,352**	**4,010,320**	**4,210,836**	**4,421,378**	**4,642,447**
NPV & IRR					
Cash Flow	2,846,812	3,010,537	3,182,876	3,364,269	3,555,176
Discount Factor	0.5645	0.5132	0.4665	0.4241	0.3855
Present Value	1,606,951	1,544,881	1,484,835	1,426,778	1,370,674
Net Present Value					
Internal Rate of Return					

Expenses V. High	Year					
Fuel/CPI-PPI 2/1	0	1	2	3	4	5
Capital Cost - Total	**(12,404,968)**					
Equipment	(7,321,978)					
Acquisition	(5,082,990)					
Expenses - Total		**(1,124,003)**	**(1,137,055)**	**(1,150,274)**	**(1,163,662)**	**(1,177,222)**
Distillate Correction		(106,597)	(108,729)	(110,904)	(113,122)	(115,384)
HFO Process & Heating		(21,319)	(21,746)	(22,181)	(22,624)	(23,077)
Operating Engineer		(416,242)	(420,404)	(424,608)	(428,854)	(433,143)
Chemical Consumption		0	0	0	0	0
Scrubber Loads		(53,299)	(54,365)	(55,452)	(56,561)	(57,692)
M&R Equip & Labor		(526,546)	(531,811)	(537,129)	(542,500)	(547,925)
Savings - Fuel Differential		**2,664,936**	**2,718,234**	**2,772,599**	**2,828,051**	**2,884,612**
NPV & IRR						
Cash Flow	(12,404,968)	1,540,933	1,581,179	1,622,325	1,664,389	1,707,390
Discount Factor	1.0000	0.9091	0.8264	0.7513	0.6830	0.6209
Present Value	(12,404,968)	1,400,848	1,306,760	1,218,877	1,136,800	1,060,155
Net Present Value	**(1,963,698)**					
Internal Rate of Return	**6.32%**					

Expenses V. High	Year				
Fuel/CPI-PPI 2/1	6	7	8	9	10
Capital Cost - Total					
Equipment					
Acquisition					
Expenses - Total	**(1,190,956)**	**(1,204,866)**	**(1,218,955)**	**(1,233,226)**	**(1,247,682)**
Distillate Correction	(117,692)	(120,046)	(122,447)	(124,896)	(127,394)
HFO Process & Heating	(23,538)	(24,009)	(24,489)	(24,979)	(25,479)
Operating Engineer	(437,474)	(441,849)	(446,267)	(450,730)	(455,237)
Chemical Consumption	0	0	0	0	0
Scrubber Loads	(58,846)	(60,023)	(61,223)	(62,448)	(63,697)
M&R Equip & Labor	(553,405)	(558,939)	(564,528)	(570,173)	(575,875)
Savings - Fuel Differential	**2,942,304**	**3,001,150**	**3,061,173**	**3,122,397**	**3,184,845**
NPV & IRR					
Cash Flow	1,751,349	1,796,285	1,842,218	1,889,170	1,937,163
Discount Factor	0.5645	0.5132	0.4665	0.4241	0.3855
Present Value	988,591	921,778	859,408	801,193	746,860
Net Present Value					
Internal Rate of Return					