Air Pollution Emission Inventory
For 2008 Tourism Season
Klondike Gold Rush National Heritage Park
Skagway, Alaska

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1.0 Introduction

The National Park Service, in conjunction with the USDA Forest Service, is conducting a research study in Southeast Alaska to address concerns about the environmental effects of increased numbers of cruise ships and associated tourism to the region. As part of this study, an air quality analysis is being conducted to help quantify the air pollution emissions from these sources and their impacts to the environment. This document describes the methodology and results of the air pollution emission inventory. A subsequent report will be issued to document the modeling methodology and the model-predicted deposition rates from these sources. While the study is specific to the Borough of Skagway, it has potential implications for other areas of Southeastern Alaska.

The tourist season in Skagway begins in May and continues through September. During this period, cruise ships arrive each day bringing thousands of passengers to the area. While the ships are docked in Skagway, buses and trains are used to transport the passengers to see the historic town and the surrounding region. The cruise ships, tour buses, and trains are each a source of air pollution, which otherwise would not be present without the tourist industry. In addition to these sources, the town also operates a municipal incinerator to handle the town's waste.

An inventory of air pollution emissions was developed for each of these sources for the two pollutants of concern – nitrogen oxides (NOx) and sulfur dioxide (SO_2). The methodology for developing this emission inventory and a summary of the results are described below. The methodology and results are presented by the source category, and then summarized as a whole.

2.0 Cruise Ships

Cruise ships are "floating communities" which generate their own electrical and propulsion power, and heat through the use of combustion equipment installed on-board the vessels. The size, capacity, and type of this equipment vary among ships.

Typical fuel combustion sources on board of large cruise vessels are:

- Diesel engine propulsion,
- Diesel engine power generators,
- Gas turbine power generation (power / propulsion),
- Oil-fired steam boilers,
- Incinerators, and
- Emergency gas turbines and diesel electric generators.

Typical fuel combustion source on board of small cruise vessels and ferries are:

- Diesel engine propulsion,
- Diesel electric power generators,
- Oil-fired steam boilers, and
- Emergency diesel electric generators.

When underway (i.e., not docked), the vessel will use most of the generated power for propulsion, and the remaining power is used for heating and operations. However, while docked in Skagway, the ships operate in "hotel mode," in that they continue to provide power, heat, air conditioning, and hot water for its guests and staff, similar to a floating hotel. As on-shore power is not available for ships to utilize while docked in Skagway, the electrical needs for the vessel are generated from the large diesel-fired engines or gas turbines, located onboard. Additionally, ships operate fossil fuel-fired auxiliary boilers to provide hot water and steam for heating purposes. However, ship incinerators are not operated while docked in Skagway, as per most cruise line policies.

The cruise ship emission inventory was developed from the 2008 schedule for the port of Skagway (ref: Cruise Line Agencies of Alaska, 2008). The 2008 cruise ship season in Skagway began May 5th and ended September 27th. While there is some variation in the number of cruise ships in port during the season, the week of July 20-28 was selected as a representative week during the height of the season.

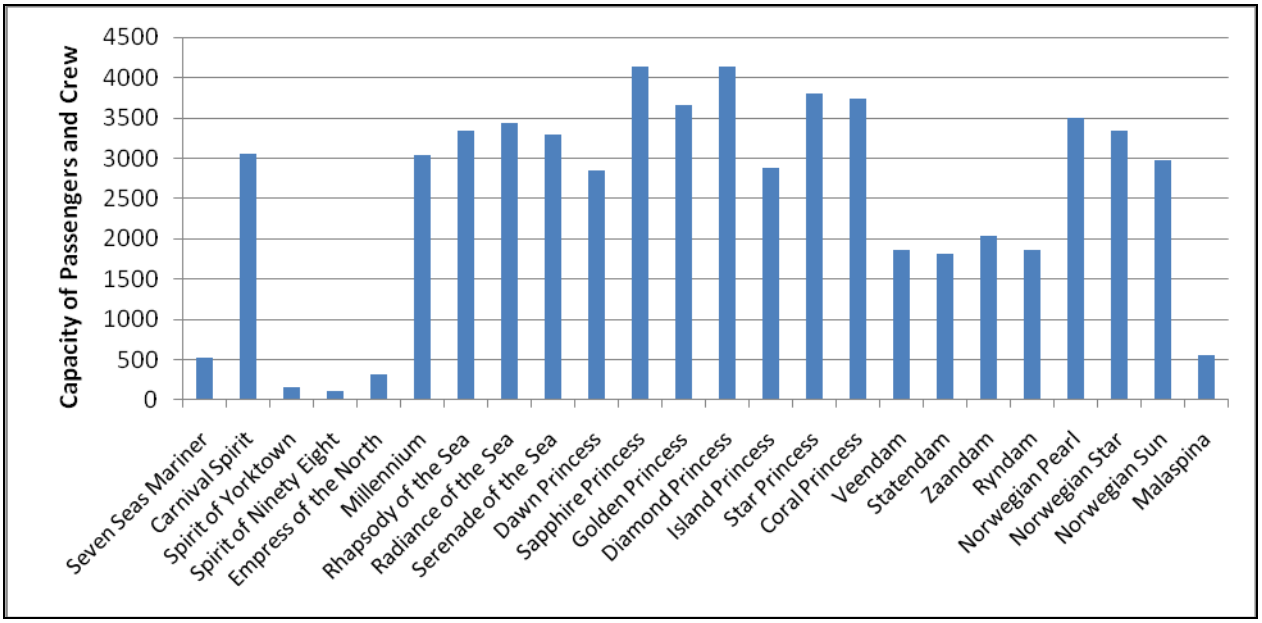
Table 1 presents a list of ships present in Skagway during the week of July 20-28, 2008, which is considered a typical week in the high season. For each ship, the docking location and duration while in Skagway is noted. There were 23 different cruise ships present this week, with only one ship operating on Sundays and as many as five operating on Monday through Thursday. The Alaska Marine Highway ship - the Malaspina, docks in Skagway each night from 10 pm until 7 am the next morning.

Table 1 Weekly Cruise Ship Schedule - *Week of July 20-26, 2008*

Cruise Line	**Ship**	**Dock**	**Time in Port**	**Sun**	**Mon**	**Tue**	**Wed**	**Thu**	**Fri**	**Sat**
Reagent	Seven Seas Mariner	RRA	07:00 - 15:30	x						
Carnival	Spirit	RRF	07:00 - 17:00	x						
Cruise West	Spirit of Yorktown	F	07:00 - 24:00	x						
	Spirit of Ninety Eight	F	07:00 - 13:00				x		x	
Majestic America	Empress of the North	OF	06:00 - 22:00		x					
Celebrity	Millennium	ORE	07:00 - 20:00		x					
Royal Caribbean	Rhapsody of the Sea	RRF	07:00 - 20:30		x					
	Radiance of the Sea	ORE	07:00 - 20:30			x				
	Serenade of the Sea	RRA	07:00 - 20:30				x			
Princess	Dawn Princess	RRA	07:00 - 20:30		x					
	Sapphire Princess	RRF	05:00 - 20:45			x				
	Golden Princess	RRA	05:30 - 20:30			x				
	Diamond Princess	RRF	06:00 - 20:45				x			
	Island Princess	RRF	05:00 - 20:15					x		
	Star Princess	RRA	05:30 - 17:00					x		
	Coral Princess	RRF	07:00 - 20:30						x	
Holland America	Veendam	BRD	08:00 - 21:00		x					
	Statendam	BRD	07:00 - 21:00			x				
	Zaandam	BRD	07:00 - 21:00					x		
	Ryndam	BRD	07:00 - 21:00							x
Norwegian	Norwegian Pearl	BRD	07:00 - 21:00				x			
	Norwegian Star	ORE	07:00 - 17:00				x			
	Norwegian Sun	ORE	07:00 - 21:00					x		

Figure 1 presents the occupant capacity (i.e., passengers and crew) for each ship. Ship capacity varies considerably, from small ships (100 to 200), to medium size ships (1500 to 2000), and large ships (3000 – 4100).

Figure 1 Ship Capacity (Passengers and Crew)



2.1 NOx Emissions

A questionnaire was developed and sent to the cruise ship companies requesting ship-specific information associated with electrical generating engines and boilers. Each company was asked to provide pollutant-specific emission rates, hotel power output, engine size and rpm, fuel type and consumption rate, stack gas release parameters (e.g., exit temperature, stack height, exit velocity, etc) and ship physical dimensions, as needed for air quality dispersion modeling. Appendix A provides a list of the responses received from the cruise lines.

For most ships, NOx emission rates were not provided. Instead, most companies provided NOx emissions factors and hotel power output, from which emissions could be calculated. An emission factor is defined by the US Environmental Protection Agency, as follows

*"An **emissions factor** is a representative value that attempts to relate the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant. These factors are usually expressed as the weight of pollutant divided by a unit weight, volume, distance, or duration of the activity emitting the pollutant (e.g., kilograms of particulate emitted per megagram of coal burned). Such factors facilitate estimation of emissions from various sources of air pollution. In most cases, these factors are simply averages of all available data of acceptable quality, and are generally assumed to be representative of long-term averages for all facilities in the source category (i.e., a population average).*

The general equation for emissions estimation is:

$$E = A \times EF \times (1-ER/100)$$

where:

- *E = emissions;*
- *A = activity rate;*
- *EF = emission factor, and*
- *ER =overall emission reduction efficiency, %"*

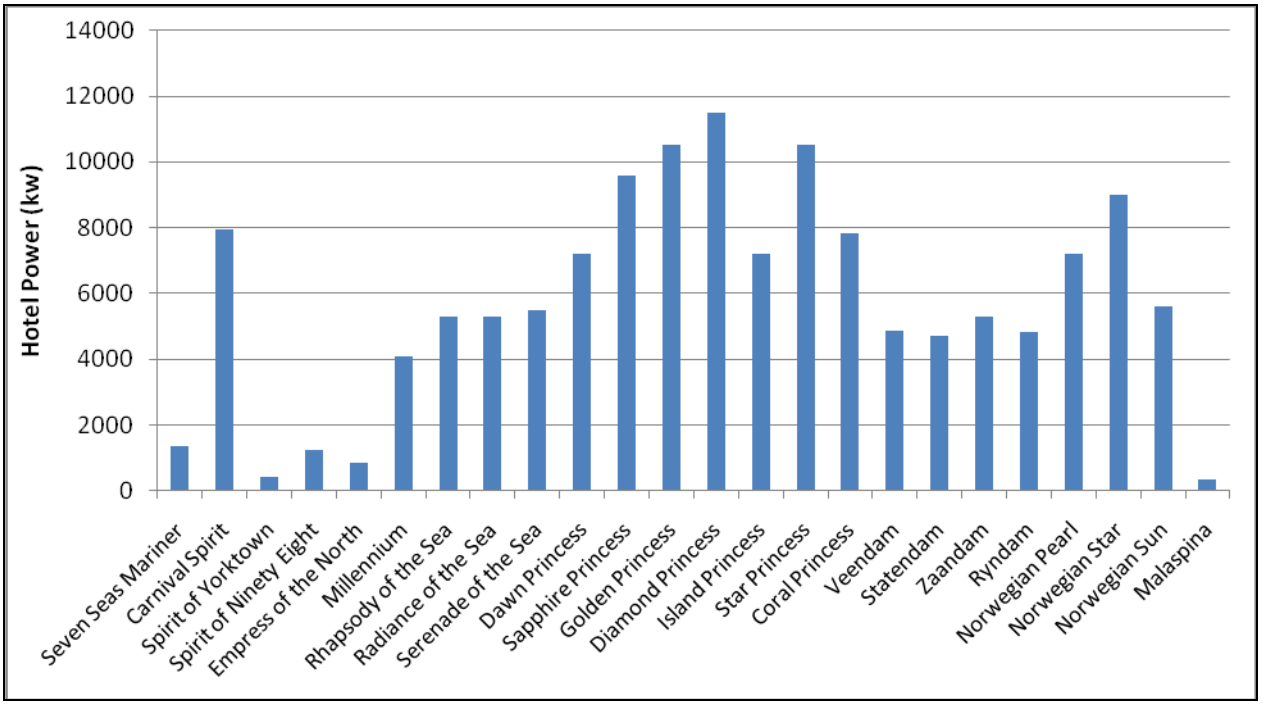
The NOx emission rates for these ships were calculated by multiplying the NOx emission factor (g/kw-hr) by the ship-specific hotel power load. No post-combustion control devices were present on any of the cruise ships.

If a NOx emission factor was not provided but hotel power was known, the NOx emission factor was assumed to 12.6 g/kw-hr. Thus, the ship's emission rate of NOx is limited as a function of its hourly rate of power generation. This value was derived from regulatory limits established by the International Maritime Organization (IMO), Amendments to the Annex of the Protocol of 1997 (MARPOL Annex VI), Chapter III, Regulation 13. The regulation establishes NOx emission limits for maritime engines. It was assumed that cruise ships are subject to Tier I of these regulations for a medium speed engine operating at between 450 - 700 rpm. NOx limits under this regulation are expressed as NOx (g/kw-hr) = $45(\text{rpm})^{-0.2}$.

To verify that this is a reasonable assumption, the emission factor of 12.6 g/kw-hr was compared with manufacturer specifications. Wartsila, a manufacturer of diesel maritime engines often used on cruise ships shows a range of 12.1 to 12.9 g/kw-hr NOx emission factors for marine diesel engines operating at 514 rpm (Wartsila 46), 600 rpm (Wartsila 38), and 720 rpm (Wartsila 32). Refer to Appendix B for the manufacturer emission factor sheets. Thus, the assumed NOx emission factor of 12.6 g/kw-hr seems reasonable.

Figure 2 illustrates the variation in power generated by each cruise ship and the Malaspina while in port. While the power generated is largely proportional to cruise ship capacity, other on-board amenities, which differ amongst ships also result in different power needs, even for ships of similar occupancy.

Figure 2 Hotel Power of Cruise Ships in Skagway

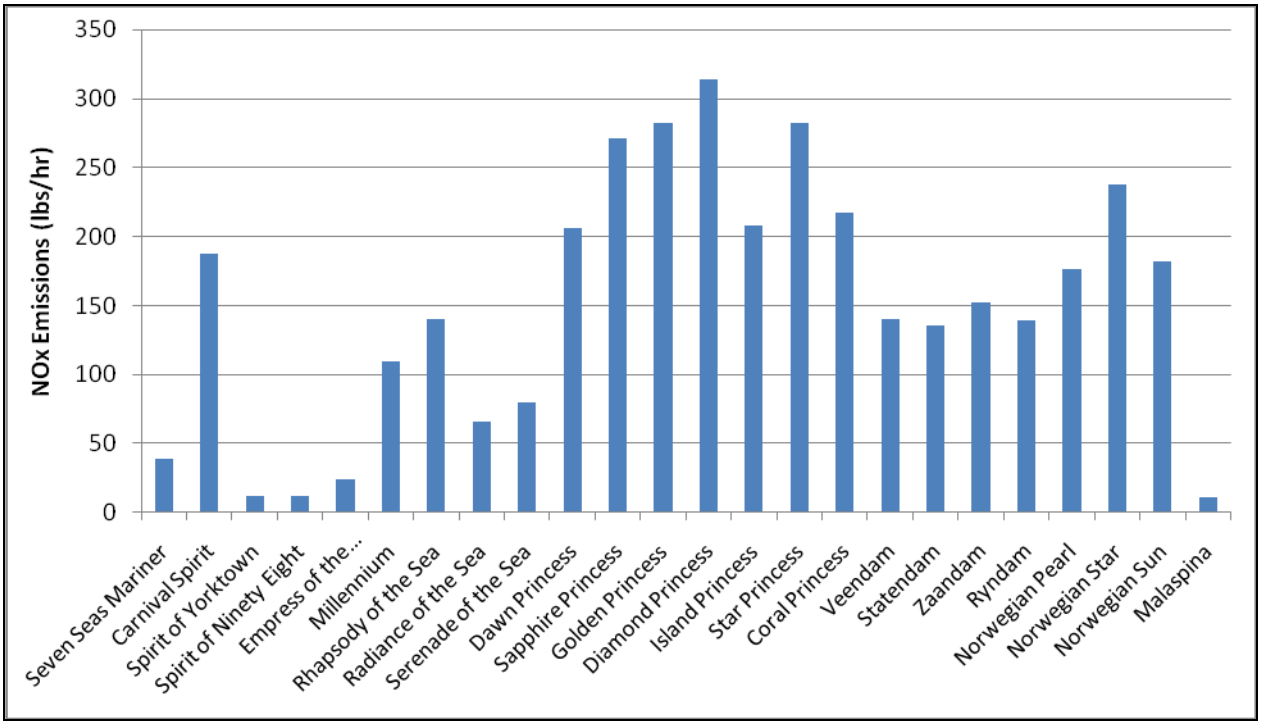


NOx emissions from the boilers were estimated using the US EPA emission factors for oil fired boilers (AP-42, section 1.3) with a heat output of less than 100 Million British Thermal Units per hour (mmBtu/hr). A NOx emission factor of 20 lbs/gal was used which is applicable for boilers fired with No. 4 or distillate oil. This emission factor was multiplied by the boiler fuel consumption rate while docked in Skagway, as provided by the cruise ship companies.

For ships which did not provide emission factors for the engines or for the boilers, or both, total ship NOx emissions were estimated by assuming linear proportionality to a ship within the same cruise line and of similar capacity, within known operating parameters. If a ship within the same cruise ship line did not have available information, then a cruise ship of similar capacity but different cruise ship Company was used to proportionally estimate the NOx emissions. For example, for the Holland America ships, emission factors and boiler fuel consumption was only available for the Zaandam, thus NOx emission from the other Holland America ships were estimated proportionally to the ships occupant capacity. Because emission factors and boiler fuel consumption rates for Carnival cruise ships were not available, NOx emission for the Carnival Spirit were estimated in proportion to the Norwegian Sun.

Figure 3 illustrates the hourly NOx emissions from each of the 23 cruise ships and the Alaska Highway Ferry (the Malaspina) while docked in Skagway. NOx emissions varied from less than 50 lbs/hr for the small cruise ships and the Malaspina to over 300 lbs/hr for the largest cruise ship. The variation in NOx emissions is primarily associated with the amount of power generated while in port. The gas-turbine engine used by the Serenade of the Seas greatly reduced NOx emissions as compared to the diesel-fired engines.

Figure 3 NOx Emissions



2.2 SO_2 Emissions:

Emissions of sulfur dioxide (SO_2) were estimated from fuel consumption rates, fuel density, and fuel sulfur content. Fuel consumption varied with size, ranging from 11 gallons per hour (gal/hr) to 1144 gal/hr for the largest ship. Figure 4 illustrates the fuel consumption rates for each ship while docked in Skagway. Most ships burned Intermediate Fuel Oil (IFO) while in dock, but a few ships burned Marine Gasoline Oil (MGO) and one burned Marine Diesel Oil (MDO). Fuel densities varied from 7.1 to 7.95 lbs/gal.

Figure 4 Cruise Ship Fuel Consumption

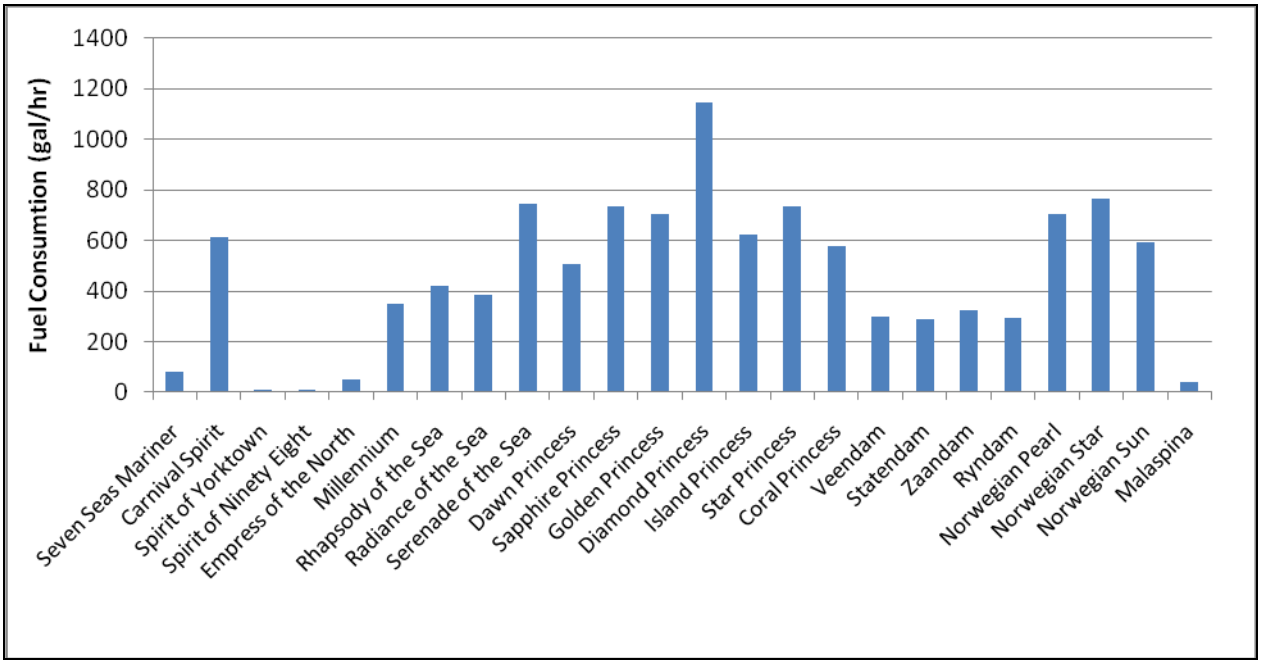


Figure 5 illustrates the varying sulfur content of the fuel from each ship. The Serenade of the Seas used a low sulfur fuel containing only 0.05 % sulfur (S) by weight, whereas most ships used fuel with 2.5% S by weight.

Figure 5 Sulfur Content of Fuel

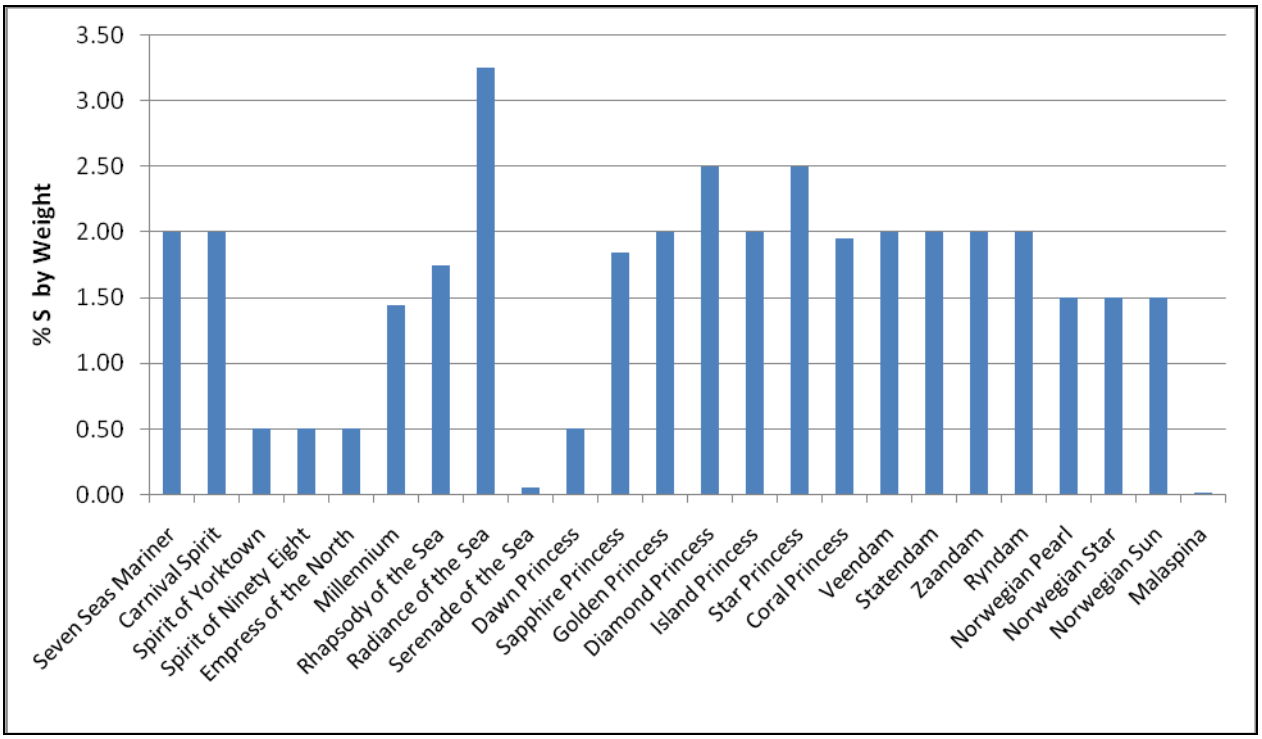


Figure 6 illustrates the hourly SO_2 emission rates from each cruise ship and the Malaspina (Alaska Marine Highway ferry) while docked in Skagway. SO_2 emissions varied from less than 1 lbs/hr to 446 lbs/hr. SO_2 emission rates are strongly related to the sulfur content of the fuel and the fuel consumption rate.

Figure 6 Hourly SO_2 Emissions from Cruise Ships in Skagway

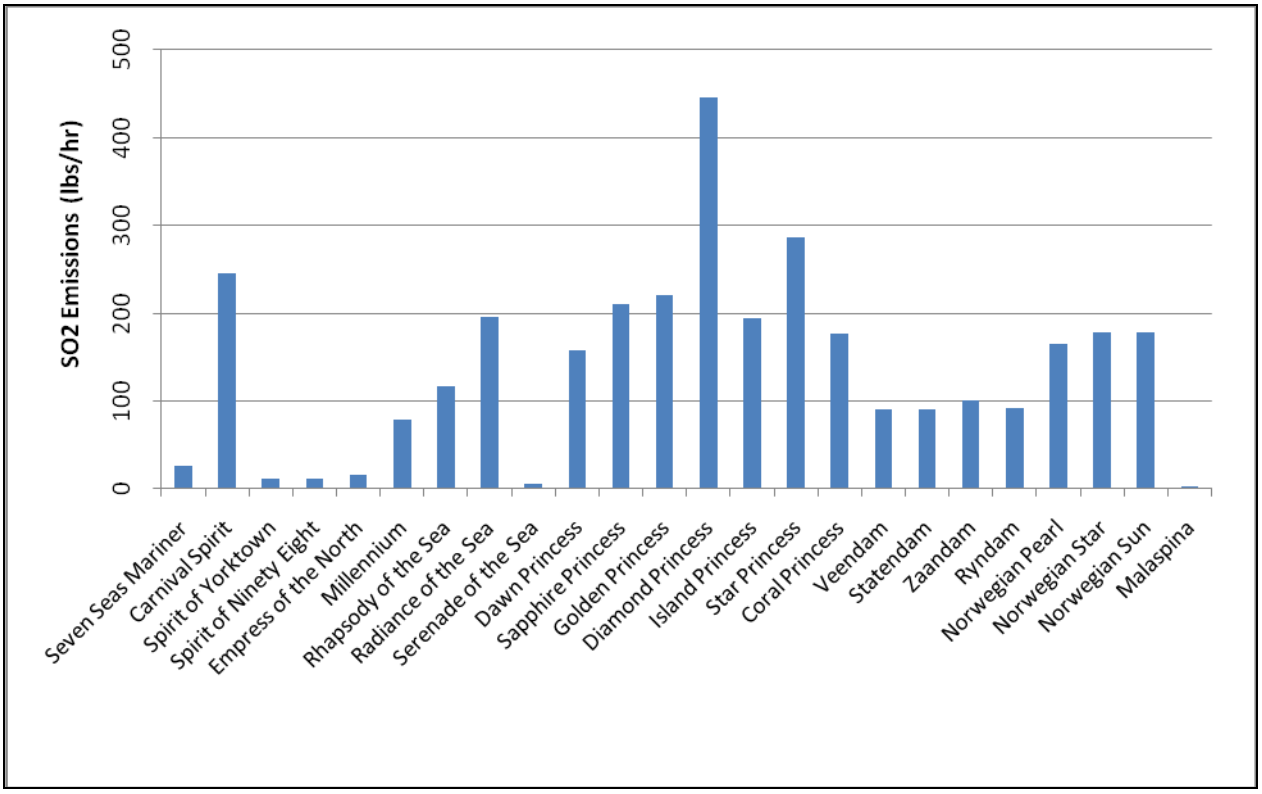
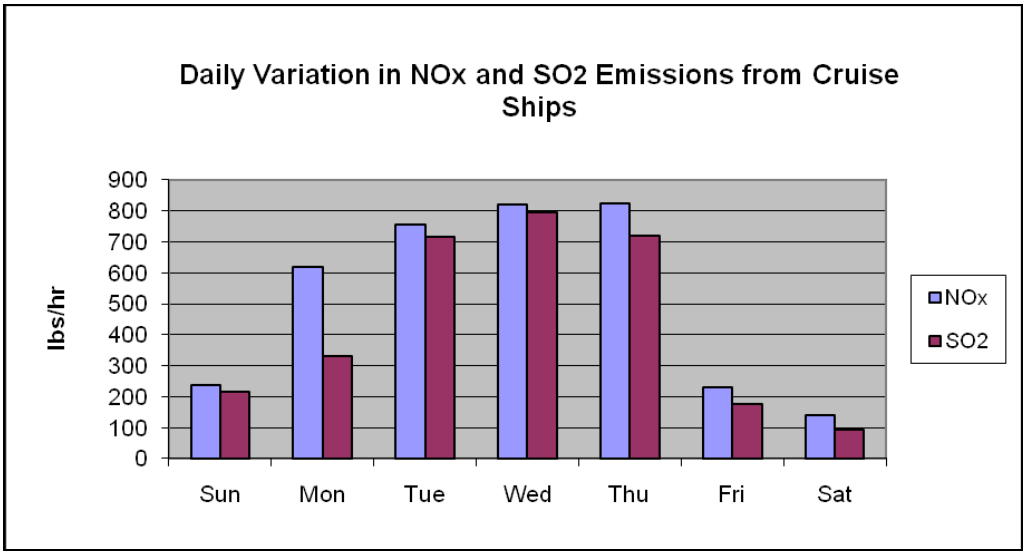


Figure 7 illustrates the variation in cruise ship emissions as a function of the day of the week. The amount of pollutants emitted are related to the number of ships in port, the power demand of each ship while in port, the emission factor applied, and the fuel type.

NOx emissions are greatest during the middle of the week, and tapper off toward the end of the week and Saturday, as fewer ships are in port during these days. SO_2 emissions are greatest during Monday and Tuesdays due to the number of ships burning diesel fuel. Although the same numbers of ships are in Skagway on Wednesday, SO_2 emissions are lower due to the ship-specific emission rates provided by the Cruise Ship companies.

Figure 7 Daily Variations in Cruise Ship Emissions



3.0 Buses

Each day tour buses arrive at the docks to take passengers up the scenic highway to White Pass. The buses are staged overnight in three parking lots. Alaska Coach has two bus parking lots: one on the north side of town for six buses, and one further south where seven buses park overnight. Princess Coach has a large bus lot on the north side of town where 20 buses are parked overnight. Greyline has a parking site for ten buses, and Holland America has a parking lot for four buses. In total, there are 47 coach buses which may operate in Skagway on a busy day.

In preparation for each day, the buses are estimated to warm up (idle) for 20 minutes each morning, prior to passenger pick up and transport up to White Pass. The number of buses operating each day corresponds to the number of passengers arriving each day.

Each bus is assumed to be 40 feet long, and 8 feet wide and 11 feet high (Motor Coach Industries, MC9 Coach). All buses have exhaust pipes on the undercarriage, approximately 1.5 feet above the ground (personal communication with Dave Schirokauer, June 8, 2009).

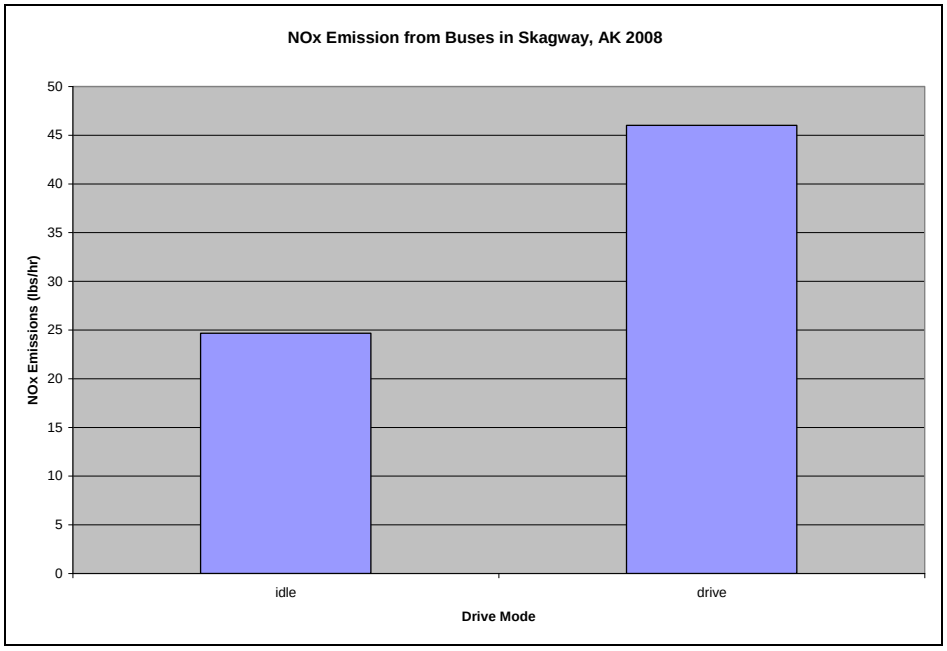
Except for the sulfur content of the fuel, bus-specific information was not available in preparation of this emission inventory. The sulfur content of the fuel was measured at 5.4 mg/kg (ASTM D 5453). Assumption about fuel consumption and NOx emission rates were made based upon material available from the American Bus Association (2006). Table 2 presents the average NOx emissions rate and fuel consumption during idling model and an urban driving cycle for buses while not operating air conditioning (American Bus Association, 2006). Buses were assumed to be older coaches (built prior to 2004).

Table 2 Bus Fuel Consumption and NOx Emission Rates

Mode	Fuel Use gal/hr	NOx g/hr
Idling	0.95	238
Urban Cycle	2.47	444

A single bus emits 0.52 lbs of NOx/hr while idling, and 0.98 lbs/hr while driving. Figure 8 illustrates the maximum hourly NOx emission rates from a total of 47 buses operating at one time. While idling, NOx is emitted at approximately 25 lbs/hr, and while driving, NOx is emitted at approximately 45 lbs/hr. Because buses do not remain in Skagway throughout the day, only the emissions during the first and last hours (total of two hours) of operation are included in the emission inventory.

Figure 8 NOx Emissions from Buses



A single bus emits 0.00008 lbs of SO_2/hr while idling, and 0.00021 lbs/hr while driving. Figure 9 illustrates the maximum hourly SO_2 emission rates from a total of 47 buses operating at one time. Whether idling, or driving, SO_2 is emitted less than one lb/hr. The low emission rate is due to the very low sulfur content of the fuel.

Figure 9 SO_2 Emissions from Buses

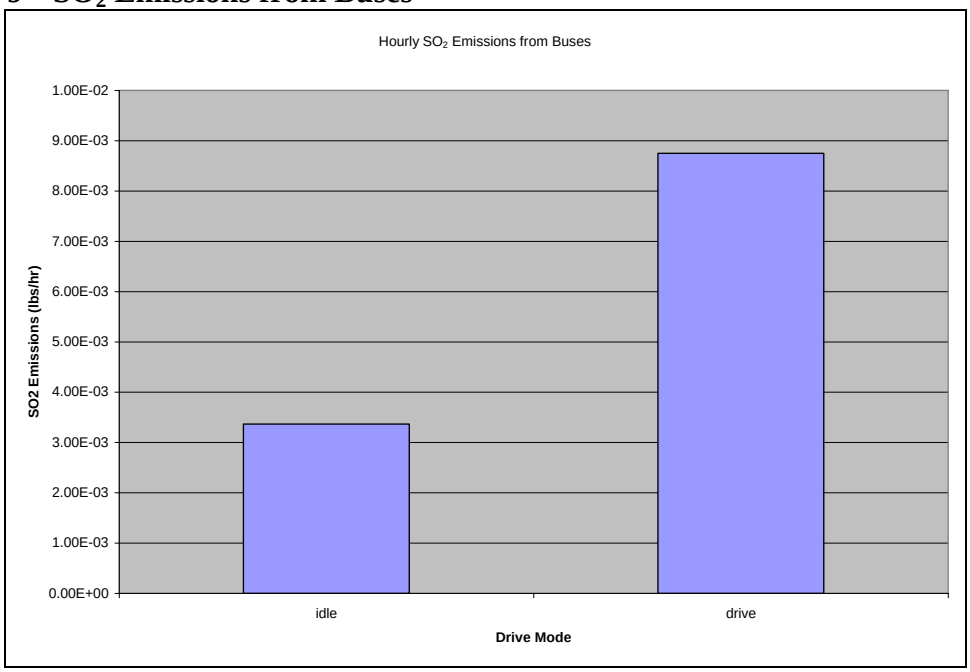
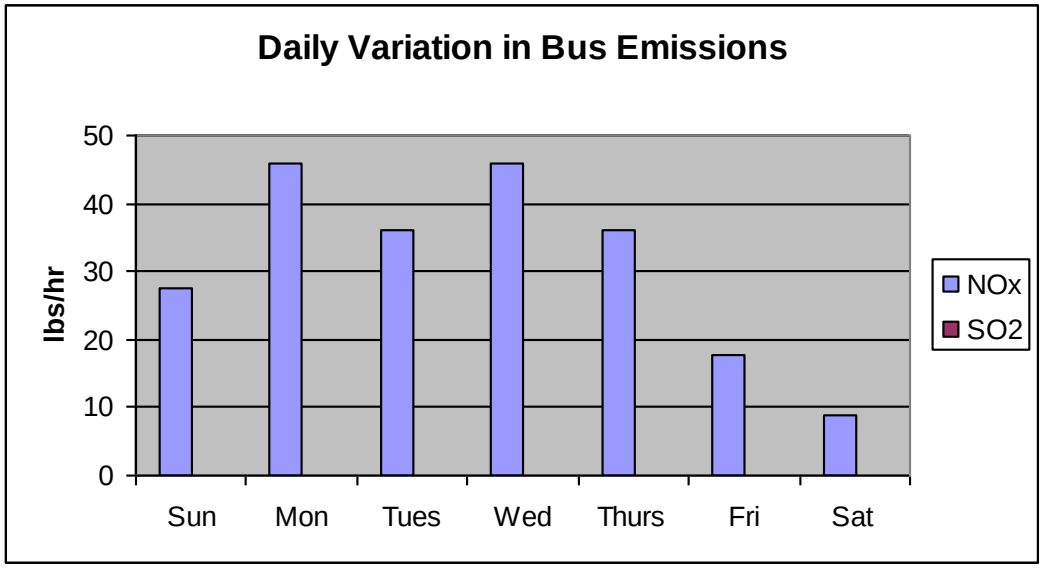


Figure 10 illustrates the variation in bus emissions as a function of the day of the week. Because the number of buses needed is assumed to be correlated with the number of cruise ship passengers arriving in Skagway each day, the weekly trend is similar to that of the cruise ship emissions. The number of buses operating on any given day was estimated based upon the maximum number of buses operating (i.e., 47) when all five cruise ships are docked. Thus, if only 3 cruise ships were in port, then only 28 buses were assumed to be operating (i.e., (3/5) x 47 = 28).

Figure 10 Daily Variations in Bus Emissions



4.0 Trains

The White Pass and Yukon Route Railway operate a scenic railroad to transport cruise ship passengers from the docks at Skagway up to White Pass and beyond. The trains frequently make two trips a day. The railroad operates two kinds of trains, diesel-fired locomotives and one steam locomotive. Except for the steam locomotives, each train is configured with three diesel-fired locomotives: one GE CC-162 with an ALCO215B engine rated at 900 hp and two ALCO DL535 with an ALCO 251D engine rats at 1200 hp (www.thedieselshop.us/DataDL535A.html). The engines burn diesel fuel with a sulfur content of 5.4 ppm. The steam locomotive is fueled with #5 fuel oil (a.k.a. residual oil). Residual oil is estimated to contain 0.5% to 4% sulfur by weight. A mean value of 2.25% sulfur content was assumed.

Table 3 presents the number of trains operating each day and the number of total trips. Each train often makes more than one trip each day, except for the steam train. The greatest number of trips is made during the middle of each week, corresponding to the number of cruise ships in port.

Table 3 Weekly Train Operation in Skagway

	Sun	Mon	Tues	Wed	Thu	Fri	Sat
No. of Trains	3	5	5	5	5	2	2
Total No. of Trips	6	9	11	12	11	4	4
No. of Steam Trains	1	0	0	0	0	1	0
Steam Train Trips	1	0	0	0	0	1	0

The trains idle each day from 5:30 am to 8:00 am, then after returning from White Pass, idle again from 11:45 am to 12:45 pm and then again from 5: 00 pm to 6:30 pm (personal communication – Dave Schirkauer, June 8, 2009).

The locomotives were assumed to emit 270 grams of NOx per gallon of fuel (U.S. EPA 1997). Each round-trip of a locomotive consumes approximatley300 gallons of diesel fuel, (personal communication with Dave Schirkauer). SO_2 emissions were calculated from the sulfur content of the fuel (5.4 mg/kg) and the fuel consumption rate.

Figure 11 illustrates the amount of NOx emitted from the trains as a function of each day of the week. During operation, the total amount of NOx emitted from the trains is approximately 180 lbs/hr during Monday through Thursday, with less than half of this on Saturday.

Figure 11 NOx Emissions from Trains.

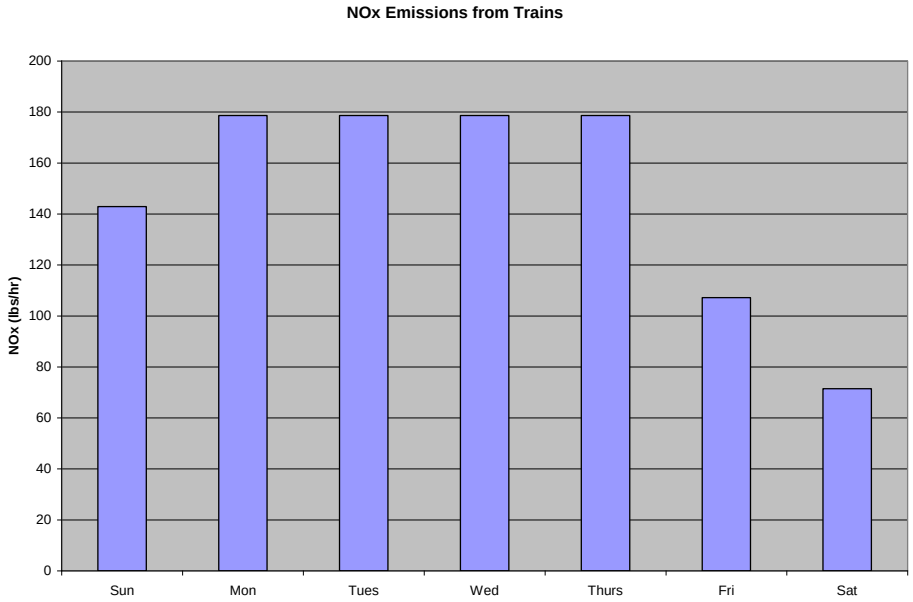
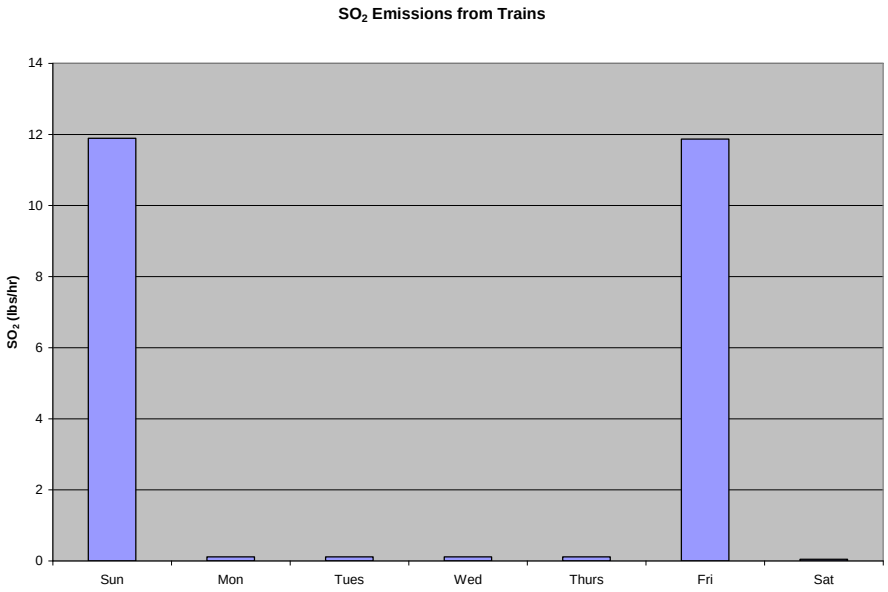


Figure 12 illustrates the amount of SO_2 emitted from the trains as a function of each day of the week. Due to the ultra low sulfur content of the diesel fuel, SO_2 emissions are very small from the operation of the diesel locomotives. Because a higher sulfur content fuel was assumed for the operation of the steam locomotive, SO_2 emissions are highest when this train operates. The maximum hourly SO_2 emission rate during these days is approximately 12 lbs/hr.

Figure 12 SO_2 Emissions from Trains



5.0 Municipal Waste Incinerator

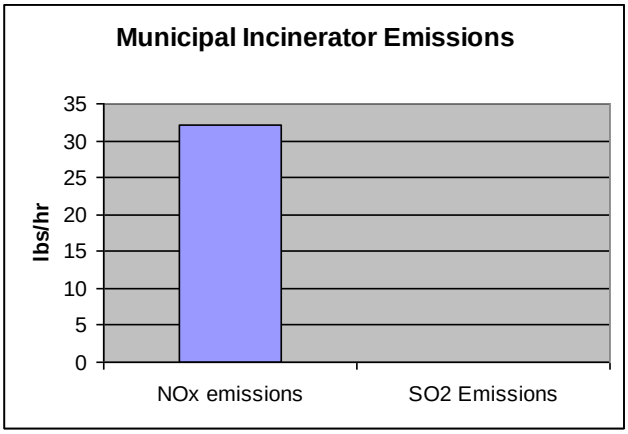
The Eco Waste municipal incinerator can process up to eight tons per day. The operation of the unit is adjusted in the spring to accommodate the anticipated five loads per week during peak tourist season. Each eight ton cycle takes only 24 hours from loading and firing (8-10 hours), to cooling and emptying. During operation, burning occurs for 6 hours, and cool down occurs during the remaining portion of a 24-hour cycle (i.e., 18 hours).

The Eco Waste municipal incinerator is a modular, starved-air combustor. It operates in a batch-mode, two-stage process. In the first stage, waste is ignited in the combustion chamber by means of a diesel-oil fired burner. Off-gases from the first stage are combusted in the second stage (afterburner) and then emitted via a stack.

Emission rates are estimated from US EPA guidance for stationary point sources, AP-42, Chapter 2.1 Refuse Combustion, and Table 2.1-9 Emission Factors for Modular Starved Air Combustors (10/96). A NOx emission rate of 3.16 lb/ton of waste was used with an assumed fuel heating value of 4500 Btu/lb. Following the guidance, the NOx emission factor was adjusted for the higher heating value of the diesel fuel (137,000 Btu/gal), resulting in a revised NOx emission factor of 96.20 lbs/ton. Multiplying this value by the amount of water burned each day (8 tons/day), and dividing by the number of hours in a day, results in a NOx emission rate of 32 lbs/hr.

SO_2 emissions were estimated based upon the sulfur content of fuel, multiplied by the fuel consumption rate. The incinerator uses the same ultra low sulfur diesel as the buses and trains. The sulfur content of this fuel was measured at 5.4 ppm. The average fuel consumption rate is 285 gallons/burn (personal communication with Grant Lawson, June 18, 2009). These operating parameters result in a very low SO_2 emission rate of 0.0009 lbs/hr. Figure 13 below presents a graphical representation of the NOx and SO_2 emission rates from the Municipal Waster Incinerator. Emissions of other contaminants were not calculated.

Figure 13 Emissions from the Municipal Waste Combustor



6.0 Summary

The combined emissions from the operation of cruise ships, trains, buses, and the municipal waste incinerator are summarized below. Figure 14 illustrates the fractional contribution to total weekly NOx emissions from these sources. Cruise ships are the largest source, contribute 73% of the total NOx emissions. Trains are the next largest contributing source (20%), followed by buses (4%) and the municipal incinerator (3%).

Figure 14 NOx Emissions

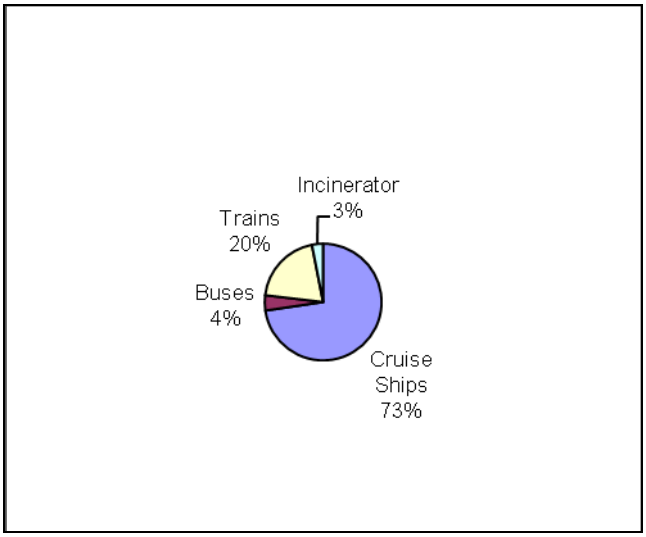


Figure 15 illustrates the fractional contribution to weekly SO_2 emissions. Emissions from cruise ships contribute to 99% of the total SO_2 emissions. The buses, trains, and municipal incinerator have very little contribution due to the low sulfur content of their fuel.

Figure 15 SO_2 Emissions

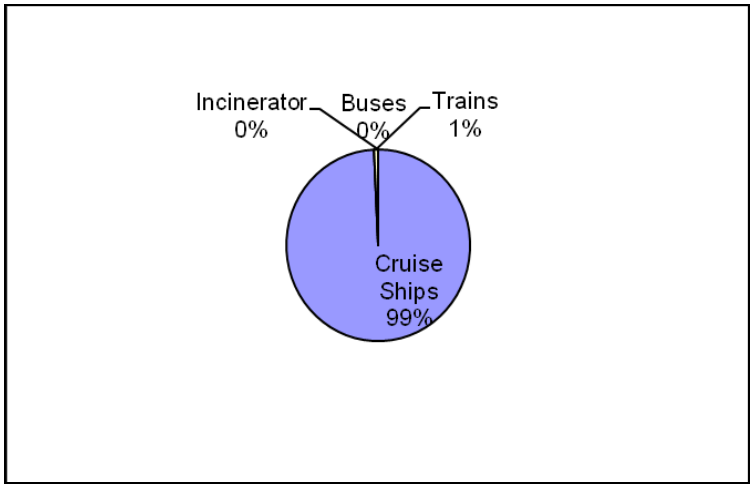
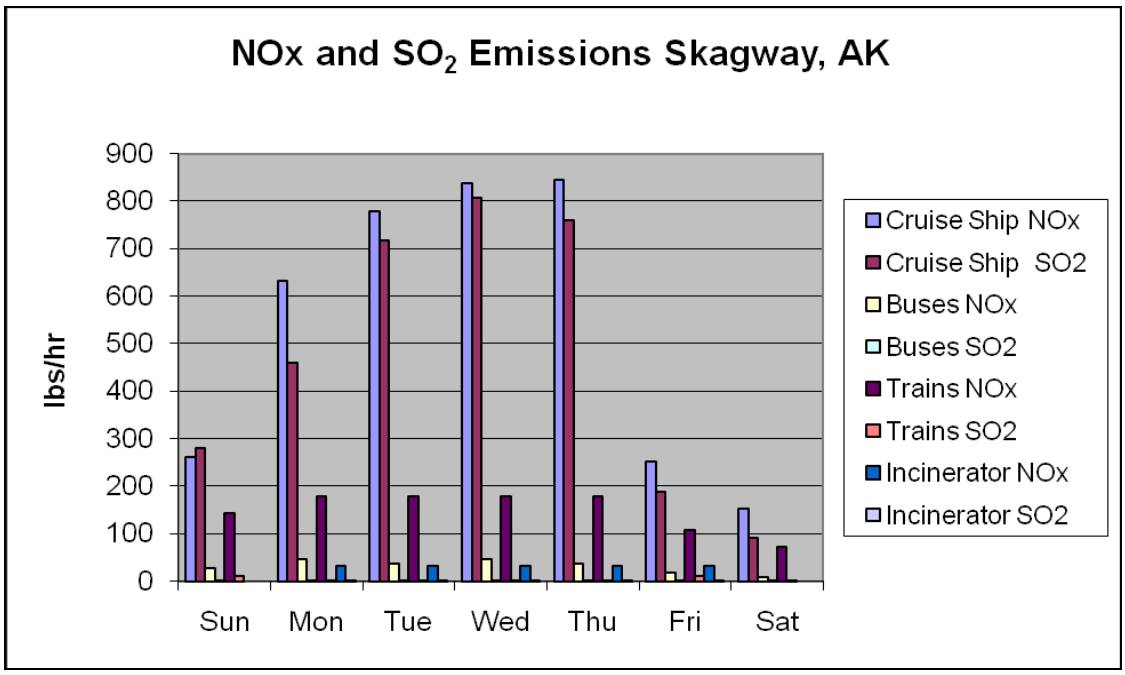


Figure 16 illustrates the NOx and SO_2 emissions, expressed in units of pounds per hour, are illustrated for each day of the week, while a source is operating. The figure illustrates that cruise ships are the largest emitters of NOx and SO_2, and can emit as much as 800 lbs/hr. Trains are the next largest emitting source and emit approximately 180 lbs/hr of NOx. Buses emit as much as 46 lbs/hr of NOx, and the incinerator emits slightly lower amounts – 32 lbs/hr. SO_2 emissions from the trains, buses, and incinerator are extremely small, due to the use of ultra low sulfur fuel.

Figure 16 Emissions Summary



7.0 References

Cruise Line Agencies of Alaska, Cruise Ship Calendar for 2009

American Bus Association. Commercial Emissions Characterization & Idle Reduction – Idle & Urban Cycle Test Results. June 14, 2006.

U.S. Environmental Protection Agency. Form APR420-F-97-051, Emission Factors for Locomotives, for 1997 Table 9: Fleet Average Emission Factors for All Locomotives, (Projected 1999), December 1997

U.S. Environmental Protection Agency. Air Pollutant Emission Factors for Stationary Sources (AP-42), Chapter 2.1 Refuse Combustion, and Table 2.1-9 Emission Factors for Modular Starved Air Combustors (10/96).

Appendix A

Cruise Ship Survey Responses

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A-1 Celebrity Cruise Lines

Note:

The Celebrity Millennium is the only Celebrity Line of cruise ship reported to be docked in Skagway during the 2008 season. Celebrity cruise lines only submitted information on the Mercury. Thus, this information was assumed to be representative of the Millennium.

Ship Name: Celebrity Mercury *Capacity PAX 2130* *Crew 850*

Line Name: Celebrity Cruises

Physical Dimensions:

Lower Tier – outer rim of ship**: This is the Promenade or Embarkation Deck.**

DECK # 6

Length: **68,5 mtrs**

Width: **5,6 mtrs on each side port + stbd**

Height above water: **11 mtrs**

Upper Tier (mean representation): **Pool Deck or the one overlooking the Pool Deck, effectively the upper boundary of the superstructure.**

DECK # 11

Length: **46 mtrs**

Width: **32 mtrs**

Height above Tier 1: **20,6 mtrs**

Stack Housing (tier 3): **The funnel area or annular spaces.**

DECK #14

Length: **88 mtrs**

Width: **5,4 mtrs on each side port + stbd**

Height above Tier 2: **3 mtrs**

Engine parameters: **Output & Rpm**

Engine: **Main Engines**

Man Father 2 x 25336 HP (Type: MAN B&W 9L-48/60)

Man Son 2 x 16891 HP (Type: MA B&W 6L-48/60)

Engine output: **Father 9450 kW (12668 HP)**

Son 6300 kW (8455 HP)

Aux. Engines

4 x MAN B&W 6L 40/54

Engine output: **4320 kW**

Displacement: **39982 About**

Stack Parameters
Stack distance from bow of ship (m): **171.28 m**
Stack height above water (m): **61.58 m**
Inside stack diameter (meters): **Boilers** – Ø610 X 2.5, **Incinerators** – Ø 559 X 2.5, **Aux. Engines** – Ø711 X 2.5, **M.E Fathers** – Ø1016 X 3.0, **M.E Sons** – Ø864 X 2.5
Stack angle from vertical (°):
Estimated exhaust gas temperature (K): **Before Gas Boiler is 380ºC, After Gas Boiler is 200ºC**
Actual stack exit velocity (m/sec): **Boilers** –16.3 m/s, **Incinerators** – 36.6 m/s, **Aux. Engine# 1 & 3 - 39.1 m/s**, **Aux. Engine# 2 & 4-** 32.7 **m/s, M.E Fathers** – 35.1 m/s, **M.E Sons** – 32.9 m/s

Emission Rates (average emission rate while in Skagway)
(If emission rates are not provided, we can estimate from ship-specific parameters or in the absence of such information, from published typical values).

NOx: _____ lbs/hr
PM: _____ lbs/hr
SO_2: _____ lbs/hr
VOCs: _____ lbs/hr
CO: _____lbs/hr

Fuel parameters for operation in Skagway
Fuel type combusted while in Skagway: **IFO 380 low sulfur**
Fuel sulfur content (maximum) based on percent of fuel weight: **1.44%**

Operational parameters while docked in Skagway:

Operation mode while docked: (number of engines, gas-turbine auxiliary, boilers, incinerators). Always 2 Aux. generators in operation while at port, No Incinerators in operation, and 2 boilers operating.
Fuel consumption per hour (average): MT/hr = approx. 1.2 MT/hr for the 2 Aux. generators while at port.
Hotel load: average 4.1 MW (2 Aux. generators engines in operation)
Auxiliary boiler fuel consumption rate (Mtons/hr): 0.04 - 0.05 Mt/hr

Air Pollution Control Device Information - no data available - such device is not installed. Only opacity meters for the exhaust gas for the Main Engines.
Type: Krystallon Seawater Scrubber
Pollutant Control Efficiency SO_2: PM: NOx: (no devices / analyzers installed to control and measure pollutants)

WÄRTSILÄ

Wärtsilä Nederland B.V.

TESTREPORT IMO Engine nr. 24000_CPP

Project	:	EIAPP - Parent Engine Test
Engine number	:	24000_CPP
Type	:	6L38B
Rated power [kW]	:	4350
Rated speed [rpm]	:	600
Application	:	Controllable Pitch Propulsion
Start of fuel injection [°CA bTDC]	:	11.5
Turbocharger identification	:	ABB TPL69 CV20CT25CA30TV20TT40TF05TA06
Type of fuel	:	DMA, according to ISO 8217
Classification	:	BV, DNV, GL, and LRS
Date	:	21 March 2001

Signatures:

Bureau Veritas	Mr. J. Desdouits	
Det Norske Veritas	Mr. R. Das	
Germanischer Lloyd	Mr. S. Neddenien	
Lloyd's Register	Mr. R. Siberden Ing. R. A. H. Siberden	
Wärtsilä NL	Mr. J. de Gorter	
Wärtsilä NL	Mr. D. Jansen	

BUREAU VERITAS MARINE DIVISION PARIS 1828 INTERNATIONAL REGISTER

DET NORSKE VERITAS 1864

GERMANISCHER LLOYD 1867

Lloyd's Register AMSTERDAM

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Wärtsilä NL	Mr. D. Jansen	

BUREAU VERITAS MARINE DIVISION PARIS 1828 INTERNATIONAL REGISTER

DET NORSKE VERITAS * 1864 *

GERMANISCHER LLOYD 1867

Lloyd's Register AMSTERDAM

WÄRTSILÄ

Emission Test Report No. **24000-CPP** **Engine Information**

Engine:

Manufacturer:	Wärtsilä Netherlands		
Engine type:	6L38B, CPP		
Group identification	Wärtsilä 38B Controllable Pitch Propulsion		
Serial number	24000		
Rated speed	600		rpm
Rated power	4350		kW
Intermediate speed	-		
Max. torque at interm. speed	-		
Static injection timing	11.5		°CA bTDC
Electronic injection control	☐ Yes	☒ No	
Variable injection timing	☐ Yes	☒ No	
Variable turbocharger geometry	☐ Yes	☒ No	
Bore	380		mm
Stroke	475		mm
Nominal compression ratio	14.8 : 1		
Mean effective pressure, at rated power	2690		kPa
Maximum cylinder pressure, at rated power	21000		kPa
Cylinder number and configuration	6 L		
Auxiliaries	-		

Specified ambient conditions:

Maximum seawater temperature	38		° C
Maximum charge air temperature	Not applicable		
Cooling system spec. intermediate cooler	☒ Yes	☐ No	
Cooling system spec. charge air stages	2-stage		
Low/high temperature cooling system set points	46 / 93		° C
Maximum inlet depression	1.5		kPa
Maximum exhaust back pressure	3.0		kPa
Fuel oil specification	DMA - ISO8217		
Fuel oil temperature	50		° C
Lubricating oil specification	Shell Argina X40		

Application/Intended for:

Customer	-
Final Application/installation, Ship	-
Final Application/installation, Engine	-

Emission test results:

Weighted NOx-value **12.0** g/kWh Test Cycle: **E2**

Load	100 %	75 %	50 %	25 %	
NO_x	10.2	12.3	13.8	15.6	g/kWh

Test identification	24000_CPP
Date/time	21-03-2001
Test site/bench	WNL Building 26, W6L38 engine lab
Test number	24000.0243
Surveyor:	BV, DNV, GL and LRS

Date and Place of report: 26.03.2001; Zwolle the Netherlands

Signature

WÄRTSILÄ

Emission Test Report No. **24000-CPP** **Engine Group Information**

Engine Group Information (Common specifications):

Combustion cycle	☐ 2 stroke cycle ☒ 4 stroke cycle	
Cooling medium	water	
Cylinder configuration	6L, 8L, 9L, 12V, 16V, or 18V	
Method of aspiration	pressure charged	
Fuel type to be used on board	distillate or heavy fuel	
Combustion chamber	open chamber	
Valve port configuration	In cylinder head	
Valve port number and size	2 inlet valves	∅ = 141
	2 exhaust valves	∅ = 133
Fuel system type	direct fuel injection	

Miscellaneous features:

Exhaust gas re-circulation	☐ Yes	☒ No
Water injection/emulsion	☐ Yes	☒ No
Air injection	☐ Yes	☒ No
Charge cooling system	☒ Yes	☐ No
Exhaust after-treatment	☐ Yes	☒ No
Exhaust after-treatment type	Not applicable	
Dual fuel	☐ Yes	☒ No

Engine Group Information:

Group Identification	Wärtsilä 38B Controllable Pitch Propulsion	
Method of pressure charging	Exhaust gas turbocharger	
Charge air cooling system	water-cooled	
Criteria of Parent Selection	9960DT011	
Number of cylinder	6, 8, 9, 12, 16, or 18	
Max. rated power per cylinder	725	kW
Rated speed	600	rpm
Injection timing (max)	11.3	°CA bTDC
Max. allowable receiver pressure	3.77	bar(a) at 75% of rated power
Selected parent engine	W 6L38B	
Application	Variable pitch propeller	

A-2 Cruise West

Vessel	Engine Mfg.	Engine Type	Rated RPM	Fuel Burn Rated / 100% load for Aux Eng	Fuel Burn 1200 RPM / 50% load for Aux Eng.
SOD Main Eng.	**Caterpillar**	3508	1600	45.5 gph	21.7gph
SON Main Eng.	***Caterpillar***	3512	1800	60.3 gph	18.2
SON Aux Eng.	**Caterpillar**	3412	1800	33.7 gph	11.0 gph
SOA Main Eng.	**Caterpillar**	3412	1800	33.7 gph	11.0 gph
SOA Aux Eng.	**Caterpillar**	3304	1800	8.7 gph 100% load	7.1 gph 50% load
SOD Aux Eng.	**Caterpillar**	3306	1800	13.8 gph 100% load	7.1 gph 50% load
SOC Main Eng.	***Detroit***	12V71	1800	30 gph	8 gph
SOC Aux Eng.	**Detroit**	671	1800	8 gph 100% load	N/A
SGB Main Eng.	***Detroit***	12V71	1800	30 gph	8 gph
SGB Aux Eng.	**Detroit**	671	1800	8 gph 100% load	N/A

Consumption Parameters	SON	SOD	SOA	SOC	SGB
Underway 100% load/ crew only	143.8	103.1	74.5	68	68
Underway 100% Load with Pax	159.3	109.8	76.1	68	68
Underway 60% Load Crew Only	52.4-62.4	55.5-65.5	29.1-39.1	24-34	24-34
Underway 60% Load with Pax	75.1-85.1	57.1-67.1	30.7-40.7	24-34	24-34
Pierside, Aux Engine only 100% Load	38.7	18.8	8.7	8	8
Pierside Aux Engine only 50% Load	16.0	12.1	7.1	8	8

- All Fuel rates are based on Gallons per hour.
- Color Green: Fuel consumption pier side 50 % load. No passengers / only crew with preparation work (FRE)

PVA Member Vessel Information

	Vessel Length (ft)	Vessel Beam (ft)	Hull Type (disp., planning, cat., etc.)	Type of Service	USCG Type (K, T, H)	Number of Propulsion Engines	Propulsion Engine Rating bhp @ rpm	Number of Genset Engines
SOA	143	28	disp.	passenger	K	2		2
SOD	166	37	disp.	passenger	K	2		2
SON	192	40	disp.	passenger	K	2		2
SOC	143	28	disp.	passenger	K	2		2
SOE	217	37	disp.	passenger	K	2		2
SOO	295	50	disp.	passenger	K	2		2
SNT	257	43	disp.	passenger	K	2		3
SOY	207	37	disp.	passenger	K	2		3

A-3 Norwegian Cruise Lines

Norwegian Sun

Capacity: 2002 passengers Crew: 968

Norwegian Cruise Lines

Physical Dimensions:

Lower Tier – outer rim of ship:
- Length: 260m
- Width: 32m
- Height above water: 12m (DK 6)

Upper Tier (mean representation):
- Length: 214 m
- Width: 32 m
- Height above Tier 1: 15.3m (DK 11)

Stack Housing (tier 3):
- Length: 59m
- Width: 32m
- Height above Tier 2: 9.72 (DK 14)

Gross Tonnage: 78,309

Skagway AK - 2008 Schedule:

Date	Times	Dock
5-15	07:00-21:00	ORE
5-22	07:00-21:00	ORE
5-29	07:00-22:00	ORE
6-05	07:00-21.00	ORE
6-12	07:00-21.00	ORE
6-19	07:00-21.00	ORE
6-26	07:00-21.00	ORE
7-03	07:00-21.00	ORE
7-10	07:00-21.00	ORE
7-17	07:00-21.00	ORE
7-24	07:00-21.00	ORE
7-31	07:00-21:00	ORE
8-07	07:00-21.00	ORE
8-14	07:00-21.00	ORE
8-21	07:00-21.00	ORE
8-28	07:00-21.00	ORE
9-04	07:00-21.00	BRD
9-11	07:00-21.00	ORE

Engine parameters:

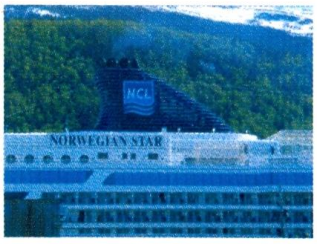
Engine: MAN 3x 6L 58/64 + 3x 7L 58/64

Engine output: 3x 7.8MW + 3x 9.1 MW

Displacement:

Is the Gas turbine engine used while tied up in Skagway? N/A

Are the other engines shut off while in Skagway? —



Stack Parameters

Stack distance from bow of ship (m): 190m

Stack height above water (m) 48m

Inside stack diameter (meters): 16m

Stack angle from vertical (°): 11°

Estimated exhaust gas temperature (K): 450°C

Actual stack exit velocity (m/sec): 40m/sec

Emission Rates (average emission rate while in Skagway)

(If emission rates are not provided, we can estimate from ship-specific parameters, or in the absence of such information, from published typical values).

NOx: 182 lbs/hr SO_2: 92 lbs/hr CO: ? lbs/hr

PM: 4 lbs/hr VOCs: ? lbs/hr

Fuel: 2.1 mt/hr

Fuel parameters for operation in Skagway

Fuel type combusted while in Skagway: (MDO, IFO, HFO) IFO

Fuel sulfur content (maximum) based on percent of fuel weight: 1.5%

Operational parameters while docked in Skagway

Operation mode while docked: (number of engines, gas-turbine auxiliary, boilers, incinerators)

Fuel consumption per hour (average): 1.5 mt/hr

Hotel load: 5.6 MW

Auxiliary boiler fuel consumption rate (tons/hr): 0.6 mt/hr

Air Pollution Control Device Information None

Type:

Pollutant Control Efficiency SO_2: PM: NOx:

National Park Service – Southeast Alaska Inventory and Monitoring Program
Airborne Contaminants Study - Emission Inventory form 2008

Norwegian Pearl

Capacity: 2399 passengers Crew: 1100

Norwegian Cruise Lines

Skagway AK - 2008 Schedule:

Date	Times	Dock
5-07	07:00-21:00	BRD
5-14	07:00-21:00	BRD
5-21	07:00-21:00	BRD
5-28	07:00-21:00	BRD
6-04	07:00-21:00	BRD
6-12	07:00-21:00	BRD
6-18	07:00-21:00	BRD
6-26	07:00-21:00	BRD
7-02	07:00-21:00	BRD
7-09	07:00-21:00	BRD
7-16	07:00-21:00	BRD
7-23	07:00-21:00	BRD
7-30	07:00-21:00	BRD
8-06	07:00-21:00	BRD
8-13	07:00-21:00	BRD
8-20	07:00-21:00	BRD
8-27	07:00-21:00	BRD
9-03	07:00-21:00	BRD
9-10	07:00-21:00	BRD
9-17	07:00-21:00	BRD

Physical Dimensions:

Lower Tier – outer rim of ship:
- Length: 965 ft
- Width: 106 ft
- Height above water:

Upper Tier (mean representation):
- Length:
- Width:
- Height above Tier 1:

Stack Housing (tier 3):
- Length:
- Width:
- Height above Tier 2:

Gross Tonnage: 91,000

Engine parameters:

Engine: 5x 12V 48/60 B MAN Boiler

Engine output: totally 72,000 kW approx. 100.000 hp

Propulsion power 39,000 kW = 53,000 hp

Displacement: 108.6 liter/cyl

Is the Gas turbine engine used while tied up in Skagway? N/A

Are the other engines shut off while in Skagway? –

Stack Parameters

Stack distance from bow of ship (m): 230m

Stack height above water (m) 59m

Inside stack diameter (meters): 1380mm

Stack angle from vertical (°): Approx 30°

Estimated exhaust gas temperature (K): 215-240°C

Actual stack exit velocity (m/sec): 40 m/sec (MAN Data)

Emission Rates (average emission rate while in Skagway)

(If emission rates are not provided, we can estimate from ship-specific parameters, or in the absence of such information, from published typical values).

NOx: 11.1 ~~lbs/hr~~ g/kwhr SO_2: 6.3 ~~lbs/hr~~ CO: 0.6 ~~lbs/hr~~

PM: 0.6 ~~lbs/hr~~ VOCs: ? ~~lbs/hr~~ All in g/kwhr

Fuel parameters for operation in Skagway

Fuel type combusted while in Skagway: (MDO, IFO, HFO) IFO

Fuel sulfur content (maximum) based on percent of fuel weight: 1.5%

Operational parameters while docked in Skagway

Operation mode while docked: (number of engines, gas-turbine auxiliary, boilers, incinerators) 1 Engine

Fuel consumption per hour (average): 2.1 mt/hr

Hotel load: 7.2 MW

Auxiliary boiler fuel consumption rate (tons/hr): 0.4 mt/hr

Air Pollution Control Device Information None in use.

Type:

Pollutant Control Efficiency SO_2: PM: NOx:

National Park Service – Southeast Alaska Inventory and Monitoring Program
Airborne Contaminants Study - Emission Inventory form 2008

Norwegian Star **Capacity:** 2,240 passengers Crew: 1,100

Norwegian Cruise Lines

Skagway AK - 2008 Schedule:

Date	Times	Dock
5-07	07:00-17:00	ORE
5-14	07:00-17:00	ORE
5-22	07:00-21:00	ORE
5-29	07:00-22:00	ORE
6-05	07:00-21.00	ORE
6-12	07:00-21.00	ORE
6-19	07:00-21.00	ORE
6-26	07:00-21.00	ORE
7-03	07:00-21.00	ORE
7-10	07:00-21.00	ORE
7-17	07:00-21.00	ORE
7-24	07:00-21.00	ORE
7-31	07:00-21:00	ORE
8-07	07:00-21.00	ORE
8-14	07:00-21.00	ORE
8-21	07:00-21.00	ORE
8-28	07:00-21.00	ORE
9-04	07:00-21.00	BRD
9-11	07:00-21.00	ORE

Physical Dimensions:

Lower Tier – outer rim of ship:

Length: 294m

Width: 32.3m

Height above water:

Upper Tier (mean representation):

Length:

Width:

Height above Tier 1:

Stack Housing (tier 3):

Length:

Width:

Height above Tier 2:

Gross Tonnage:

Engine parameters:

Engine: 4 MAN B&W type 14V48/60diesel generators

Engine output: ~~14,000 KW~~ each output 14700 kW each

Displacement: 108.6 liters @ cylinder

Is the Gas turbine engine used while tied up in Skagway? N/A

Are the other engines shut off while in Skagway? —

Stack Parameters

Stack distance from bow of ship (m): 228 M

Stack height above water (m) 53.71m

Inside stack diameter (meters): 1380mm

Stack angle from vertical (°): 15°

Estimated exhaust gas temperature (K): 215-290°C

Actual stack exit velocity (m/sec): 40m/s (max)

Emission Rates (average emission rate while in Skagway)

(If emission rates are not provided, we can estimate from ship-specific parameters, or in the absence of such information, from published typical values).

NOx: 12.0 ~~lbs/hr~~ SO_2: 6.3 ~~lbs/hr~~ CO: 0.6 ~~lbs/hr~~

PM: 0.45 ~~lbs/hr~~ VOCs: ? ~~lbs/hr~~

All in g/kwhr

Fuel parameters for operation in Skagway

Fuel type combusted while in Skagway: (MDO, IFO, HFO) IFO

Fuel sulfur content (maximum) based on percent of fuel weight: 1.5%

Operational parameters while docked in Skagway

Operation mode while docked: (number of engines, gas-turbine auxiliary, boilers, incinerators) 1 Engine

Fuel consumption per hour (average): 2.1mt for 10hours

Hotel load: About 9 MW

Auxiliary boiler fuel consumption rate (tons/hr): 6 mt for 10hours

Air Pollution Control Device Information None

Type:

Pollutant Control Efficiency SO_2: PM: NOx:

National Park Service – Southeast Alaska Inventory and Monitoring Program
Airborne Contaminants Study - Emission Inventory form 2008

A-4 Princess Cruise Lines

Star Princess

Capacity: 2600 passengers, Crew: 1200

Princess Cruise Lines

Physical Dimensions:

Lower Tier – outer rim of ship**:**

Length: 290m (951 feet)

Width: 36.03m (118 feet)

Height above water:

Upper Tier (mean representation): (Assumed to mean superstructure, i.e. Deck 7-18.)

Length: 252m

Width: 32.6m

Height above Tier 1: 31.50m

Stack Housing (tier 3):

Length: 35.9m

Width: 5.6m

Height above Tier 2: 8.76m

Gross Tonnage: 109,000 gross tons.

Engine parameters:

Engine: **Type is diesel electric powered by Wartsila/Sulzer 4 x ZA40S V16 and 2 x ZA40S V12**

Engine output: **Engine power at 100% MCR 4 @11520 KW and 2 @8640 KW**

Displacement:

Is the Gasturbine engine used while tied up in Skagway? N/A

Are the other engines shut off while in Skagway? N/A

Skagway AK - 2008 Schedule:

Date	Times	Dock
5-08	05:30-17:00	RRF
5-15	05:30-17:00	RRF
5-22	05:30-17:00	RRA
5-29	05:30-17:00	RRA
6-05	05:30-17:00	RRA
6-12	05:30-17:00	RRA
6-19	05:30-17:00	RRA
6-26	05:30-17:00	RRA
7-03	05:30-17:00	RRA
7-10	05:30-17:00	RRA
7-17	05:30-17:00	RRA
7-24	05:30-17:00	RRA
7-31	05:30-17:00	RRA
8-07	05:30-17:00	RRA
8-14	05:30-17:00	RRA
8-21	05:30-17:00	RRA
8-28	05:30-17:00	RRA
9-04	05:30-17:00	RRA
9-11	05:30-17:00	RRA
9-18	05:30-17:00	RRA

Stack Parameters

Stack distance from bow of ship (m): 216.54m (distance taken from center of stack housing)

Stack height above water (m): 52.36 m

Inside stack diameter (meters): Approx. 1.1m at exhaust

Stack angle from vertical (°): 0

Estimated exhaust gas temperature (K): 250 centigrade

Actual stack exit velocity (m/sec):

Emission Rates (average emission rate while in Skagway)

(If emission rates are not provided, we can estimate from ship-specific parameters or in the absence of such information, from published typical values).

NOx: .026433 lbs/hr

PM: .037478 lbs/hr

SO_2: .155205 lbs/hr

VOCs: _____ lbs/hr

CO: .187798 lbs/hr

Fuel parameters for operation in Skagway
Fuel type combusted while in Skagway: IFO
Fuel sulfur content (maximum) based on percent of fuel weight: 2.0%

Operational parameters while <u>docked</u> in Skagway
Operation mode while docked: (number of engines, gas-turbine auxiliary, boilers, incinerators)
2 Main Engine (1 x V16 + 1 x V12) – 1 intermittent oil fired boiler
Fuel consumption per hour (average): 2.3 MT/hour
Hotel load: 10500 KW
Auxiliary boiler fuel consumption rate (tons/hr): 0.3 tons/hour

Air Pollution Control Device Information N/A
Type:
Pollutant Control Efficiency SO_2: PM: NOx:

Diamond Princess *Capacity:* ***3,078 PAX, Crew: 1,060***

Princess Cruise Lines

Skagway AK - 2008 Schedule:

Date	Times	Dock
5-12	07:00-20:30	RRA
6-1	07:00-20:30	BRD
6-21	07:00-20:30	RRA
7-11	07:00-20:30	RRF
7-21	07:00-20:30	RRA
8-1	07:00-20:30	RRA
8-10	07:00-20:30	BRD
8-30	07:00-20:30	RRF
9-19	07:00-20:30	RRF

Physical Dimensions:

Lower Tier (deck 7) – outer rim of ship**:**
- Length: 288.33 meters
- Width: 37.5 meters
- Height above water: 12.5 meters

Upper Tier (deck 15):
- Length: 250 meters
- Width: 36 meters
- Height above Tier 1 (deck 7) : 21 meters

Stack Housing (tier 3 – deck 18):
- Length: 35 meters
- Width: 21 meters
- Height above Tier 2 (top of stack to deck 15): 21 meters

Gross Tonnage: 115,875

Engine parameters:

Engine: 2 x 9L46C & 2 x 8L46C Wärtsilä diesel-electric configuration 1 x LM2500+ Gas Turbine

Engine output: 9 Cyl 9,450 KW, 8 Cyl 8,400 KW & GT 25,000 KW

Displacement: 60,636t

Is the Gas turbine engine used while tied up in Skagway?
No

Are the other engines shut off while in Skagway? 2
Running with 2 Off

Stack Parameters

Stack distance from bow of ship (m): 195 meters

Stack height above water (m) **54 m**

Inside stack diameter (meters): D/G'S = 1 meter & GT = 2.2 meters

Stack angle from vertical (°): **0°**

Estimated exhaust gas temperature (K): **523 K**

Actual stack exit velocity (m/sec):

Emission Rates (average emission rate while in Skagway) PLEASE SEE BELOW FOR FIGURE CALCULATIONS.

(If emission rates are not provided, we can estimate from ship-specific parameters, or in the absence of such information, from published typical values).

NOx: _314____ lbs/hr
PM: _____ lbs/hr
SO_2: __7___ lbs/hr
VOCs: _____ lbs/hr
CO: 3.75 lbs/hr

Fuel parameters for operation in Skagway
Fuel type combusted while in Skagway: IFO
Fuel sulfur content (maximum) based on percent of fuel weight: 2.5

Operational parameters while <u>docked</u> in Skagway
Operation mode while docked: (2 x Diesel Engines, gas-turbine shut down, 1 x boiler, incinerators off)
Fuel consumption per hour (average): 3.7mt/Hr
Hotel load: 11,500 KW
Auxiliary boiler fuel consumption rate (tons/hr): 0.35 mt/Hr

Air Pollution Control Device Information
Type:
Pollutant Control Efficiency SO_2: PM: NOx:

Wartsila book of engine parameters for Nox Certification states the following:

NOx produced at 50% = 13 g/KwH = 0.0286 lbs/KwH

With the hotel load in port being approx. 11 MW there would be a total of 314 lbs/hour of Nox being produced.

Ship Name: *Golden Princess* *Capacity PAX 2598* *Crew 1060*

Line Name **Princess Cruise Line**

Physical Dimensions:

Lower Tier – outer rim of ship**:**

Length: 289.5m LOA
Width: 36.03m
Height above water: 12.1m (This is neither Moulded Depth nor Height, but distance from summer load line to Deck 7 at-side. NB: Deck 7 is not the freeboard deck.)

Upper Tier (mean representation): (Assumed to mean superstructure, i.e. Deck 7-18.)

Length: 252m
Width: 32.6m
Height above Tier 1: 31.50m

Stack Housing (tier 3):

Length: 35.9m
Width: 5.6m
Height above Tier 2: 8.76m

Engine parameters:

Engine: Type is diesel electric powered by 4 Wartsila/Sulzer ZA40S V16 and ZA40S V12
Engine output: Engine power at 100% MCR 4 @11520 KW and 2 @8640 KW
Displacement:

Stack Parameters

Stack distance from bow of ship (m): 216.54m (distance taken from center of stack housing)

Stack height above water (m): 52.36m
Inside stack diameter (meters): Approx. 1.1m at exhaust
Stack angle from vertical (°): 0
Estimated exhaust gas temperature (K): 250 centigrade
Actual stack exit velocity (m/sec):

Emission Rates (average emission rate while in Skagway)
(If emission rates are not provided, we can estimate from ship-specific parameters or in the absence of such information, from published typical values).

NOx: .026433 lbs/hr
PM: .037478 lbs/hr
SO_2: .155205 lbs/hr
VOCs: _____ lbs/hr
CO: .187798 lbs/hr

Fuel parameters for operation in Skagway
Fuel type combusted while in Skagway: IFO,
Fuel sulfur content (maximum) based on percent of fuel weight: 2.0%

Operational parameters while <u>docked</u> in Skagway
Operation mode while docked: (number of engines, gas-turbine auxiliary, boilers, incinerators)
1 main engine, one intermittent oil fired boiler
Fuel consumption per hour (average): 2.2 mt/hr
Hotel load: 10500 KW
Auxiliary boiler fuel consumption rate (tons/hr): approx 0.3 tons/hour

Air Pollution Control Device Information N/A
Type: Krystallon Seawater Scrubber
Pollutant Control Efficiency SO_2: PM: NOx:

Ship Name: *Golden Princess* *Capacity PAX 2598* *Crew 1060*

Line Name **Princess Cruise Line**

Physical Dimensions:

Lower Tier – outer rim of ship**:**

Length: 289.5m LOA
Width: 36.03m
Height above water: 12.1m (This is neither Moulded Depth nor Height, but distance from summer load line to Deck 7 at-side. NB: Deck 7 is not the freeboard deck.)

Upper Tier (mean representation): (Assumed to mean superstructure, i.e. Deck 7-18.)

Length: 252m
Width: 32.6m
Height above Tier 1: 31.50m

Stack Housing (tier 3):

Length: 35.9m
Width: 5.6m
Height above Tier 2: 8.76m

Engine parameters:

Engine: Type is diesel electric powered by 4 Wartsila/Sulzer ZA40S V16 and ZA40S V12
Engine output: Engine power at 100% MCR 4 @11520 KW and 2 @8640 KW
Displacement:

Stack Parameters

Stack distance from bow of ship (m): 216.54m (distance taken from center of stack housing)

Stack height above water (m): 52.36m
Inside stack diameter (meters): Approx. 1.1m at exhaust
Stack angle from vertical (°): 0
Estimated exhaust gas temperature (K): 250 centigrade
Actual stack exit velocity (m/sec):

Emission Rates (average emission rate while in Skagway)
(If emission rates are not provided, we can estimate from ship-specific parameters or in the absence of such information, from published typical values).

NOx: .026433 lbs/hr
PM: .037478 lbs/hr
SO_2: .155205 lbs/hr
VOCs: _____ lbs/hr
CO: .187798 lbs/hr

Fuel parameters for operation in Skagway

Fuel type combusted while in Skagway: IFO,
Fuel sulfur content (maximum) based on percent of fuel weight: 2.0%

Operational parameters while <u>docked</u> in Skagway
Operation mode while docked: (number of engines, gas-turbine auxiliary, boilers, incinerators)
1 main engine, one intermittent oil fired boiler
Fuel consumption per hour (average): 2.2 mt/hr
Hotel load: 10500 KW
Auxiliary boiler fuel consumption rate (tons/hr): approx 0.3 tons/hour

Air Pollution Control Device Information N/A
Type: Krystallon Seawater Scrubber
Pollutant Control Efficiency SO_2: PM: NOx:

ISLAND *Capacity:* ***PAX: 1,970 , Crew: 905***

Princess Cruise Lines

Physical Dimensions:

Lower Tier (Deck 7-Tier 1) – outer rim of ship**:**
- Length: 293 meters
- Width: 32.2 molded width
- Height above water: 11.90 meters

Upper Tier (Deck 15-tier 2):
- Length: 242 meters
- Width: 28 meters
- Height above Tier 1 (deck 7): 21.3 meters

Stack Housing:
- Length: 39.7 meters
- Width: 23 meters
- Height above Tier 2: 20.75 meters

Gross Tonnage:

Engine parameters:

Engines: 2 x 16V46C DWI Wartsila Diesel Electric +1 x LM2500 + GTG
Engine output: 2 x 16.200 kW nominal + 1 x 25000 kW nominal
Displacement: 57,400 kW
Is the Gas turbine engine used while tied up in Skagway? No
Are the other engines shut off while in Skagway? 1 running with 1 off
Stack Parameters
Stack distance from bow of ship (m): 203 meters
Stack height above water (m) 53.7 meters
Inside stack diameter (meters): D/G's = 1.3 meters – GTG = 2.2 meters
Stack angle from vertical (°): 0°
Estimated exhaust gas temperature (K): 600K
Actual stack exit velocity (m/sec):

Emission Rates (average emission rate while in Skagway)

(If emission rates are not provided, we can estimate from ship-specific parameters or in the absence of such information, from published typical values).

NOx: 208 lbs/hr
PM: _____ lbs/hr
SO_2: 7 lbs/hr
VOCs: _____ lbs/hr
CO: 3.75 lbs/hr

Fuel parameters for operation in Skagway
Fuel type combusted while in Skagway: IFO
Fuel sulfur content (maximum) based on percent of fuel weight: 2.5

Operational parameters while <u>docked</u> in Skagway
Operation mode while docked: 1 Diesel Engine/GTG OFF – Incin. OFF – 1 Boiler ON
Fuel consumption per hour (average): 1.95 MT/hour
Hotel load: 7,200 kW
Auxiliary boiler fuel consumption rate (tons/hr): 0.30 MT/Hour

Air Pollution Control Device Information
Type:
Pollutant Control Efficiency SO_2: PM: NOx:

Wartsila book of engine parameters emission test:

NOx Produced at 50% = 13.1 g/kWh = 0.0289 lbs/kWh

Hotel Load in port = 7.2 MW = 7,200 kW

7,200 kW x 0.0289 lbs/kWh = 208 lbs/h

<u>208 lbs/h</u> = NOx being produced

Sapphire Princess *Capacity:* ***3,078 passengers,*** ***Crew: 1,060***

Princess Cruise Lines

Skagway AK - 2008 Schedule:

Date	Times	Dock
5-21	06:00-20:45	RRF
5-27	06:00-20:45	RRF
6-04	06:00-20:45	RRF
6-10	06:00-20:45	RRF
6-18	06:00-20:45	RRF
6-24	06:00-20:45	RRF
7-02	06:00-20:45	RRF
7-08	06:00-20:45	RRF
7-16	06:00-20:45	RRF
7-22	06:00-20:45	RRF
7-30	06:00-20:45	RRF
8-05	06:00-20:45	RRF
8-13	06:00-20:45	RRF
8-19	06:00-20:45	RRF
8-27	06:00-20:45	RRF
9-02	06:00-20:45	RRF
9-10	06:00-20:45	RRF
9-16	06:00-20:45	RRF

Physical Dimensions:

Lower Tier (deck 7) – outer rim of ship**:**
Length: 288.3-metre (951 ft)
Width: 37.5-metre (121 ft)
Height above water: 12.5 meters
Upper Tier (deck 15):
Length: 250 meters
Width: 36 meters
Height above Tier 1: 21 meters
Stack Housing (tier 3 – deck 18):
Length: 35 meters
Width: 21 meters
Height above Tier 2 (top of stack to deck 15) : 21 meters
Gross Tonnage: 115,875 GRT

Engine parameters:
Engine: 2 x Alstom 20,000kW, 145rpm
Engine output: .60.7 MW
Displacement:

Is the Gasturbine engine used while tied up in Skagway?
No, usually we run with 2 d/gs (motors)

Are the other engines shut off while in Skagway?
Yes,

Stack Parameters
Stack distance from bow of ship (m): 195 meters
Stack height above water (m) 54m
Inside stack diameter (meters): Motors=1 m ---GT = 2.2 m
Stack angle from vertical (°): 0
Estimated exhaust gas temperature (K): 525 K (av. 252 C +273)
Actual stack exit velocity (m/sec):

Emission Rates (average emission rate while in Skagway) PLEASE SEE BELOW FOR FIGURE CALCULATIONS.

(If emission rates are not provided, we can estimate from ship-specific parameters or in the absence of such information, from published typical values).
9 Cyl.motors

NOx: 271 lbs/hr
PM: _____ lbs/hr
SO_2: 12.12 lbs/hr
VOCs: _____ lbs/hr
CO: 7.71 lbs/hr

Fuel parameters for operation in Skagway
Fuel type combusted while in Skagway: (MDO, IFO, HFO)
IFO
Fuel sulfur content (maximum) based on percent of fuel weight:
1.84% (Max 2%)

Operational parameters while <u>docked</u> in Skagway
Operation mode while docked: (number of engines, gas-turbine auxiliary, boilers, incinerators)
2 motors +1 boiler (no incinerators in service)
Gas turbine On (no boiler in service no incinerators in service)

Fuel consumption per hour (average): 2.1 m/tons per hour (2 motors)

Hotel load: 9.6 MW
Auxiliary boiler fuel consumption rate (tons/hr): 0.23 M/Tons per hour

Air Pollution Control Device Information
Type:
Pollutant Control Efficiency SO_2: PM: NOx:

Wartsila book of engine parameters for Nox Certification states the following:

NOx produced at 50% = 13 g/KwH = 0.0286 lbs/KwH

With the hotel load in port being approx. 9.5 MW there would be a total of 271 lbs/hour of Nox being produced.

A-5 Royal Caribbean Cruise Lines

Ship Name: M/S Rhapsody of the Seas **Capacity PAX: 2435 Crew: 765**
Line Name: Royal Caribbean International

Physical Dimensions:
Lower Tier – outer rim of ship**: Deck 5**
Length: 278 meter
Width: 32 meter
Height above water: 14meter
Upper Tier (mean representation): **Deck 10**
Length: 219 meter
Width: 36 meter
Height above Tier 1: 16 meter
Stack Housing (tier 3): **Top of Stack**
Length: 11 meter
Width: 16 meter
Height above Tier 2: 21 meters

Engine parameters:
Engine: Wartsila 12V46 (V-12 arrangement with 46 centimeter cylinders)
Engine output: 4 x 12.6 (MW)
Displacement: 1, 1156.8 (L) per cylinder

Stack Parameters
Stack distance from bow of ship (m): 231 meters
Stack height above water (m) 52 meters
Inside stack diameter (meters): There are multiple exhaust pipes inside structure, 4 from Main Engines 1.2 meters diameter each, 2 from Boilers 0.7 meters diameter each, 2 from incinerators 0.6 meters in diameter each.
Stack angle from vertical (°): 27 degrees
Estimated exhaust gas temperature (K): N/A
Actual stack exit velocity (m/sec): N/A

Emission Rates (average emission rate while in Skagway)
(If emission rates are not provided, we can estimate from ship-specific parameters or in the absence of such information, from published typical values).
Not measured
NOx: _____ lbs/hr
PM: _____ lbs/hr
SO_2: _____ lbs/hr
VOCs: _____ lbs/hr
CO: _____lbs/hr

Fuel parameters for operation in Skagway
Fuel type combusted while in Skagway: (MDO, IFO, HFO) HFO 380 cst
Fuel sulfur content (maximum) based on percent of fuel weight: (1.5% - 2.0%)

Operational parameters while <u>docked</u> in Skagway
Operation mode while docked: (number of engines, gas-turbine auxiliary, boilers, incinerators)
Fuel consumption per hour (average): 1x DG 1.0-1.25 mt/hr
Hotel load: 5.3 MW (4.5-6)
Auxiliary boiler fuel consumption rate (tons/hr): 0.3-0.44 mt/hr

Air Pollution Control Device Information
Type: Scandinavian Boiler Service Opacity Monitor on all emitters
Pollutant Control Efficiency SO_2: PM: NOx:

Ship Name: *Serenade of the Seas* *Capacity PAX 2400 Crew 900*

Line Name: Royal Caribbean Cruise Line

Physical Dimensions:

Lower Tier – outer rim of ship**: PROMENADE DECK 05**
- Length: 285 meters
- Width: 32 meters
- Height above water: 11 meters

Upper Tier (mean representation): **DECK OVERLOOKING THE POOL DECK, DK 12**
- Length: 236 meters
- Width: 32 meters
- Height above Tier 1: 22,5 meters

Stack Housing (tier 3): **TOP OF THE FUNNEL**
- Length: 11 meters
- Width: N/A
- Height above Tier 2: 19 meters

Engine parameters:

Engine: **gas turbine General Electric LM 2500+**
Engine output: 25000 kW
Displacement: N/A

Stack Parameters

Stack distance from bow of ship (m): 202 meters
Stack height above water (m): 52,5 meters
Inside stack diameter (meters): apx 3 meters
Stack angle from vertical (°): 0 deg
Estimated exhaust gas temperature (K): apx 200 deg C
Actual stack exit velocity (m/sec): data not available

Emission Rates (average emission rate while in Skagway)
(If emission rates are not provided, we can estimate from ship-specific parameters or in the absence of such information, from published typical values).

NOx: less than 0.01 lbs/hr
PM: _n/a____ lbs/hr
SO_2: n/a__ lbs/hr
VOCs: _n/a____ lbs/hr
CO: n/a lbs/hr

Fuel parameters for operation in Skagway
Fuel type combusted while in Skagway: (MDO, IFO, HFO): **MGO**
Fuel sulfur content (maximum) based on percent of fuel weight: as per analysis less than 0.05 %m/m

Operational parameters while <u>docked</u> in Skagway
Operation mode while docked: if Wartsila diesel stopped for maintenance gas turbine is running
Fuel consumption per hour (average): apx 2.6 tons/ hour
Hotel load: 5.5 MW
Auxiliary boiler fuel consumption rate (tons/hr): if GT is running steam produced by exhaust boiler

Air Pollution Control Device Information
Type: N/A
Pollutant Control Efficiency SO_2: PM: NOx:

Info from the web: "The COGES plant being installed on the Royal Caribbean and Celebrity ships will produce only 5.0 g/kWh NOx at 47 MW without any emission reduction systems. By using GE's Dry Low Emission system for the LM2500 and 2500+, NOx can be reduced to less than 1 g/kWh. The engine controls monitor emissions on-line and adjust fuel burn automatically to maintain preset levels of both NOx and CO."

Ship Name: *Serenade of the Seas* *Capacity PAX 2400 Crew 900*

Line Name: Royal Caribbean Cruise Line

Physical Dimensions:

Lower Tier – outer rim of ship**: PROMENADE DECK #05**

Length: 285 meters
Width: 32 meters
Height above water: 11meters

Upper Tier (mean representation): **DECK OVERLOOKING THE POOL DECK, DK #12**

Length:236 meters
Width: 32 meters
Height above Tier 1: 22,5 meters

Stack Housing (tier 3): **TOP OF THE FUNNEL**

Length: 11 meters
Width: n/a
Height above Tier 2: 19 meters

Engine parameters:

Engine: **Wartsila W38B**
Engine output: 11600 kW
Displacement: N/A

Stack Parameters

Stack distance from bow of ship (m): 202 meters
Stack height above water (m): 52,5 meters
Inside stack diameter (meters): stack is not circle / it is oval
Stack angle from vertical (°): 0 deg
Estimated exhaust gas temperature (K): apx 200 deg C
Actual stack exit velocity (m/sec): data not available

Emission Rates (average emission rate while in Skagway)
(If emission rates are not provided, we can estimate from ship-specific parameters or in the absence of such information, from published typical values).

NOx: apx 80 lbs/hr
PM: _n/a____ lbs/hr
SO_2: n/a__ lbs/hr
VOCs: _n/a____ lbs/hr
CO: apx 1.2 lbs/hr

Fuel parameters for operation in Skagway
Fuel type combusted while in Skagway: (MDO, IFO, HFO): **IFO 380**
Fuel sulfur content (maximum) based on percent of fuel weight: as per analysis 1.44 %m/m

Operational parameters while <u>docked</u> in Skagway
Operation mode while docked: Wartsila diesel with oil fired boiler
Fuel consumption per hour (average): apx 1.3 tons/ hour
Hotel load: 5.5 MW
Auxiliary boiler fuel consumption rate (tons/hr): apx 0.1 ton/ hour

Air Pollution Control Device Information
Type: N/A
Pollutant Control Efficiency SO_2: PM: NOx:

Ship Name: *Radiance of the Sea* *Capacity PAX* *Crew*

Line Name: Royal Caribbean

Physical Dimensions:

Lower Tier – outer rim of ship**:** dk 6.
- Length: 293.2m
- Width: 32.2m.
- Height above water: 10.9m

Upper Tier (mean representation): dk. 11.
- Length:245.7m
- Width: 32.2m.
- Height above Tier 1:18.75m.

Stack Housing (tier 3): dk 14
- Length: 28.21m
- Width: 13.65m
- Height above Tier 2: 24.350m

Engine parameters:

Engine: GE LM 2500+
Engine output: GE LM2500+ Gas turbine 25MW. Wartsila 16V38B – 11.6MW.
Displacement: Wartsila 38 = 53.870,578 cc/cyl.

Stack Parameters

Stack distance from bow of ship (195m):
Stack height above water (52.40m)
Inside stack diameter (2.246 meters):
Stack angle from vertical (90°):
Estimated exhaust gas temperature (K): GE Gas turbine @ ambient temperature 15C, 100% load, 25 MW, 509C @ 21.1 MW.515C. After eco. 255 C.
Actual stack exit velocity (m/sec): 79.69 m/s. (275639kg/hr)

Emission Rates (average emission rate while in Skagway)
(If emission rates are not provided, we can estimate from ship-specific parameters, or in the absence of such information, from published typical values).

(I only have onboard so far Infinity's emission test report that was done in Vancouver a few years back).

NOx: _____ lbs/hr
PM: _____ lbs/hr
SO_2: _____ lbs/hr
VOCs: _____ lbs/hr
CO: _____lbs/hr

SOx emissions are purely a function of the % of sulfur in the fuel and the amount of fuel burned. MGO typically has 0.2-0.3% sulfur, HFO typically has 2-4.5% sulfur so at like plant efficiency, a diesel plant produces 10-20X SOx compared to the LM2500+.

NOx emissions for the LM2500+ are 5-6g/kWhr maximum. When the COGES plant is considered, with additional output from the steam turbine generator with no more fuel input, NOx emissions are less than 5g/kWhr. This is approximately half of the new IMO Marpol Annex VI regulations. From GE.

Fuel parameters for operation in Skagway

Fuel type combusted while in Skagway: MGO burned on GT's or IFO 380 burned on DG. Incinerators MGO.

Fuel sulfur content (maximum) based on percent of fuel weight: 0.05 % m/m

Operational parameters while <u>docked</u> in Skagway

Operation mode while docked: (number of engines, gas-turbine auxiliary, boilers, incinerators): 1 GT or DG on line with OFB in service. Incinerators burning.

Fuel consumption per hour (average): 1 GT on line burning MGO, 2425 kg/hr. DG on line 8 MW burning IFO 380, 1850 kg/hr. and OFB burning IFO 465kg/hr.

Hotel load: 5.3 MW

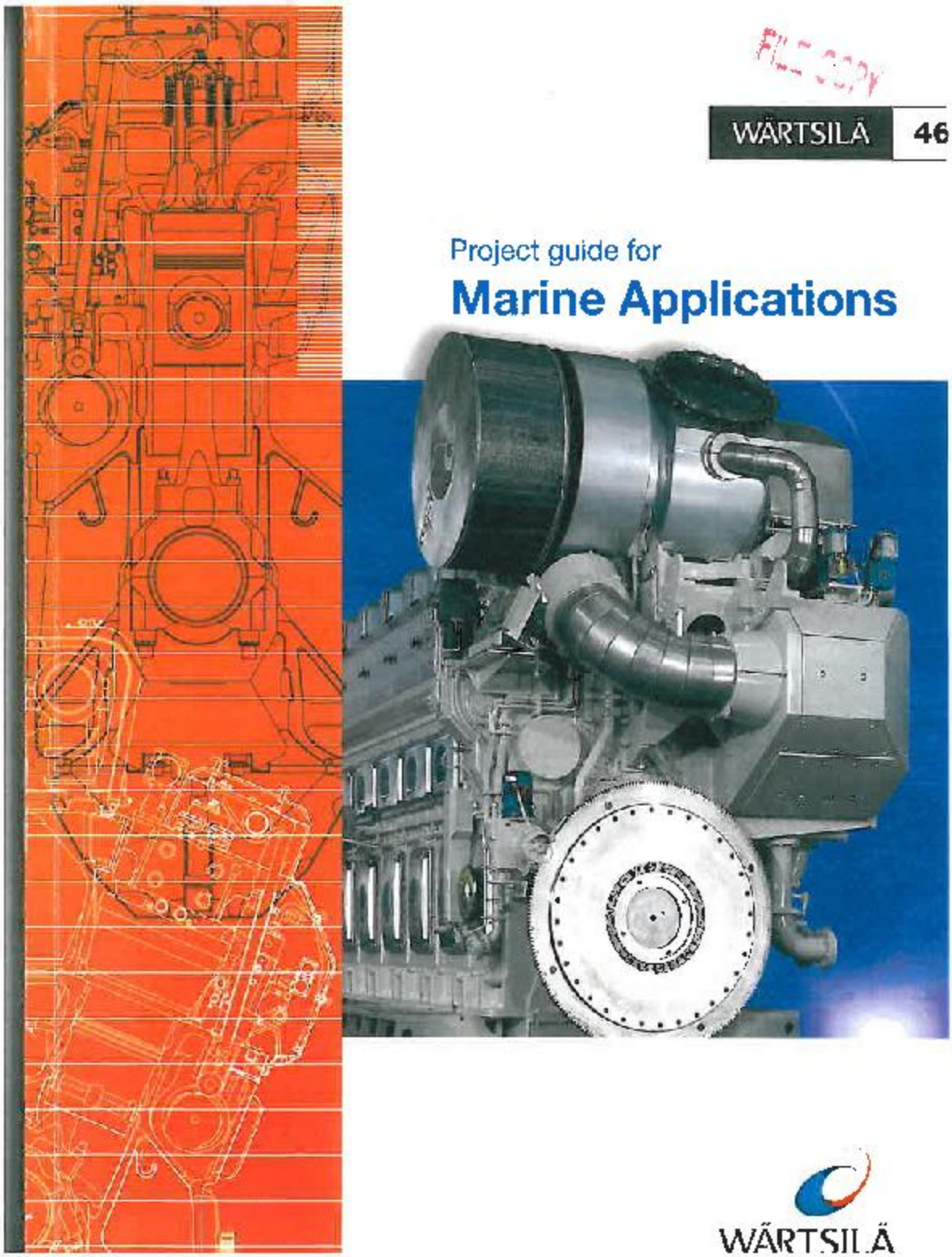
Auxiliary boiler fuel consumption rate (tons/hr): 465kg/hr.

Air Pollution Control Device Information

Type: Krystallon Seawater Scrubber

Pollutant Control Efficiency SO_2: PM: NOx:

Appendix B Wartsila NOx Emission Factor



-514 RPM-

14. Emission control options

14.1. General

Emission control of large diesel engines means primarily control of nitrogen oxides (commonly called NO_x). Other emissions such as carbon monoxide (CO) and hydro-carbons (CH) are low. Sulphur oxide (SO_x) emissions are directly proportional to the sulphur content in the fuel. Specific carbon dioxide (CO_2) emissions for the diesel engine are low due to high efficiency rate.

Wärtsilä has chosen three methods for NOx reduction:

- Low NOx combustion
- Direct Water Injection, optional
- SCR (Selective Catalytic Reduction), optional

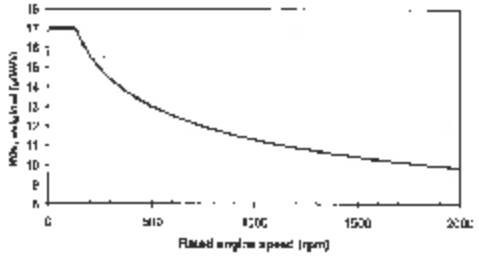
14.2. Low NOx combustion

The Low NO_x combustion concept has been implemented in the standard engine to comply with the proposed IMO NOx regulation. For Wärtsilä 46 this means that with a rated speed of 500 rpm the NOx level is below 13.0 g/kWh and with 514 rpm the NOx level is below 12.9 g/kWh, when tested according to IMO regulations (NOx Technical Code).

The IMO NOx limit is defined as follows:

$$NOx\ (g/kWh) = \begin{cases} 17 & rpm < 130 \\ 45 \times rpm^{-0.2} & 130 \leq rpm < 2000 \\ 9.8 & rpm \geq 2000 \end{cases}$$

IMO NO_x limit

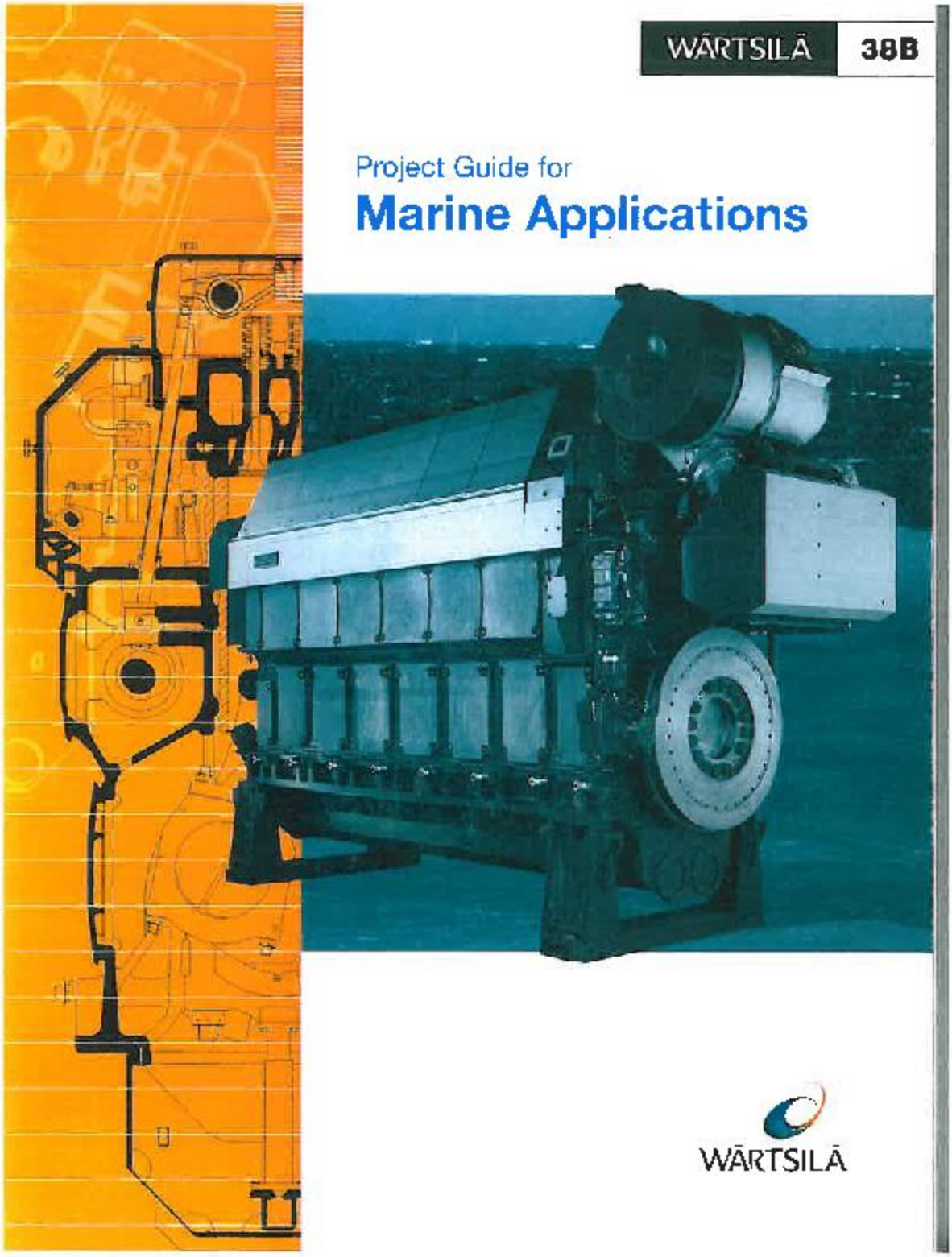


14.3. EIAPP Statement of compliance

The MARPOL Diplomatic Conference has agreed about a limitation of NO_x emissions, referred to as Annex VI to Marpol 73/78. The regulation will enter into force 12 months from the date on which not less than 15 states, constituting not less than 50% of the gross tonnage of the world's merchant fleet, have signed the protocol. Ships constructed after 1st of January 2000 (date of keel-laying) will be required to comply (also retroactively if the Annex VI enters into force after this date).

When testing the engine for NO_x emissions, the reference fuel is Marine Diesel Oil (Distillate) and the test is performed according to ISO 8178 test cycles:

E2: Diesel electric propulsion, variable pitch propeller	Speed (%) Power (%) Weighting factor	100 100 0.2	100 75 0.5	100 50 0.15	100 25 0.15	
E3: Propeller law	Speed (%) Power (%) Weighting factor	100 100 0.2	91 75 0.5	80 50 0.15	63 25 0.15	
D2: Auxiliary engine	Speed (%) Power (%) Weighting factor	100 100 0.05	100 75 0.25	100 50 0.3	100 25 0.3	100 10 0.1


WÄRTSILÄ
38B
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Marine Applications
WÄRTSILÄ

-600RPM-

14.3 Marine exhaust emissions legislation

The increasing concern over the air pollution has resulted in the introduction of exhaust emission controls to the marine industry. To avoid the growth of uncoordinated regulations, the IMO (International Maritime Organization) has developed the Annex VI of MARPOL 73/78, which represents the first set of regulations on the marine exhaust emissions.

There is yet no legislation concerning the particulate emissions from the marine diesel engines, although the authorities are planning to set strict limits to the particulates in the near future. Smoke is regulated in some countries or regions based on its visibility.

14.3.1 MARPOL Annex VI

MARPOL 73/78 Annex VI includes regulations for example on such emissions as nitrogen oxides, sulphur oxides, volatile organic compounds and ozone depleting substances. The Annex VI has yet to be ratified. The regulations will enter into force 12 months after the date on which at least 15 states, constituting not less than 50% of the gross tonnage of the world's merchant shipping, have signed the protocol. The most important regulation of the MARPOL Annex VI is the control of NO_x emissions.

All Wärtsilä engines are Low NO_x design engines and comply with the proposed NO_x levels set by the IMO in the MARPOL Annex VI. The NO_x controls apply only to diesel engines over 130 kW installed on ships built (defined as date of keel laying or similar stage of construction) on or after January 1, 2000 along with engines which have undergone a major conversion on or after January 1, 2000.

For Wärtsilä 38 with a rated speed of 600 rpm, the NO_x level is below 12.6 g/kWh, when tested according to IMO regulations (NO_x Technical Code).

The IMO NO_x limit is defined as follows:

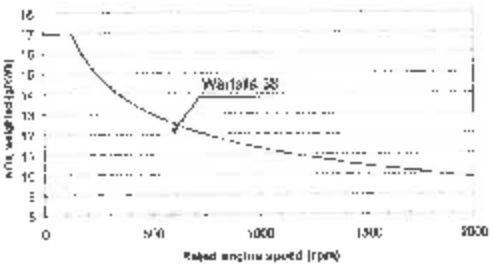
NO_x [g/kWh]

= 17 rpm < 130

= 45 x $rpm^{-0.2}$ 130 < rpm < 2000

= 9.8 rpm > 2000

Figure 14.3.2



14.3.2 EIAPP Statement of Compliance

An EIAPP (Engine International Air Pollution Prevention) Statement of Compliance will be issued for each engine showing that the engine complies with the NO_x regulations set by the IMO. For the time being only a Statement of Compliance can be issued, because the regulation is not yet in force.

When testing the engine for NO_x emissions, the reference fuel is light fuel oil and the test is performed according to ISO 8178 test cycles. Subsequently, the average NO_x value has to be calculated using different weighting factors for different loads that have been corrected to ISO 8178 conditions. The most commonly used ISO 8178 test cycles are shown in Table 14.3.1.

Table 14.3.1 The most commonly used ISO 8178 test cycles

D2: Diesel electric propulsion, CPP	Speed (%)	100	100	100	100	
	Power (%)	100	75	50	25	
	Weighting factor	0.2	0.5	0.15	0.15	
E3: Propeller law FPP	Speed (%)	100	91	80	63	
	Power (%)	100	75	50	25	
	Weighting factor	0.2	0.5	0.15	0.15	
D2: Auxiliary engine	Speed (%)	100	100	100	100	100
	Power (%)	100	75	50	25	10
	Weighting factor	0.05	0.25	0.3	0.3	0.1

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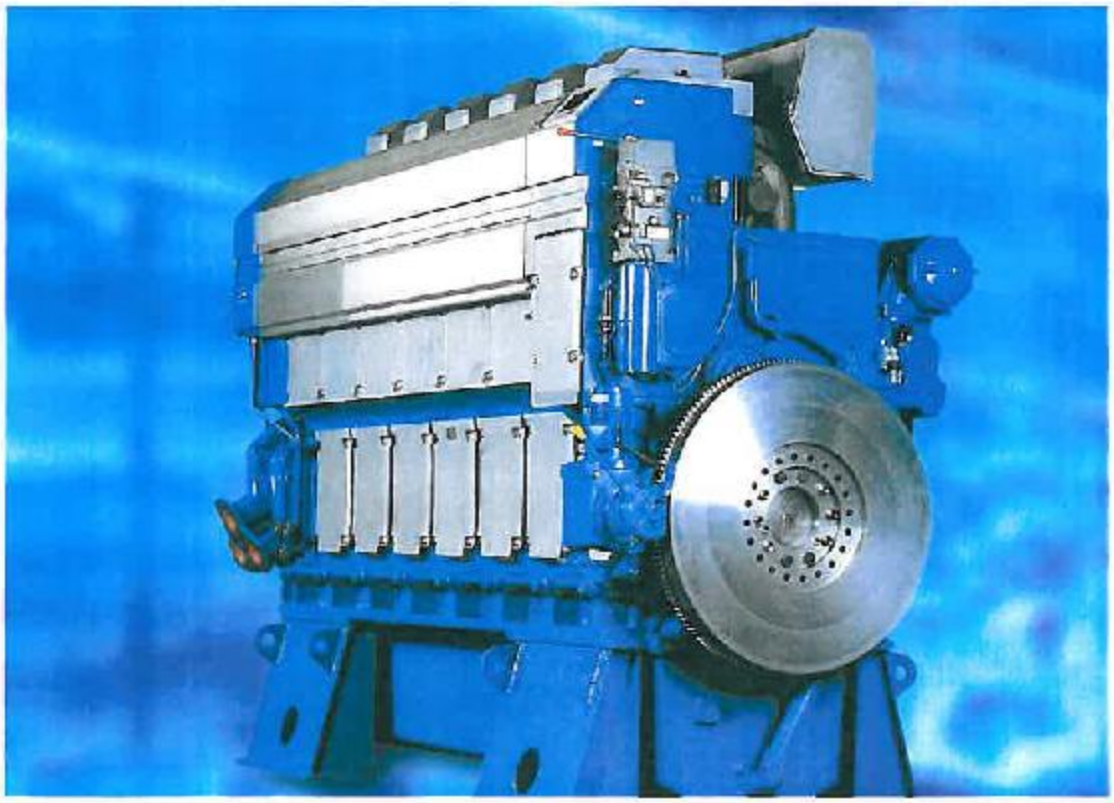


WÄRTSILÄ

— 720 RPM —

13.3 Marine exhaust emissions legislation

The increasing concern over the air pollution has resulted in the introduction of exhaust emission controls to the marine industry. To avoid the growth of uncoordinated regulations, the IMO (International Maritime Organisation) has developed the Annex VI of MARPOL 73/78, which represents the first set of regulations on the marine exhaust emissions.

There is yet no legislation concerning the particulate emissions from the marine diesel engines, although the authorities are planning to set strict limits to the particulates in the near future. Smoke is regulated in some countries or regions based on its visibility.

13.3.1 MARPOL Annex VI

MARPOL 73/78 Annex VI includes regulations for example on such emissions as nitrogen oxides, sulphur oxides, volatile organic compounds and ozone depleting substances. The Annex VI has yet to be ratified. The regulations will enter into force 12 months after the date on which at least 15 states, constituting no less than 50 % of the gross tonnage of the world's merchant shipping, have signed the protocol. The most important regulation of the MARPOL Annex VI is the control of NOx emissions.

The engines comply with the proposed NOx levels set by the IMO in the MARPOL Annex VI. The NOx controls apply to diesel engines over 130 kW installed on ships built (defined as date of keel laying or similar stage of construction) on or after January 1, 2000 along with engines which have undergone a major conversion on or after January 1, 2000.

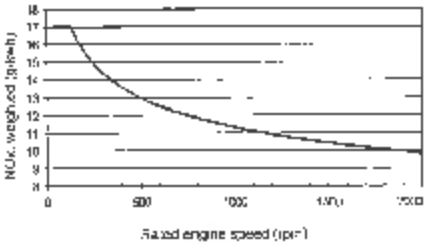
For Wärtsilä 32 with a rated speed of 720 rpm, the NOx level is below 12.1 g/kWh and with 750 rpm, the NOx emissions are below 12.0 g/kWh, when tested according to IMO regulations (NOx Technical Code).

The IMO NOx limit is defined as follows:

NOx [g/kWh]

- $= 17$ (rpm < 130)
- $= 45 \times \text{rpm}^{(-0.2)}$ (130 ≤ rpm < 2000)
- $= 9.8$ (rpm ≥ 2000)

Figure 13.1 IMO NOx emission limit



13.3.2 EIAPP Statement of Compliance

An EIAPP (Engine International Air Pollution Prevention) Statement of Compliance will be issued for each engine showing that the engine complies with the NOx regulations set by the IMO. For the time being only a Statement of Compliance can be issued, because the regulation is not yet in force.

When testing the engine for NOx emissions, the reference fuel is Marine Diesel Fuel (distillate) and the test is performed according to ISO 8178 test cycles. Subsequently, the NOx value has to be calculated using different weighting factors for different loads that have been converted to ISO 8178 conditions. The most commonly used ISO 8178 test cycles are presented in following table.

For EIAPP certification, the "engine family" or the "engine group" concepts may be applied. This has been done for the Wärtsilä 32 diesel engine. The engine family is represented by the parent engine and the certification emission testing is only necessary for these parent engines. Further engines can be compared by checking documents,

Table 13.2 ISO 8178 test cycles

D2: Diesel electric propeller, variable pitch	Speed (%)	100	100	100	100	
	Power (%)	100	75	50	25	
	Weighting factor	0.2	0.5	0.15	0.15	
E3: Propeller law	Speed (%)	100	91	80	62	
	Power (%)	100	75	50	25	
	Weighting factor	0.2	0.5	0.15	0.15	
D2: Auxiliary engine	Speed (%)	100	100	100	100	100
	Power (%)	100	50	50	25	10
	Weighting factor	0.05	0.5	0.2	0.2	0.1