Carnival Corporation
Holland America Line
Krystallon
Sea Water Scrubber Technology
Demonstration Project

Installation and early operations

Fall 2007

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Topics Covered

- Project introduction (Slides 3-6)
- Scrubber installation/early operations (Slides 7 and 8)
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- Early wash water monitoring results (Slides 10 – 21)
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- Conclusions/project endorsements/contacts (Slides 23 -25)

Our Strategic Partners

Agencies and Funders from Important Locales

- ***U.S. Environmental Protection Agency****
- ***Environment Canada*, B.C. Ministry of the Environment*, and the Canadian Petroleum Products Institute****
- ***Alaska Department of Environmental Conservation***
- ***Washington Department of Ecology***
- ***Puget Sound Clean Air Agency****
- ***Port of Seattle, Washington****
- ***Port of Vancouver, B.C.****
- ***California Air Resources Board***
- ***California Water Resources Board***
- ***Hawaii Department of Health***
- Carnival Corporation companies* including Carnival Cruise Line, Princess Cruises, and Costa Cruises
- Caterpillar Marine Power Systems – MAK*

•Asterisk denotes funding partner

•***Bold italic font indicates Technical Advisory Committee (TAC) member organization***

The Test Platform

The ms Zaandam

- Keel laid 1998, delivered 2000
- Displacement: 68,000 tons.
- Ship's complement:
  - 1,432 guests
  - 600 Crew
- Propulsion:
  - Five 12-cylinder Sulzer ZA40S engines
  - 720 kW per cylinder
- 2007 – 2008 itinerary: Alaska, Hawaii, California, Mexico

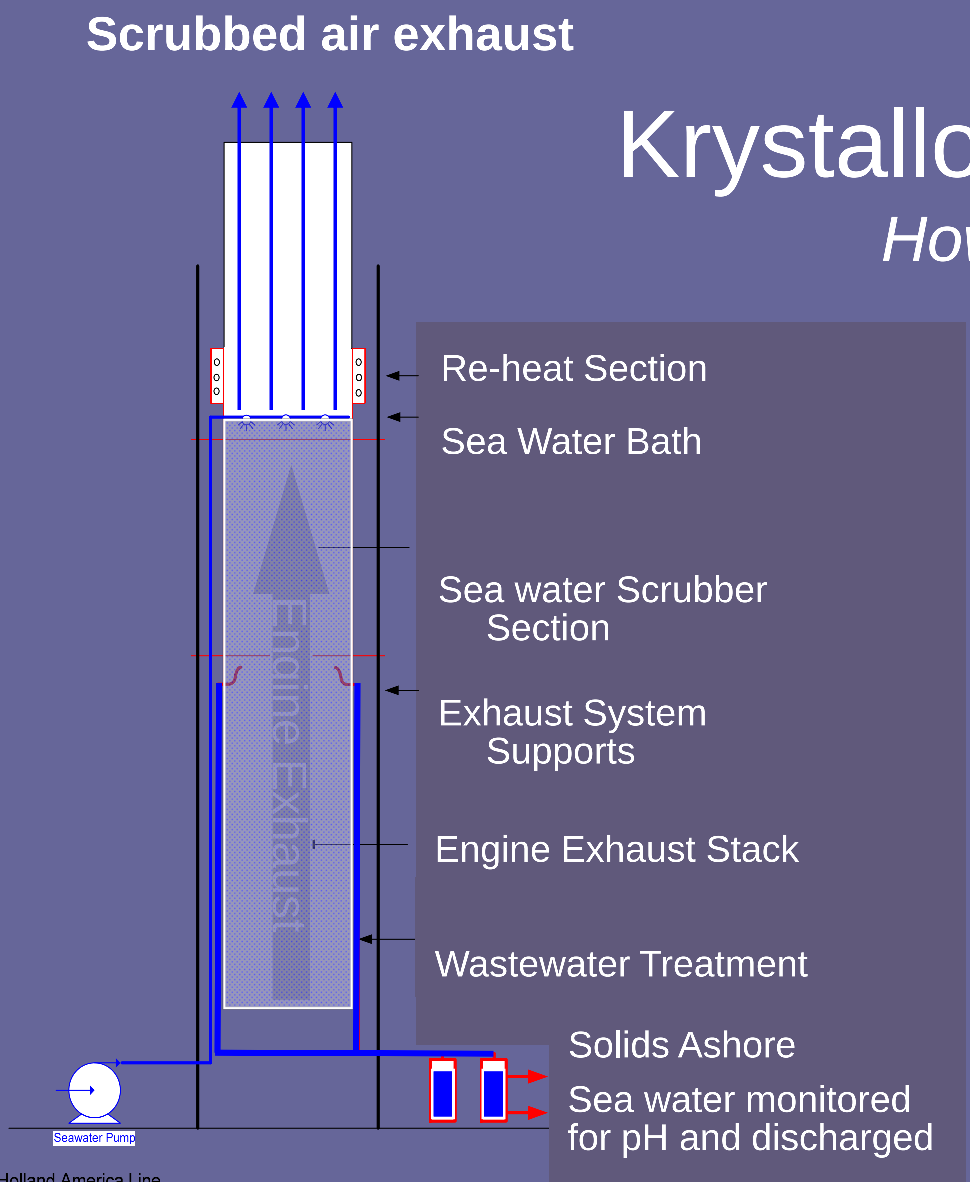
Technology for Cleaner Air

Why Sea Water Scrubbing?

- Simple chemistry
- Proven application for land-based facilities and as inert gas systems on petroleum and chemical tankers
- Substantially minimizes harmful emissions from diesel engines (SO_x and particulate matter)
- Can be used in port or at sea

Krystallon Seawater Scrubber

How it Works - in Concept



Holland America Line
July 2006

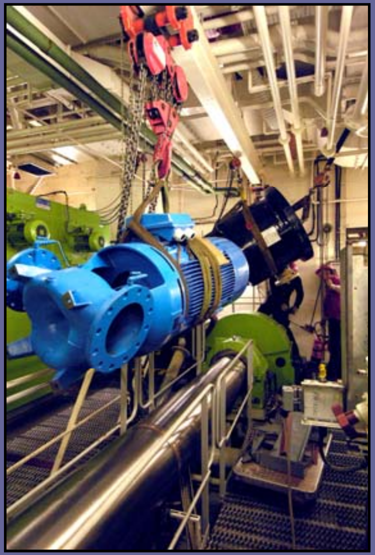
- **Exhaust passes through a multi-sectioned scrubber.** Scrubber is designed to promote thorough mixing of gaseous engine emissions and seawater (wash water)
- **Wash water is treated to raise pH and separate solids from liquids prior to overboard discharge**
- **Solids are collected as a sludge and are properly discharged ashore**

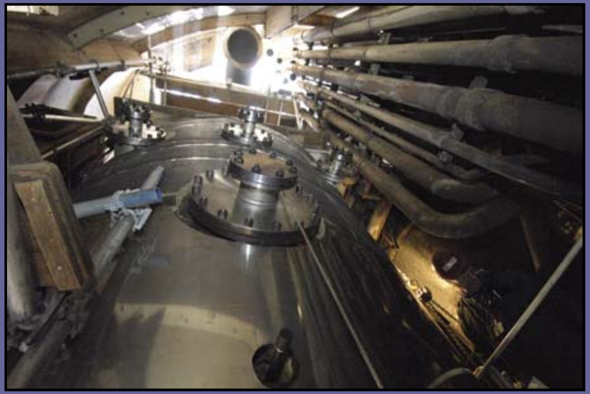
Scrubber Installation

Pilot Projects Take Time and Patience!

- Scrubber unit installed at Victoria Shipyard – April 8-21, 2007

- Piping and instrumentation installed during ship operations – April 21 through August 11, 2007





Early Scrubber Operations

Mid-August to mid-October 2007

Operating constraints:

- Was operated while the Zaandam was “at sea”
- Was not operated in any port of call except three times when wash water samples were collected (August 18th and 24th and September 12th)

Days of full and partial operation covered in this summary:

- **August** 12-16, 18, 19, 21, 22, 24, 25, 27-29 (Roundtrips out of Vancouver, B.C.)
- **September** 6, 7, 11, 12, 13, 16-19, 21-25, 27, 28, 30 (Same as above)
- **October** 1-7, 10, 13, 14-16 (Roundtrips out of San Diego, CA)

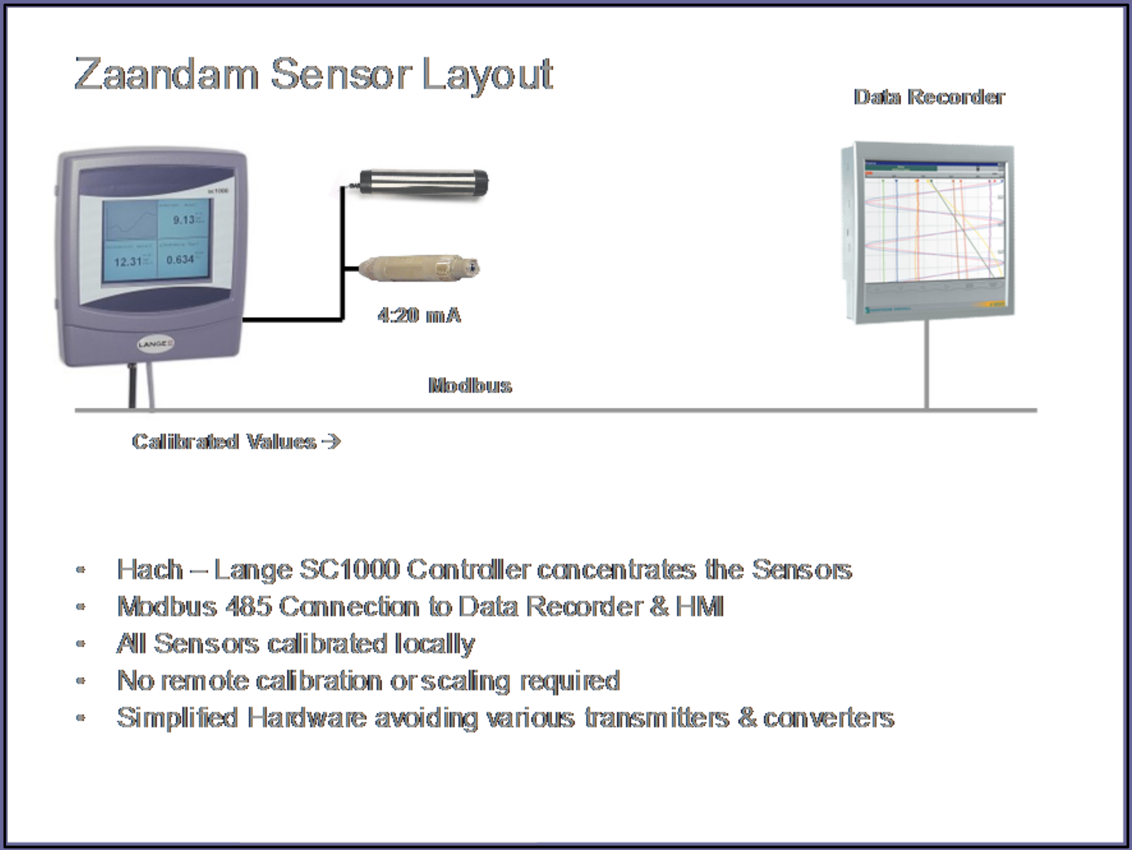
Environmental Monitoring

Monitoring all Emissions/Discharges to the Environment

- **Scrubber wash water:**
  - **Continuous monitoring -** Flow, pH, turbidity, polycyclic aromatic hyrdrocarbons (PAHs), temperature, and dissolved oxygen (DO).
  - **Periodic Testing –** Constituents listed above and a wider suite of conventional water pollutants, petroleum hydrocarbon compounds, and total and dissolved metals.
- **Engine emissions:**
  - **Continuous monitoring –** Date/time, engine power, sulfur dioxide (SO_2), carbon dioxide (CO_2), nitrogen oxide (NO), nitrogen dioxide (NO_2).
  - **Periodic testing –** Expanded suite of gaseous constituents including those listed above and particulate matter (PM).
- **Sludge:**
  - **Periodic Testing** - The sludge generated by the wash water treatment system will be tested for pH, petroleum hydrocarbons, and metals to characterize it for proper disposal ashore.

Continuous Wash Water Monitoring

Krystallon System Hardware

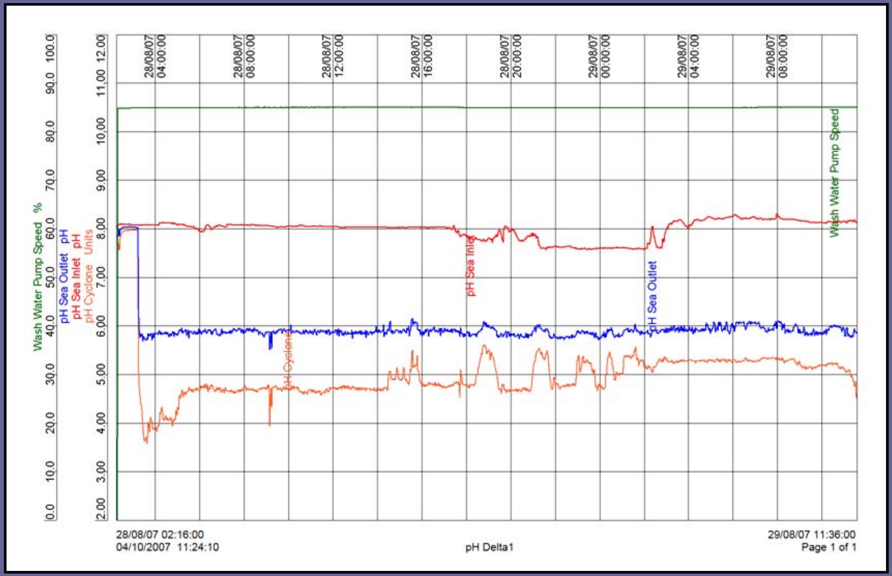


HMI = Human Machine Interface

Data Management

Managing Tens of Thousands of Pieces of Data

- Data recorded by “Eurotherm” software
- Downloaded data into Microsoft Excel
- Data filtered to evaluate only data generated while the scrubber was running
- Analyzed 16,595 lines of data
- Completed statistical analysis of the data set



pH of Overboard Discharge

Current Status and Action Plan for Improvement

CURRENT STATUS

pH of Overboard Discharge

Minimum	5.3
Maximum	7.9
Mean	5.9
Std. Dev.	0.18

ACTION PLAN

Goal: pH of 6.5 or greater prior to overboard discharge.

Approach: Increase proportion of reaction water to scrubber wash water to raise pH.

Action taken: New motor and impellor on reaction water pump to increase capacity of this pump by 150 tonnes per hour or 28%.

Schedule: Completed in December 2007.

Change in Turbidity Between Inlet and Discharge

Current Status and Action Plan for Improvement

CURRENT STATUS

Change in Turbidity Between the Inlet and the Discharge (in NTUs)

Minimum	-107
Maximum	641
Mean	47
Std. Dev.	23

ACTION PLAN

Goal: Maximum change of 25 NTUs between inlet and discharge.

Approach: Investigate hypothesis that entrained air bubbles are interfering with turbidity probe readings at the discharge.

Planned Actions:

1. Bench test to determine whether turbidity measurements change as air bubbles dissipate.
2. Modify sample lines to allow for de-aeration of sample water.

Schedule: Complete by 1st Quarter 2008.

Change in PAH* Between Inlet and Discharge

Current Status and Action Plan for Improvement

CURRENT STATUS

Change in PAH Between the Inlet and the Discharge (in ppb)

Minimum	6
Maximum	220
Mean	98
Std. Dev.	41

* **PAH** = Polycyclic Aromatic Hydrocarbons

ACTION PLAN

Goal: Reduce difference in PAH concentration between inlet and discharge.

Approach: Investigate hypothesis that entrained air bubbles are interfering with PAH probe readings at the discharge, just as they may be with turbidity probe readings.

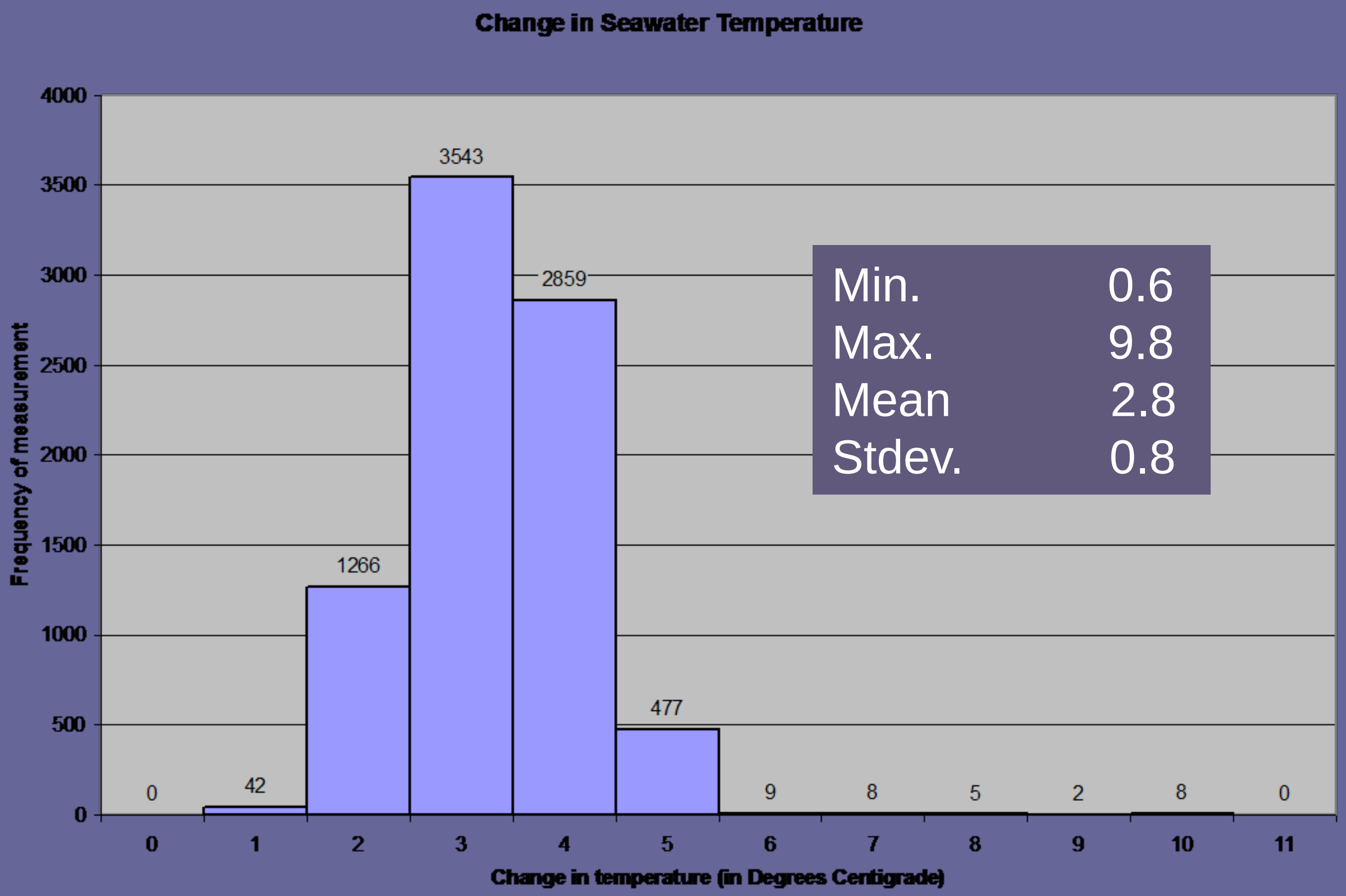
Planned Actions:

1. Bench test to determine whether PAH concentrations change as air bubbles dissipate.
2. Modify sample lines to allow for de-aeration of sample water.

Schedule: Complete by 1st Quarter 2008.

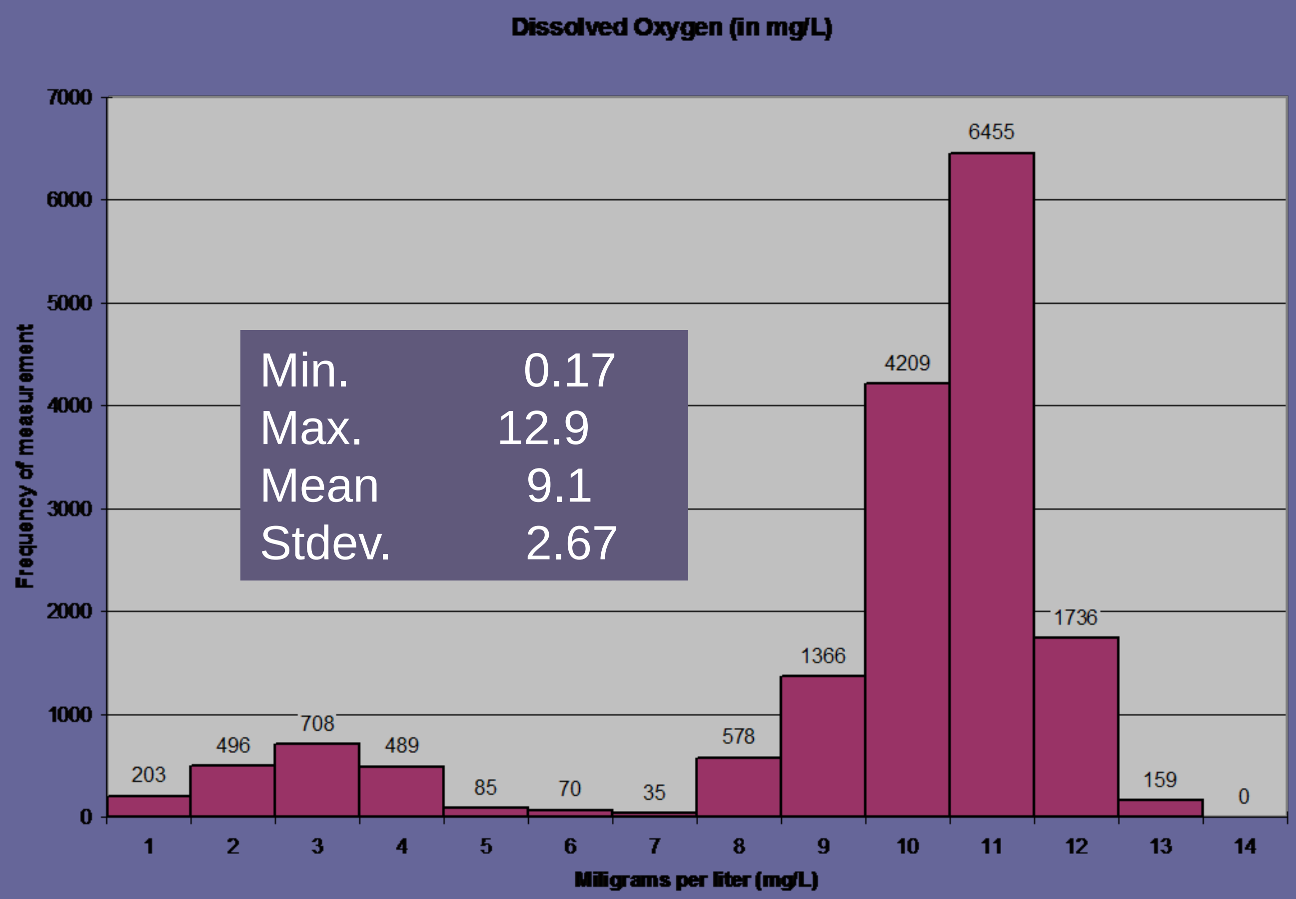
Temperature

Small Change Between Inlet and Outlet meets Expectations



Dissolved Oxygen (DO)

Acceptable Concentrations of DO in the Discharge



Periodic Water Quality Sampling

Lab Analysis of Conventional Parameters

Water quality samples were collected on August 18th and 24th, and September 12th, in Skagway and Juneau, Alaska and Vancouver, British Columbia, respectively. Samples were analyzed for conventional parameters by Analytica Laboratories. The results are in-line with expectations as follows:

- ***Alkalinity*** – Alkalinity was used up in the scrubbing process. Alkalinity was reduced between 76 to 98%, with a minimum alkalinity measured in the effluent of 21 mg/l $CaCO_3$.
- ***Compounds containing nitrogen*** – Ammonia, nitrite, and Kjeldahl nitrogen were not detected in the influent or the effluent in Alaska. Nitrate was detected in both the influent and the effluent in Vancouver, B.C. at less than 23 mg/l.
- ***Solids –*** Turbidity and total suspended solids (TSS) decreased in concentration between the influent and the effluent. The maximum turbidity in the effluent was 8 NTUs – the maximum change between influent and effluent was -9%. The maximum TSS in the effluent was 17 mg/l – the maximum change was -73%.
- ***Chemical oxygen Demand (COD)*** – COD increased between the influent and the effluent. The change ranged between 33 and 91% with a maximum concentration in the effluent of 130 mg/l.

Periodic Water Quality Sampling

Very Low Concentrations of Petroleum Hydrocarbon Compounds were Detected

- Gasoline-Range Organics (GRO) – Not detected (ND) in all samples
- BTEX* – Benzene detected at 1.9 ppb in the discharge in Skagway. ND in all other samples.
- Diesel Range Organics (DRO) – Not detected in the influent. Detected at 160, 280, and 510 ppb in the discharge in Skagway, Juneau, and Vancouver, respectively.
- EPA 16 PAHs – ND in all samples except 1.3 ppb phenanthrene in the discharge in Vancouver, B.C.

BTEX = Aromatic petroleum hydrocarbon compounds benzene, toluene, ethylbenzene, and xylene.

Periodic Water Quality Sampling

Total Metals

The following 7 metals were found above a water quality criterion in at least one of the six samples collected during this period (influent and effluent samples from the three different geographic locations):

Arsenic Beryllium Copper Lead Nickel Selenium Zinc

Key findings:

- Where the effluent exceed a water quality criterion so does the influent. For all the metals listed above except zinc, at least 2/3rds of the time that the effluent exceeded water quality criteria, the associated influent concentration also exceeded water quality criteria.
- The variability in this small data set (3 samples) precludes definitive conclusions about the potential impact of total metals in this discharge. For example, the changes in concentration between the influent and the effluent for arsenic, beryllium, lead and zinc were both positive and negative, meaning that sometimes there was more of that metal in the effluent than the influent (positive change) and in another sample there was less of that metal in the effluent than the influent (negative change).

Periodic Water Quality Sampling

Dissolved Metals

Key findings:

- The same 7 metals were detected in the dissolved phase.
- They were detected in generally the same order of magnitude concentrations and behaved in a similar manner as the total metals.

Whole Effluent Toxicity (WET) Test Results

Wash Water Sample Collected in Juneau, Alaska

Test Type	Test Species	Endpoint	NOEC (% effluent)	LOEC (% effluent)
Acute Toxicity	A. Bahia (mycid shrimp)	Survival	100	>100
Acute Toxicity	A. Affinis (topsmelt)	Survival	100	>100
Chronic Toxicity*	Echinoderm	Fertilization	6.25 See note below	12.5 See note below

- **The chronic toxicity results were disqualified because the laboratory control did not meet the acceptability criterion of 70% fertilized eggs.**

NOEC = No Observed Effect Concentration
LOEC = Lowest Observed Effect Concentration

Engine Emissions Monitoring

Current Status and Action Plan for Improvement

CURRENT STATUS

1. Continuous engine emission monitoring – Cascade Technologies CT 1000
   – The fiber optic cables have not functioned reliably.

2. Stack Test by Environment Canada

ACTION PLAN

1. A second generation system, not using fiber optics, has been designed and successfully installed on the ferry *The Pride of Kent.* A similar system will be installed on the ms Zaandam in the 1st quarter 2008.

2. The stack test was completed in September 2007. The draft report is in internal review.

Conclusions

- **The existing environmental monitoring program is sufficiently robust to effectively evaluate emissions and discharges from the Krystallon sea water scrubber.**

- **Wash water monitoring results are in-line with expectations.** Monitoring will continue through 2008. Plans are in-place to improve wash water system performance relative to pH, turbidity, and PAHs.

- **Plans are in-place to upgrade the continuous engine emission monitoring system in the 1st quarter 2008.**

Continuing High Level Support for this Important Pilot Project

"We are very pleased with these early results but there is room for improvement. In our own trials seawater scrubbers have achieved substantial reductions in diesel engine emissions while effectively treating the wash water discharged. We are continuing to work to improve on these early results"

Chris Leigh-Jones, Managing Director, Krystallon

"*HAL and Krystallon, working together, are determined to maximize the benefits of this unique opportunity to help safeguard and protect the marine environment."*

Dan Grausz, Senior Vice President of Fleet Operations, Holland America Line

For More Information about this Project……

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