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Working together for clean air

Holland America Line Sea Water Scrubber Demonstration Project

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Faster Freight, Cleaner Air - September 17, 2008

Topics Covered

- **Strategic partners**
- **Introduction to sea water scrubbing**
- **Environmental performance monitoring**
- **Conclusions**

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Our Strategic Partners

Agencies and Funders from Important Locales

- U.S. Environmental Protection Agency* - $300,000
- Environment Canada* - $50,000 plus in-kind stack testing
- B.C. Ministry of the Environment* and the Canadian Petroleum Products Institute* - $38,000
- Alaska Department of Environmental Conservation
- Washington Department of Ecology
- Puget Sound Clean Air Agency* - $100,000
- Port of Seattle, Washington* - $50,000
- Port Metro Vancouver, B.C.* - $50,000
- 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*

* Denotes funding partner

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The Test Platform

The ms Zaandam

Passengers	1,500
Crew	600
Length Overall	237.9 meters
Breadth Overall	32.25 meters
Top Mast above Keel	56.00 meters
Maximum Draft	8.12 meters
New Building Hull Number	6035 Fincantieri
Ships Registry	Rotterdam, the Netherlands
Classification	Lloyds
Gross Tonnage	60,906 MT
Displacement	33,310 MT
Dead Weight	6,349 MT
Engine	Sulzer ZA40S by Wartsila
Bore	400mm
Stroke	560mm
Cylinders	12
Nominal power	720 kW per cylinder
Nominal speed	514 rpm
Output under normal operating conditions	7 MW

Scrubber Installation

Pilot Projects Take Time and Patience!

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- **Scrubber installed:**

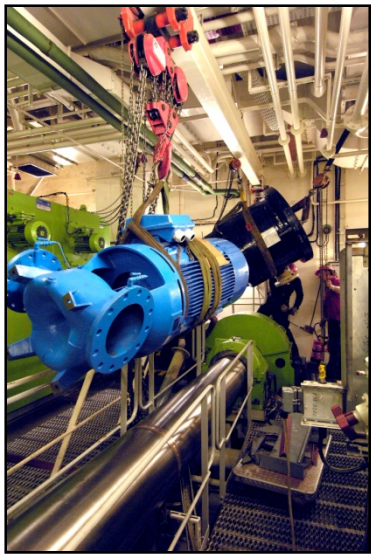
  April 8-21, 2007

- **Piping and instrumentation installed during ship operations:**

  April 21 through August 11, 2007

- **Monitoring began:**

  August 2007



Substantially Reduces Sulfur Dioxide (SOx) and Particulate Matter (PM) Emissions

- **Simple chemistry**
- **Proven application for land-based facilities and as inert gas systems on petroleum and chemical tank vessels**
- **Can be used in port or at sea**

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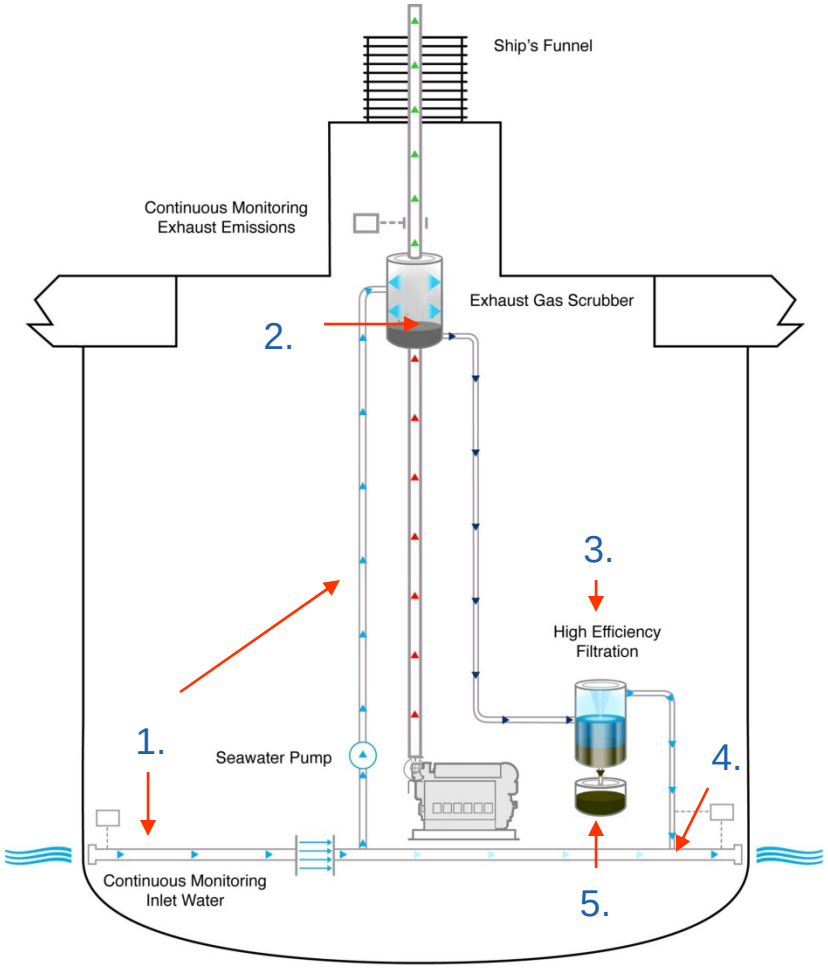
Krystallon Sea Water Scrubber

How it Works - in Concept



CROSS SECTION THROUGH SHIP

1. **Wash water**
2. **Scrubber**
3. **Filtration**
4. **pH adjustment**
5. **Sludge**

Environmental Performance Monitoring

Monitoring all Emissions/Discharges to the Environment

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- **Engine emissions**
  - **Date/time, engine power, sulfur dioxide (SO_2), particulate matter (PM) carbon dioxide (CO_2), nitrogen oxide (NO), nitrogen dioxide (NO_2)**
- **Scrubber wash water**
  - **Flow, pH, turbidity, temperature, dissolved oxygen (DO), petroleum hydrocarbons, conventional parameters, and metals**
- **Sludge**
  - **pH, petroleum hydrocarbons, and metals to characterize it for proper disposal ashore**

Stack Test -

Support from our Canadian Partners

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TEST GOAL:

Evaluate the efficiency of the sea water scrubber at removing sulfur dioxide (SO_2) and particulate matter (PM) from engine exhaust.

Stack Test Results

75% Removal of SO_2 and 57% Removal of PM

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Scrubber	Units	SO_2	PM
Inlet	g/kWh	6.7	0.83
Outlet	g/kWh	1.6	0.35
Efficiency	%	75	57

In this test, the scrubber removed approximately 75% of the SO2 and 57% of the PM generated by the engine as measured by the differences in mass of emissions between the inlet and the outlet. These reductions approximate the use of 0.5% S distillate oil. Further improvements during the demonstration project are likely to produce reductions equivalent to 0.1% S distillate oil.

Wash Water is Treated Prior to Discharge

We Remove Particles and the Associated Petroleum Hydrocarbons and Metals

- **Wash water is treated by a multicyclone prior to discharge. Cyclonic action separates particles from liquids.**

Summary: In-Line Monitoring Results – 2007 and early 2008

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Parameter (*Mean Concentration)*	**Goal**	**Alaska and B.C.** August to October	**California/Pacific Ocean** October to December	**California/Pacific Ocean** December to February
DO *(in mg/l)*	**Saturation**	**9.1**	**5.5**	**n/a**
pH	**> 6.5[1]**	**5.9**	**6.0**	**6.5**
Change in Turbidity *(in mg/l)*	**<25[1,2]**	**46**	**62**	**30**
Change in Temp. *(in degrees C)*	**<8[1]**	**2.8**	**2.8**	**2.8**
Change in PAHs *(in ug/l)*	**<50[2]**	**98**	**91**	**75**

Sea Water Scrubbing……

……*Net Environmental Benefit*

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Constituents emitted from ship's engines are ultimately deposited in the ocean through the hydrologic cycle.

Engine emissions

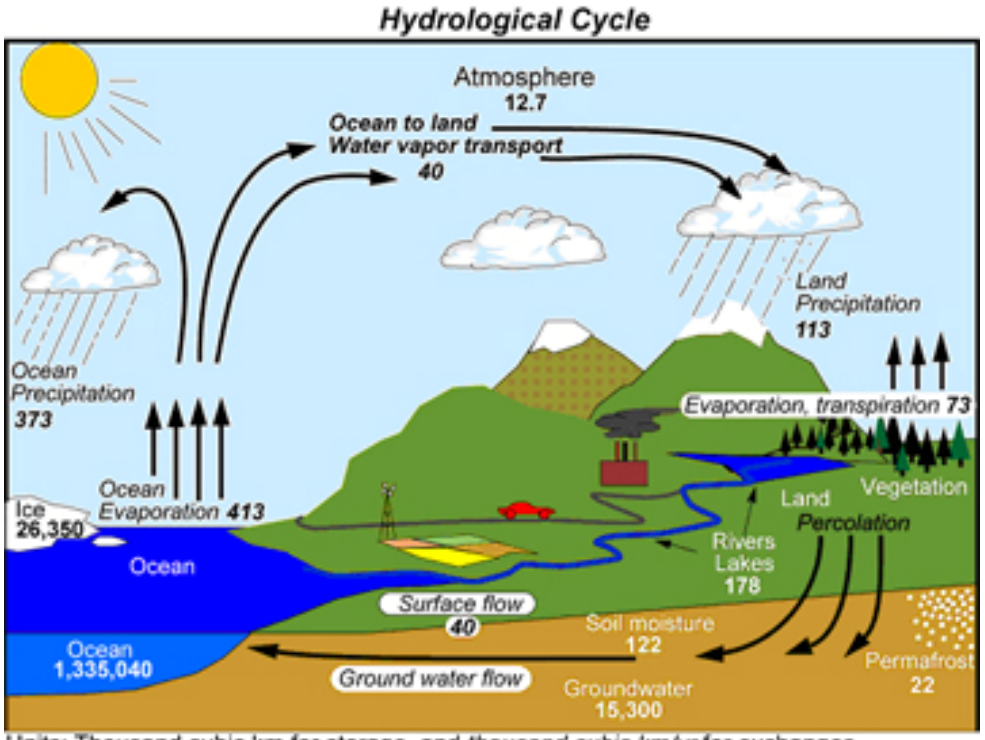
- **SO_2 –** Sea water scrubbing reduces harmful SO_2 emissions from engines by converting it into calcium sulfate - a natural constituent in the ocean.

- **PM –** Particulate matter is also reduced by 57%. This material is turned into a sludge, keeping it from deposition in the ocean.

Wash water discharge

- **pH –** Reaction water is used to raise the pH of the wash water to near neutral prior to discharge. pH is fully neutralized within meters of the ship.

- **Trace metals –** While some metals have been detected in scrubber wash water, on average 57% of their original concentration is eliminated through filtering in the multicyclone.



Units: Thousand cubic km for storage, and *thousand cubic km/yr* for exchanges

Recent Developments.....

.....Testing in Alaska in early September 2008

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- Negotiated with Port Metro Vancouver and the Alaska Department of Environmental Conservation (ADEC) to operate the scrubber in port in Canada and Alaska in late August and September 2008.
- Starting August 31st operated the scrubber in port in Port in Vancouver, B.C., and Ketchikan and Skagway, Alaska. During in-port operation in Ketchikan (September 2nd) and Skagway (September 4th), shipboard personnel observed that the wash water discharge contained soot particles and caused a light sheen on the water.
- Holland America Line has ceased operating the scrubber until modifications are made to the improve the quality of the wash water discharge.

Conclusions: Sea Water Scrubbing

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- **It works to reduce engine emissions. It provides a net environmental benefit taking 75% of SO_2 and 57% of PM out of the engine exhaust. It is likely that further refinements will result in larger reductions in both SO_2 and PM**
- **Can be used anywhere a ship sails.**
- **Is cost effective - Allows the continued use of heavy fuel oil (HFO) at $750 per tonne as opposed to using distillate fuel (MDO) at $1,275 per tonne (at July 2008 prices).**
- **Contributes to energy global security as it allows the continued use of residual petroleum hydrocarbon fuel.**
- **Krystallon's technical team is evaluating potential improvements to wash water treatment.**