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VESSEL EMISSION MANAGEMENT
Using a Krystallon Seawater Scrubber

US EPA Regulation 40 CFR 1042 &
IMO MARPOL Annex VI

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The final EPA rules under 40 CFR 1042 include standards for existing marine engines larger than 600kW but with less than 30 L/Cylinder, when they are remanufactured and for newly manufactured engines.

Following, are the emission reductions required to be achieved by an EPA approved "remanufacture kit" contrasted to emissions from an old engine with a Krystallon seawater scrubber. The scrubber, which is a one-time capital investment good for the remaining life of the vessel, raises all existing commercial Category 1 and Category 2 engines to the same standard for SOx and PM as new Tier 3 engines, regardless of the type of fuel used.

EPA Fuel Spec	Emission Parameter	Diesel Engine Emissions Reduction / Concentration Tier II Remanufacture Kits
ULSD 0.0015% Sulfur	SOx	99% 15-20 ppm
	Total Particulate Matter	25%
	Nitrogen Oxides (NOx)	No appreciable reduction
	Hydrocarbons (HC)	No appreciable reduction
Increased Fuel Use		2-5%
		Krystallon Scrubber
ULSD 0.0015% Sulfur	SOx	99.9% <1 ppm
No. 2 Oil 0.5% Sulfur	SOx	99.9% <10 ppm
IFO380 3.5% Sulfur	SOx	99.9% <10 ppm
	Total Particulate Matter	80-85% <0.12g/kW.hr
	Hydrocarbons (HC)	80-85%
	Nitrogen Oxides (NOx)	5% 8.9g/kW.hr
Increased Fuel Use		1-2%

IMO Fuel Spec	Fuel Sulfur Conten
2012, Global sulfur cap 3.50%	35,000 ppm sulfur
2010, Emission Control Areas (ECA), 1.00%	10,000 ppm sulfur
2015, Emission Control Areas (ECA), 0.10%	1,000 ppm sulfur
2020, Global sulfur cap 0.50% review in 2018	5,000 ppm sulfur

The Relationship of Hydrocarbons to the Formation Ozone and Other Secondary Pollutants

Summary

The Krystallon Seawater Scrubber eliminates SOx, significantly reduces particulates including volatile contaminants in the emissions from a diesel engine and by doing so tends to limit the formation of secondary pollutants. Reducing the concentration of volatiles in the emission essentially has the same impact as reducing NOx.

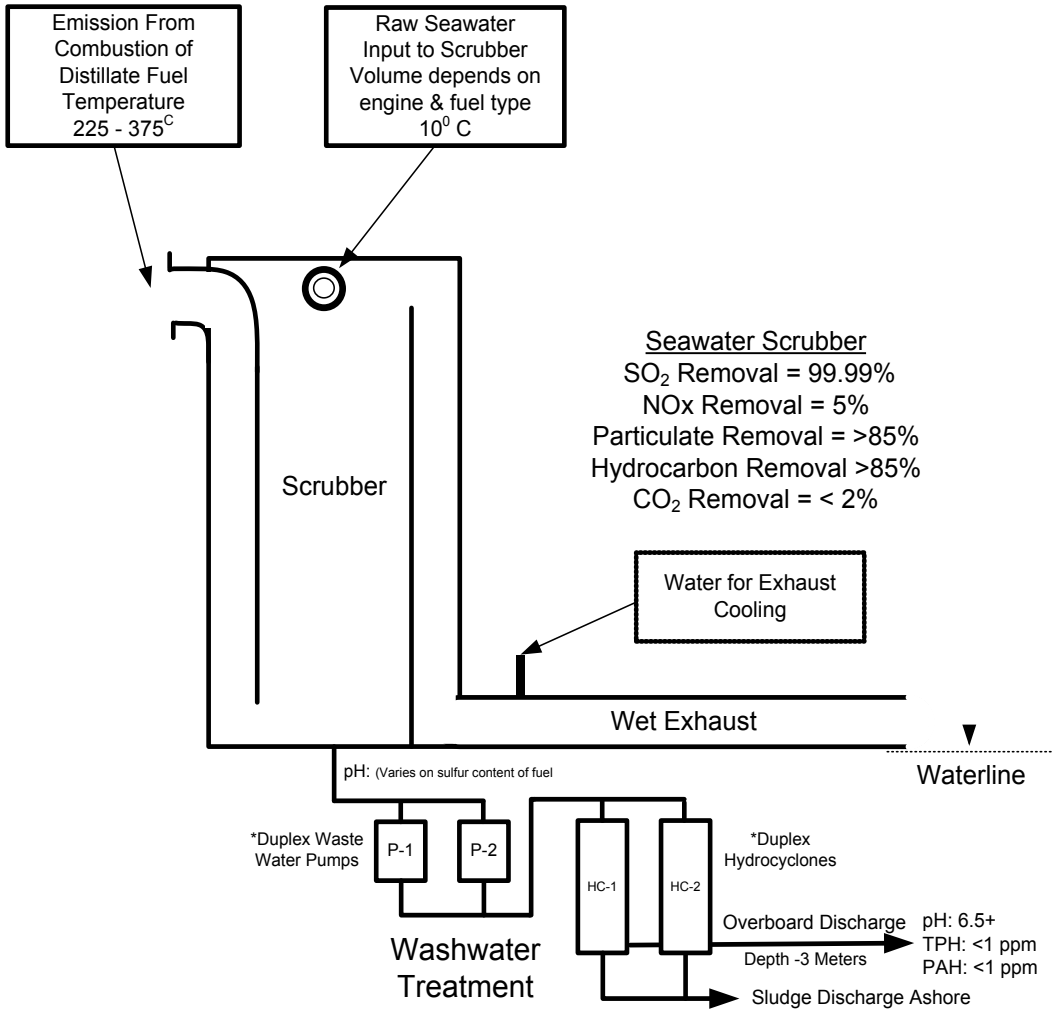
NOx is regulated primarilarly as a means of limiting the formation of certain secondary pollutants and the potential for ground level ozone formation which causes smog. Ozone itself is a health hazard as well as a primary constituent of photochemical smog. NOx contributes to ozone formation when hydrocarbons, also referred to as volatile organic compounds (VOC's) in an emission, or from other sources in the surrounding atmosphere, chemically react in the presence of sunlight and warm atmospheric conditions. However, it is well known that Ozone production is hydrocarbon limited meaning that it takes a certain concentration of hydrocarbons combined with NOx and sunlight for the reaction to take place. The very low concentration of hydrocarbons emitted from a diesel engine with a scrubber in effect, caps the potential for ozone formation from the emission.

The Krystallon scrubber removes up to 85% of all forms of particulates in an emission along with a similar percentage of hydrocarbons. Unlike vehicles, vessels travel where there are few other sources of hydrocarbons so a vessel equipped with a scrubber produces very low potential to generate ozone and other secondary pollutants such as sulfates (SO_4). Therefore, removing hydrocarbons from a marine diesel emission has essentially the same effect as an equivalent reduction of NOx.

The relationship between hydrocarbons and NOx is extremely well documented, and in fact is the basis for regulatory programs to reduce fugitive hydrocarbons as a means of reducing the potential for forming ozone and photochemical smog.

Post Combustion Diesel Exhaust Treatment for Workboats

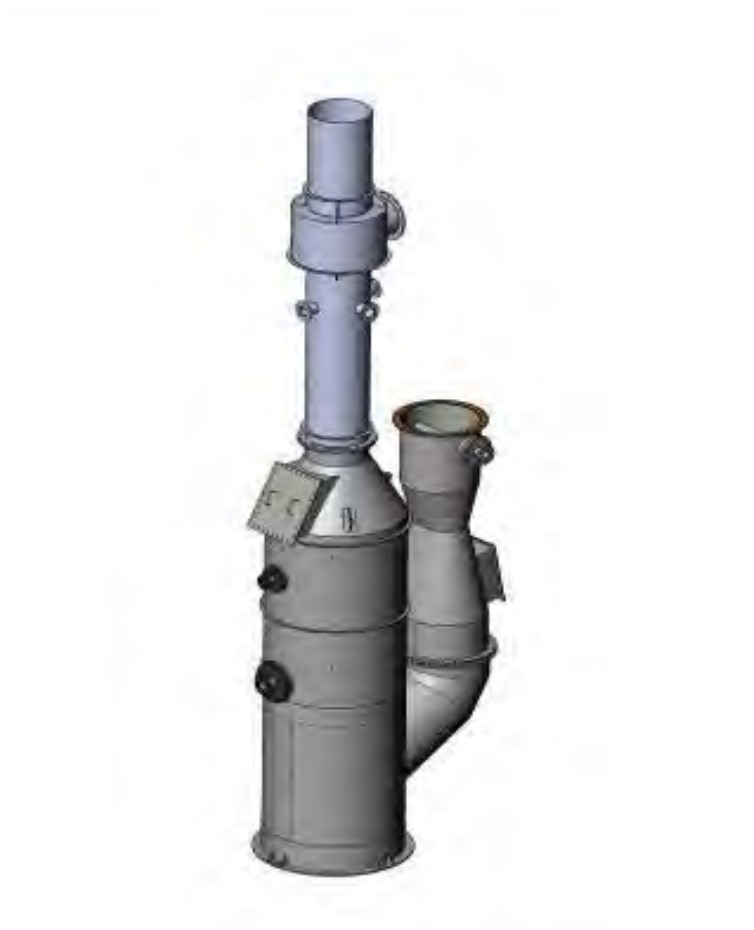
(Draft Concept)



* Requires Titanium Housing and Impeller

Pantheon Group, Seattle

Rendering of a typical 2-4 MW unit



Krystallon Seawater Scrubber

Retrofit Concept for Auxiliary Engines and Boilers on a 5000 TEU Container Ship

- One, 4 MW Seawater Scrubber sized for concurrent operation of one (1) auxiliary engine and one (1) steam boiler; exhaust ductwork will allow emissions from all auxiliary engines and boilers to be routed through the scrubber. Approximate price: $875,000

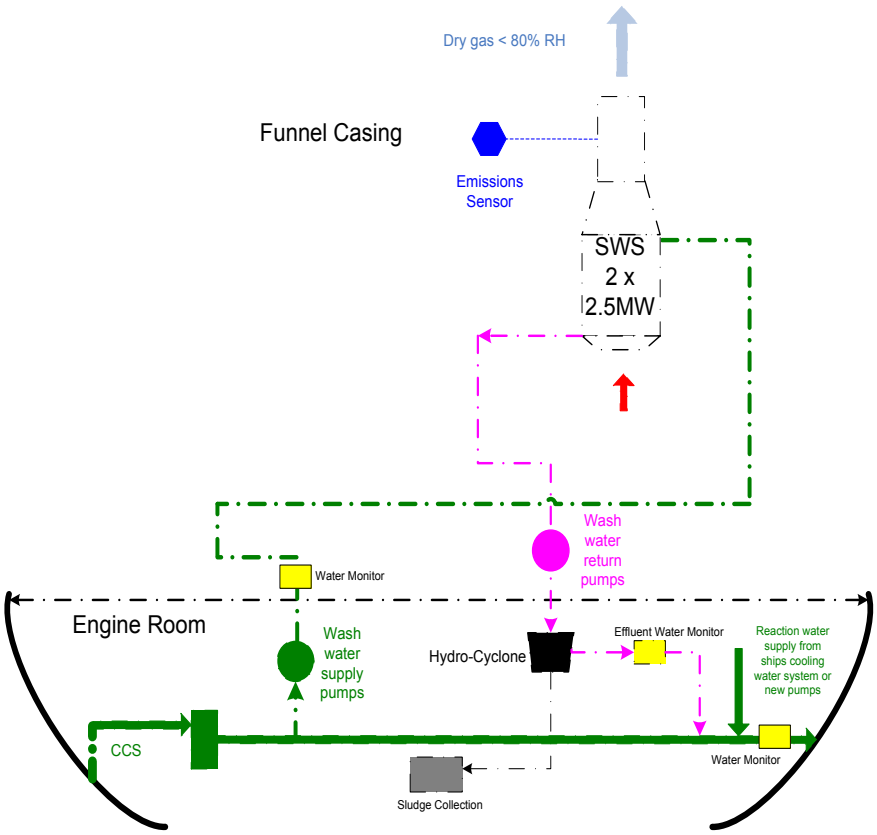
  Engines: (2) MAN B&W Model 872738, 2500 kW AC diesel generators operating at 85% MCO

  Boiler: (1) 750 HP steam boiler

Krystallon seawater scrubbers meet all IMO Annex VI standards: “an approved after-treatment exhaust gas cleaning system must limit Sulphur Dioxide (SOx) emissions to 6.0g SOx per kilowatt hour (kWh)”. The SOx emission from the Krystallon scrubber is 0.10g/kWh, (<10 ppm).

PM is reduced to < 0.12g/kWh (particulates, VOC’s, PAH’s).

Machinery Layout Schematic



Full instrumentation providing essential information and audit trail on the vessel*

Continuous Emissions Monitoring: Date/time, engine power, sulfur dioxide (SOx), particulate matter (PM) carbon dioxide (CO_2), nitrogen oxide (NO) and nitrogen dioxide (NO_2) are measured and recorded in a database on the vessel.

Washwater Monitoring: Incoming seawater water is continuously monitored for turbidity and oil content; effluent is monitored for flow, hydrocarbons (including PAH's), turbidity, pH, temperature, and dissolved oxygen. The treated washwater is mixed with additional seawater (cooling water) to raise pH to near neutral prior to overboard discharge.

Solids Disposal: Recovered solids are tested for pH, petroleum hydrocarbons and metals to characterize the sludge for proper disposal ashore. The sludge is collected in an Intermediate Bulk Container (IBC) for offloading several times per year.

*Data can also be transmitted ashore

Typical IBC used to store solids on-board