ECA Compliance & PM

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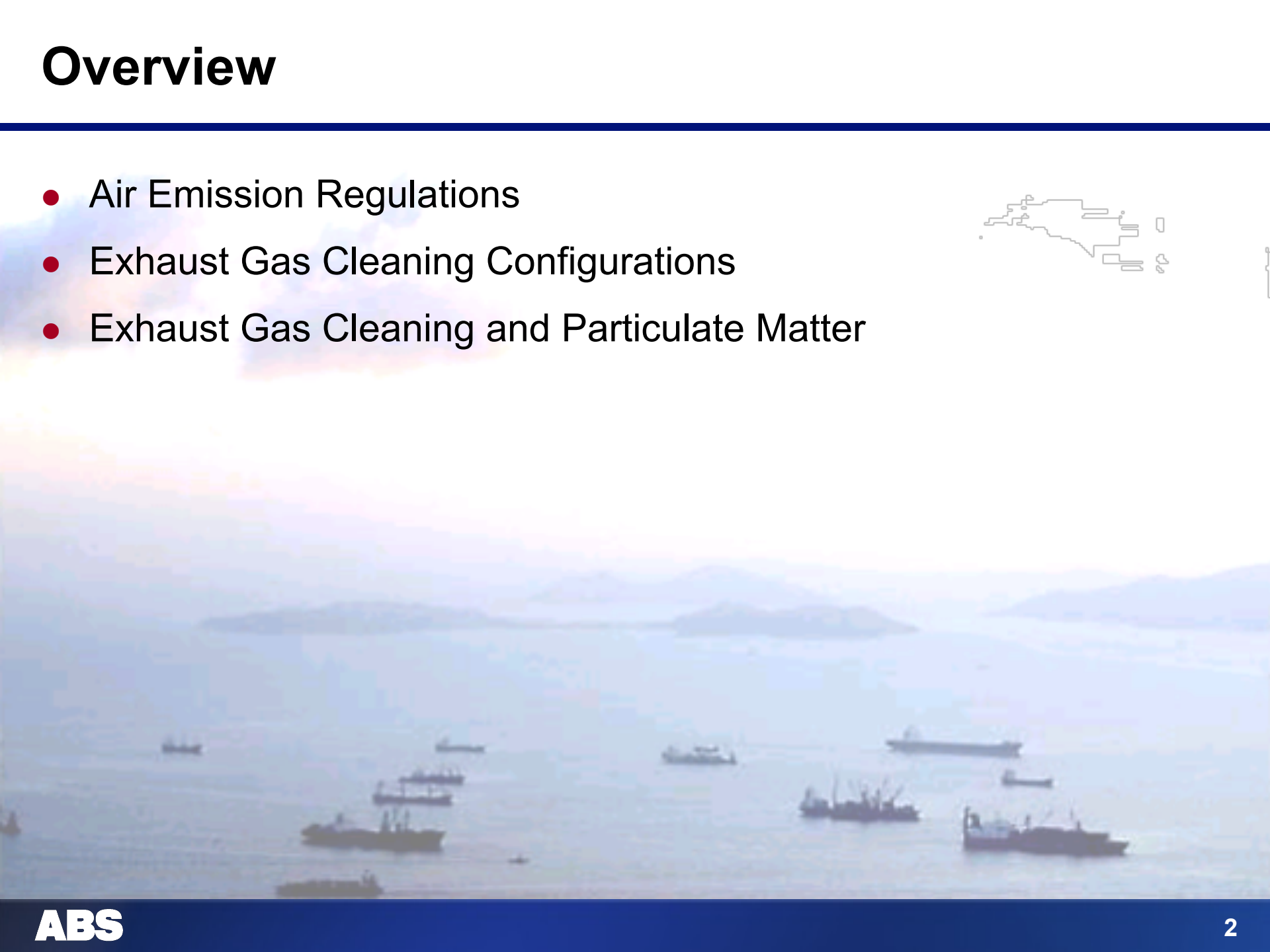
Overview

- Air Emission Regulations
- Exhaust Gas Cleaning Configurations
- Exhaust Gas Cleaning and Particulate Matter



MARPOL Annex VI: Sulfur Content Limits

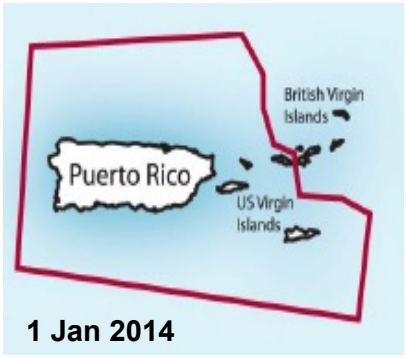
	Global Excluding SECAs & ECAs (1 January)		SOx Emission Control Area		Emission Control Area (SOx and NOx)		
			Baltic & North Sea		USA Canada	USA Caribbean	USA Canada Caribbean
Compliance Date	≥ 2012	≥ 2020/25*	≥1 July 2010	≥1 Jan 2015	≥1 Aug 2012	≥1 Jan 2014	≥1 Jan 2015
Limit (mm)	3.5% +	0.5% +	1.0% +	0.10%+	1.0% +		0.10% +

*** Note: Effective year (2020 or 2025) will be decided by 2018**

+ Note: Alternative technology acceptable (e.g., Exhaust Gas Cleaning Systems

USA/Canada ECA – 200nmi

USA/Caribbean ECA



MARPOL Annex VI: Adopted NOx Limits

Ship Constructed (≥1 January)	Application of Requirements	Emission Limits	Compliance at engine's delivery except as below
1990 to 2000 *Retroactive to existing engines*	Engine size > 5000 kW and ≥ 90 liters / cylinder	**Tier I**	1st IAPP Renewal Survey ≥ 12 mo after IMO advised by Party of availability (physical and cost) of "*upgrade kit*"
2000 ≤ x <2011	Engine > 130 kW		Operation outside and within of ECA
2011 ≤ x <2016		**Tier II**	
≥ 2016			Operation outside of ECA
≥ 2016 3 exceptions *		**Tier III**	Operation within ECA

* ***L<24m if used for recreational purposes;***
total propulsion <750kW if unable to achieve due to design limitations;
purely recreational ships constructed prior to 1 January 2021 less than 500 GT and L ≥ 24 m.

RPM	NOx calculated as total weighted emission of NO_2 (g/kWh)			Relative Reduction from Tier I
	< 130	130 ≤ n < 2000	≥ 2000	
Tier I	17.0	$45*n^{(-0.2)}$	9.8	---
Tier II	14.4	$44*n^{(-0.23)}$	7.7	15.5% - 21.8%
Tier III	3.4	$9*n^{(-0.2)}$	2.0	80%

MARPOL VI: Exhaust Gas Cleaning (SOx)

- Res. MEPC.184(59) 2009 Guidelines for Exhaust Gas Cleaning Systems
  - Recommendatory
  - To be applied from 1 July 2010
  - Revokes MEPC.170(57)
  - Apply to any EGC unit as fitted to fuel oil combustion machinery, excluding shipboard incinerators, installed on board a ship
  - Required for testing, survey, certification and verification of EGC system
  - 2 schemes:
    - Scheme A – unit certification with parameter and emission checks
    - Scheme B – continuous emission monitoring with emission checks
- Approved SOx Emissions Compliance Plan (SECP)

MARPOL Annex VI: SOx Guidelines

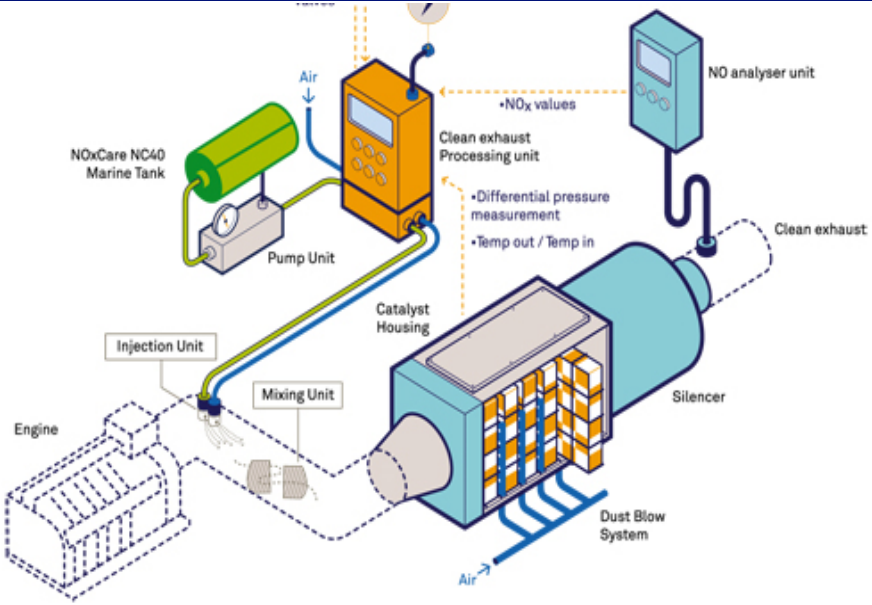
- MEPC.184(59) adopted 17 July 2009
- Original EGCS SOx limited to 6.0g/kWh
- Equivalence verified by SO_2/CO_2 ratio
  - 3.5% Sulfur Content Oil → Meet Global Level after 2020 (0.5% Sulfur Content Oil) 1 -21.7/151.7 = 0.857, 85.7% Sulfur Abatement Required
  - 3.5% Sulfur Content Oil → Meet ECA Revel after Jan. 2015 (0.1% Sulfur Content Oil) 1 – 4.3/151.7 = 0.972, 97.2% Sulfur Abatement Required

Fuel Oil Sulphur Content (%m/m)	Ratio Emission SO_2(ppm)/ CO_2(%v/v)
4.50	195.0
3.50	151.7
1.50	65.0
1.00	43.3
0.50	21.7
0.10	4.3

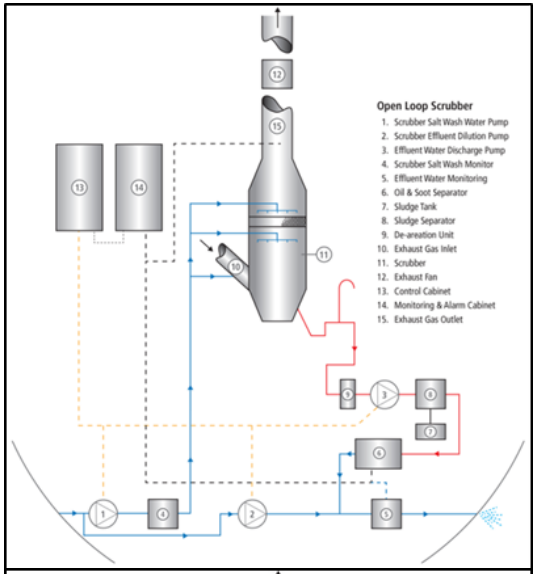
Note: The use of the Ratio Emissions limits is only applicable when using petroleum based Distillate or Residual Fuel Oils.

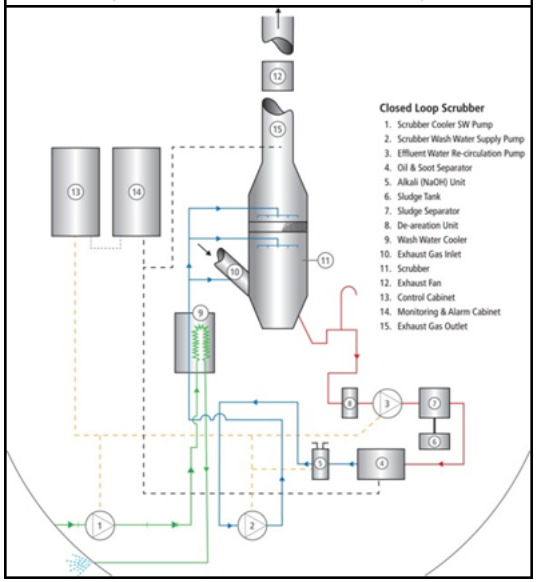
MARPOL Annex VI: Complying with Emissions Limits

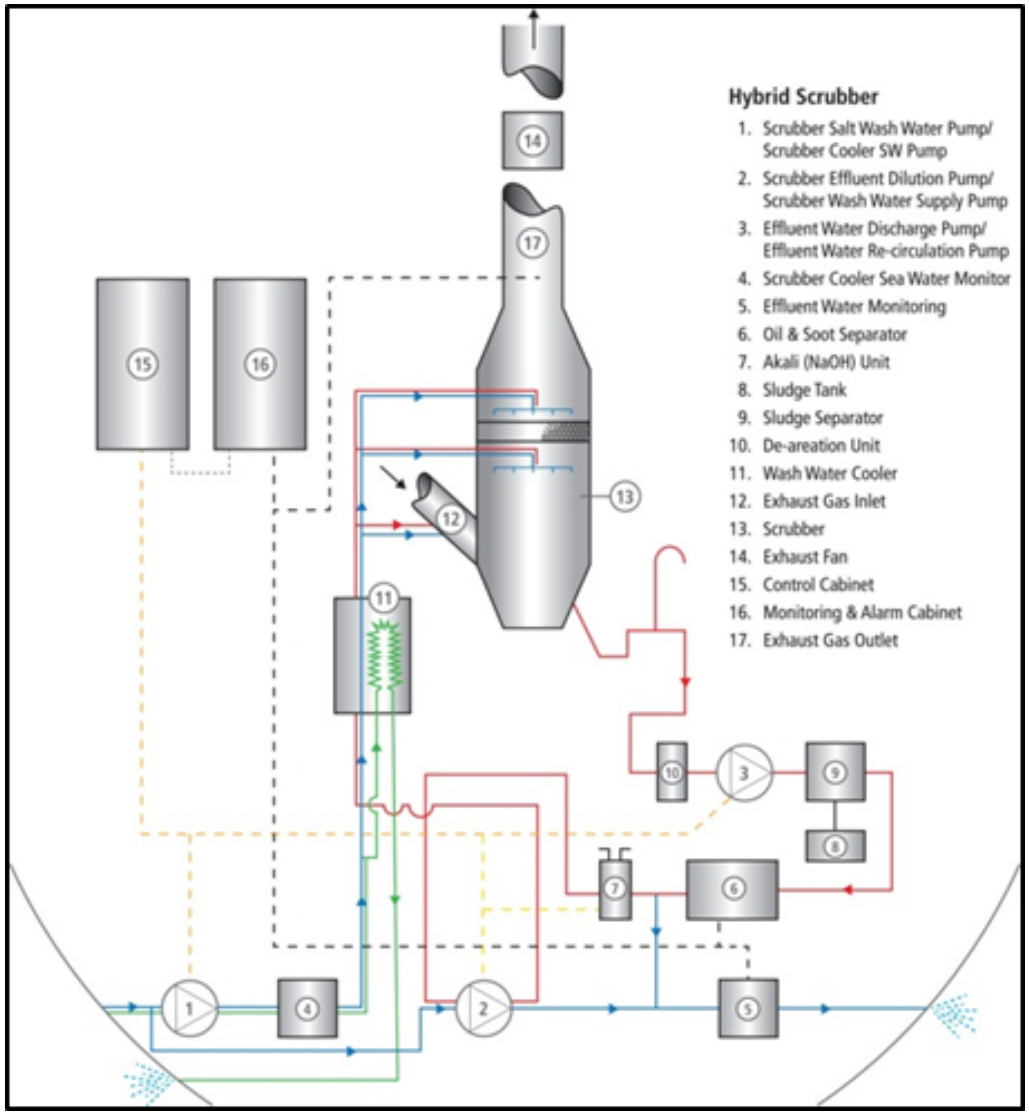
- SOx emission reduction
  - Exhaust Gas Cleaning (Scrubbing) (90-99% reduction)
  - Switch from HFO to MDO (40% reduction w/1.5% MDO) (80% reduction w/0.5% MDO)
- NOx emission reduction technologies
  - Internal Engine Modifications (30-70% reduction)
  - Water Injection/Humid Air Engine (65-85% reduction)
  - Exhaust Gas Recirculation (30-70% reduction)
  - Selective Catalytic Reduction, SCR (90-95% reduction)



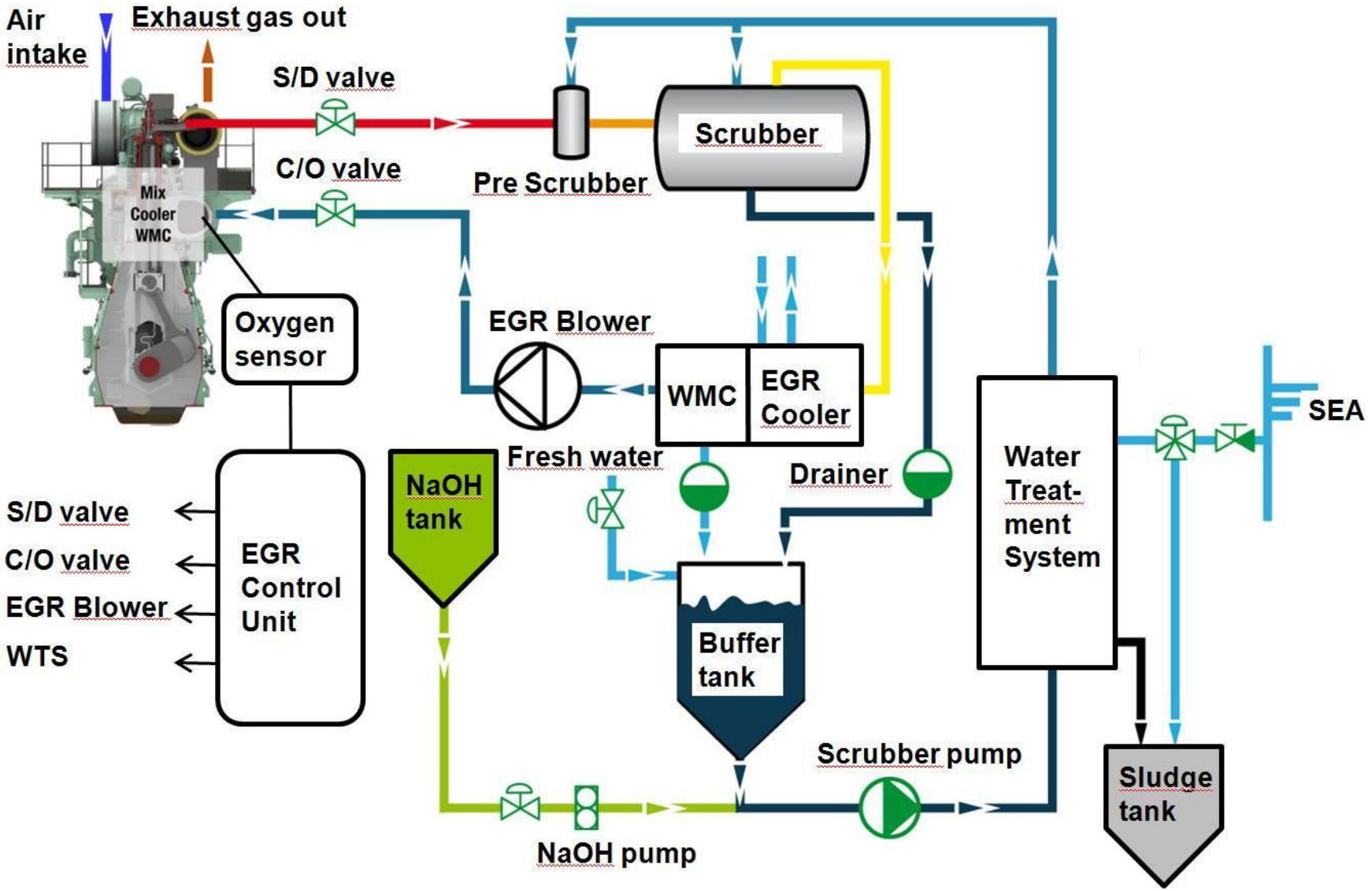
Scrubber Configurations







Exhaust Gas Recirculation



Exhaust Gas Cleaning & PM

- "Our patented EDV® Wet Gas Scrubbing Systems can achieve very high levels of control on pollutants, including, acid gases, fine particulate, and heavy metals."
  – **DuPont™ BELCO® Marine Systems for Ship Exhaust Gas Cleaning**
- "We offer systematic adjustments to improve the capture of PM from the exhaust."
  – **Wärtsilä Hybrid Scrubber System**
- "Particulate matter (PM) trapping up to 80%" – **Alfa Laval's PureSOx**
- "By reduction of particulate matter (PM) in the early stage of exhaust gas purification all successive components benefit from significantly lowered PM contamination."
  – **SAACKE Exhaust Gas Scrubber**
- "Recognizing that the IMO sulfur requirement reflects a demand to minimize human exposure to harmful Particulate Matter (PM), a unique PM trapping feature surpassing the present sulfur requirement has been incorporated into our product."
  – **Clean Marine EGCS**
- "Our specialists are solving this problem with an exhaust gas scrubber, the first stage of the complex recirculation system. It cleans the exhaust gas to remove sulphur and particles." – **MAN Exhaust Gas Recirculation (EGR)**

Methodology for Verification of PM Reduction

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