Hitachi Zosen
Technology and Business Innovator

Effect of SOx and NOx Regulation Implementation, ECA’s and NOx Tier III Current Developments in General

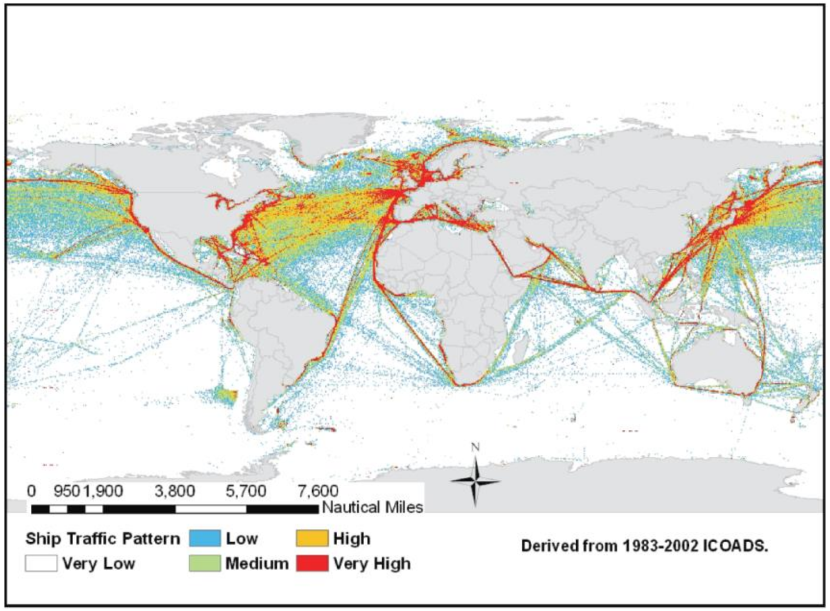
ASEF 2013, KOBE, November 6, 2013

Toru Nakao
Hitachi Zosen Corporation, Japan

ECA status

Emission Control Areas

- **High traffic areas**



- **Map – ECAs fixed**

Source: "Understanding exhaust gas treatment systems", LRS

- **ECAs fixed (existing and coming)**

ECA (Annex VI: Prevention of air pollution by ships)	In Effect From
Baltic Sea (SOx)	**19 May 2006**
North Sea (SOx)	**22 Nov 2007**
North America (SOx and NOx)	**1 Aug 2012 (NOx from 2016)**
United States Caribbean Sea ECA (SOx and NOx)	**1 Jan 2014 (NOx from 2016)**

SOx

SOx regulation

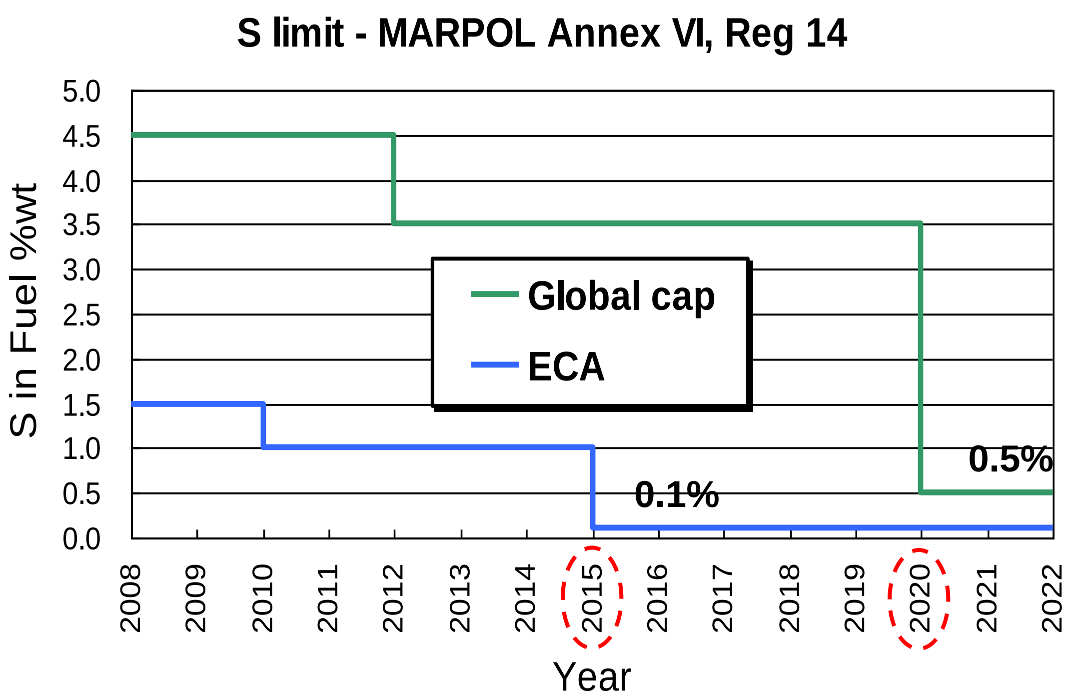
Hitz Hitachi Zosen

Regulation 14 of MARPOL Annex VI

Sulfur content limit in Fuel

- 0.5%wt Globally, 2020*

  ** Availability of low S fuel will be reviewed by 2018. (If postponed, 2025.)*
- 0.1%wt in ECA, 2015



- ✓ ***Applied to both new and existing ships***
- ✓ ***High degree of reduction***
- ✓ ***Maker to develop technology***
- ✓ ***Shipowner to make decision***

Solutions for SOx regulation

What solutions are applicable?

Use of Low Sulfur Fuel

- **CAPEX is negligible**, but **OPEX will increase** considerably.
- Availability of such low sulfur bunker fuels - if **refinery industry** will be prepared?
- **Poor ignition?** – may damage combustion chamber

SOx Scrubber

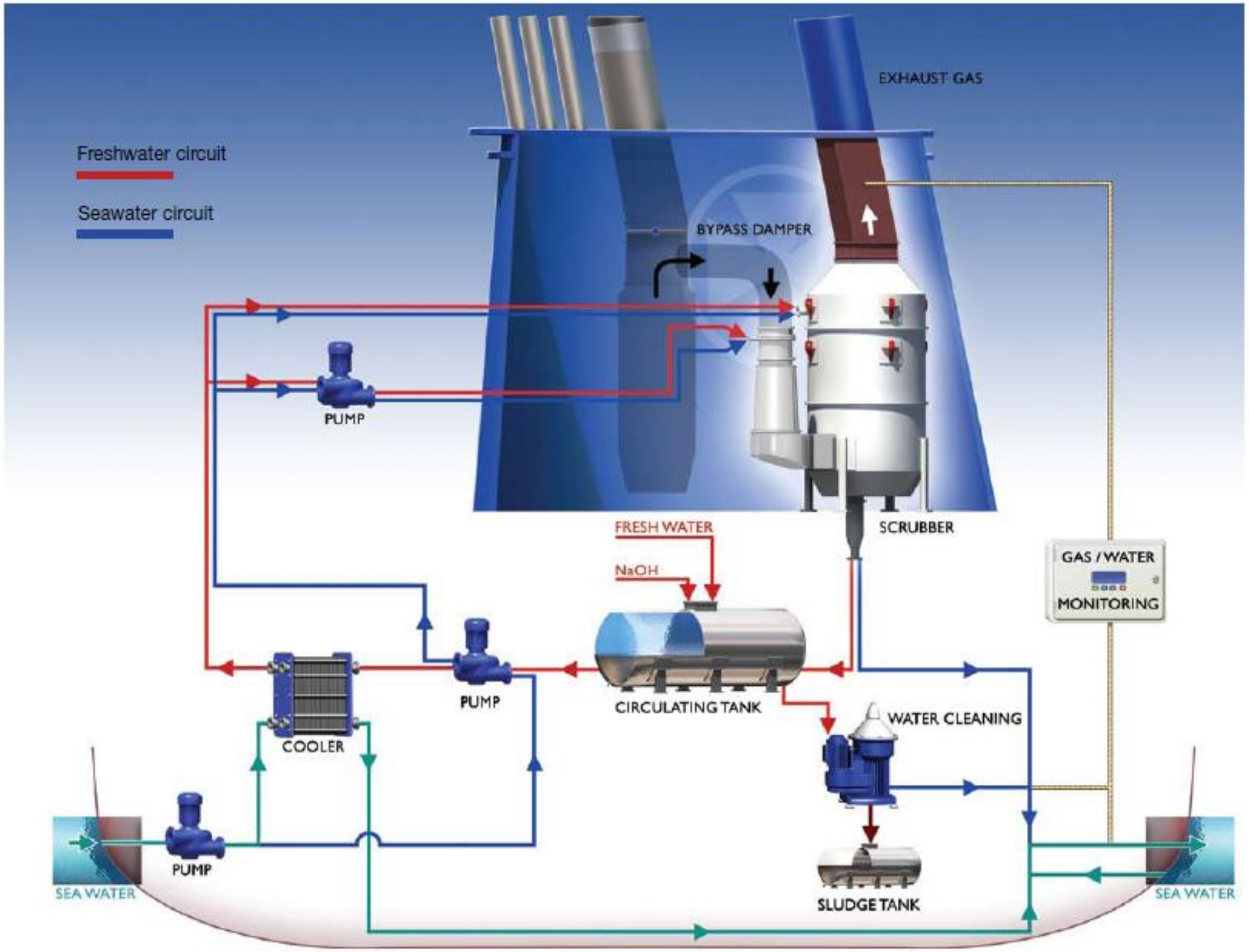
- Enables the existing propulsion system burning **high sulfur heavy fuel oil.**
- Manufacturers claim that **payback time** of SOx scrubber installation will be **a few years** and that the ship operators will obtain economical advantages against use of low sulfur fuels.
- **Turbine back pressure** acceptable?

LNG-fuelled Vessels

- **No SOx** emission and **less CO_2/NOx** emission.
- **Design** standards of vessels?
- **Infrastructure** and supply-chain?
- **Building cost** increase and **safe** operation of LNG-fuelled vessels?
- LNG fuel **price in future?**

Wet SOx Scrubbers

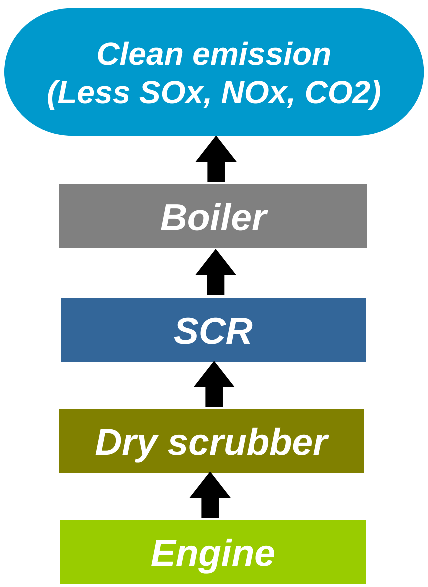
- **Open-loop type**
  - Operated by **seawater**
- **Closed-loop type**
  - Operated by circulating **fresh water added with NaOH**
  - Essential in low alkalinity waters such as inland rivers.
- **Hybrid type**
  - Possible in **either mode** of open-loop or closed-loop.

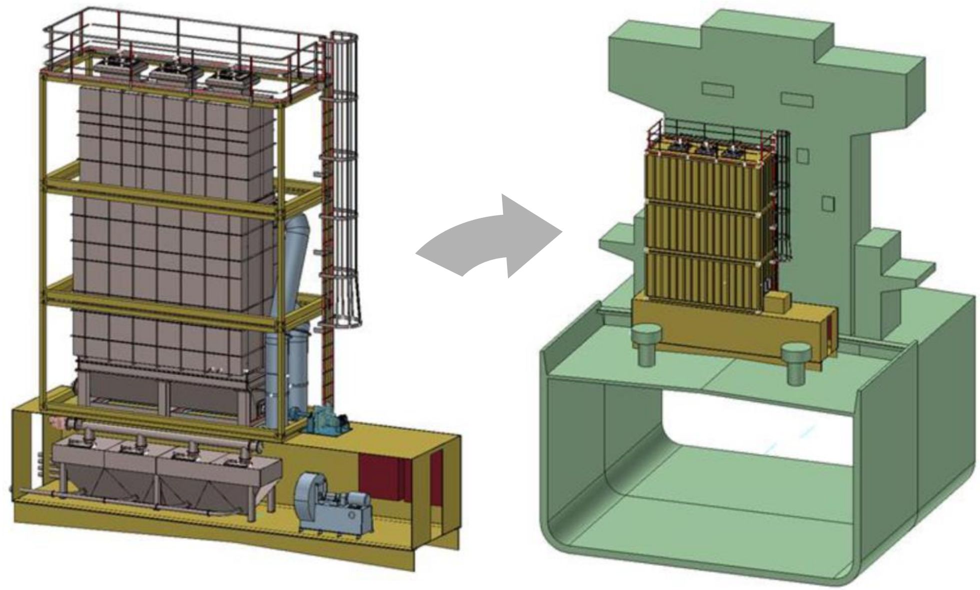


Typical configuration of EGCS with "Hybrid" wet scrubber
Source: Alfa Laval's PureSOx catalogue

Dry SOx Scrubber

- uses dry chemical such as **$Ca(OH)_2$**
- Hot process, i.e. **Large system**
- Good combination with **SCR**



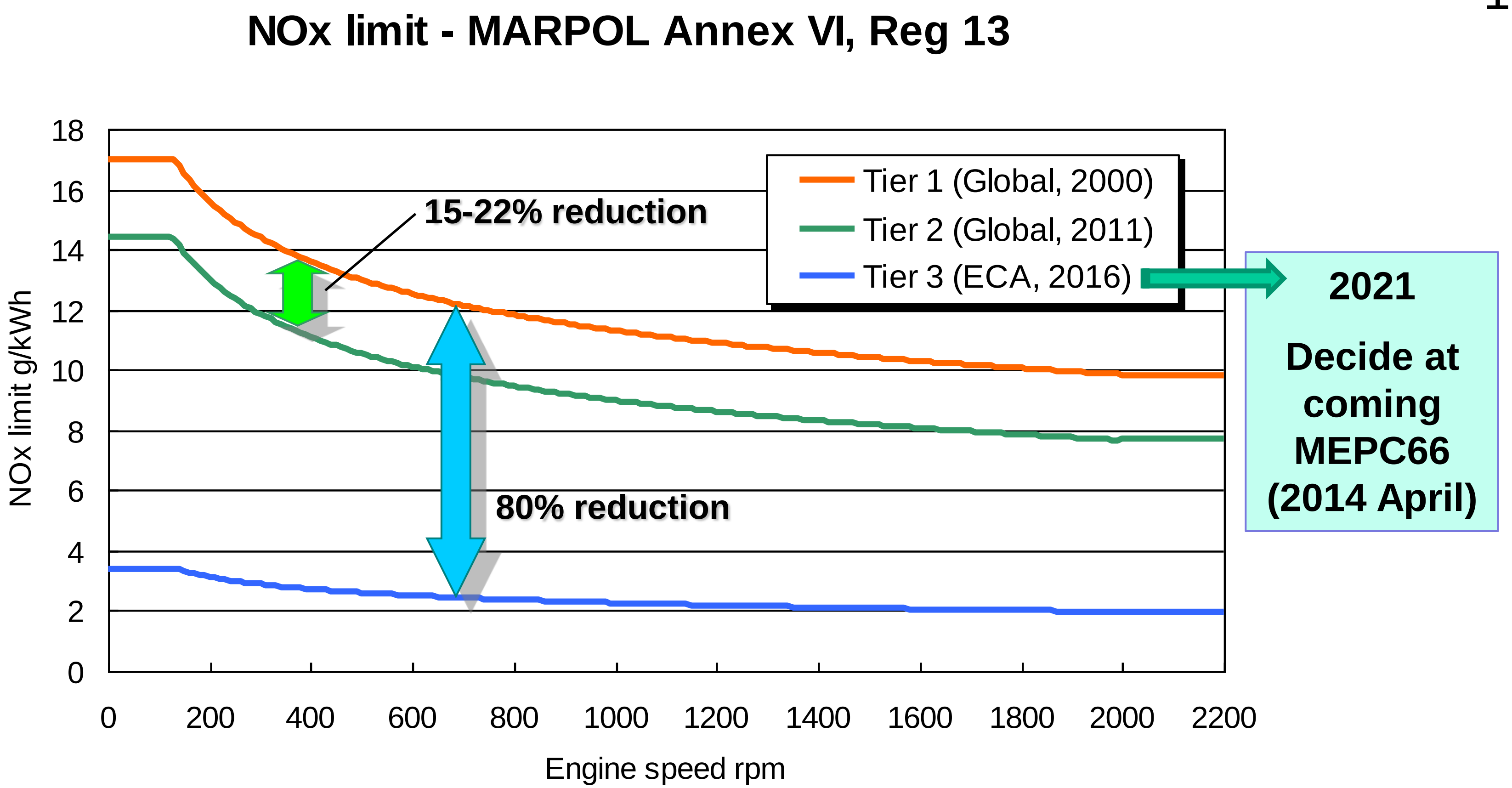


Source: 'De-SOx via Scrubbers - An Overview' by EGCSA at SAE 2012, Emission Control from Large Ships

Source: 'Reederei Rord Braren, Kollmar, Germany' by Reederei Rord Braren at SAE 2012, Emission Control from Large Ships

NOx

IMO NOx Regulation Tier III



- Tier 1: Low NOx atomizer, injection retard,,,
- Tier 2: Miller cycle,,,
- Tier 3: ***???*** *(Existing engine technology **not enough**)*

Consider other requirements

- Besides NOx, consider also...

EEDI (less CO2, i.e. less FOC)

Fuel flexibility (High S with SOx scrubber)

Cost (CAPEX and OPEX)

Less space

Availability of consumables

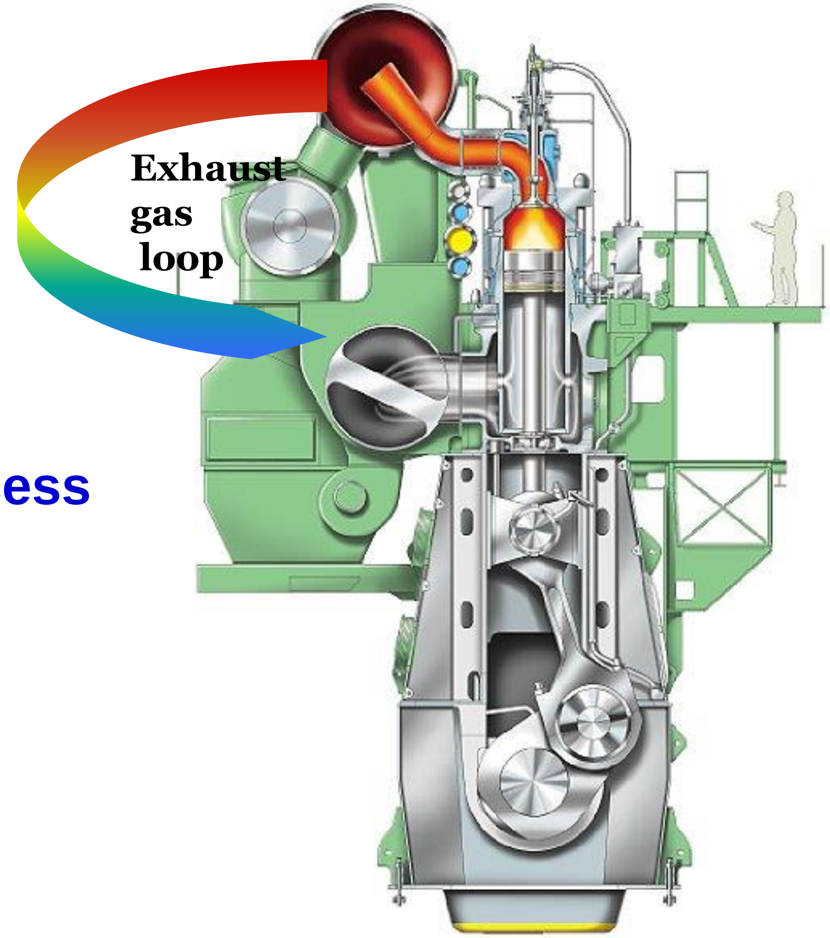
What is used for aux. engines?

EGR

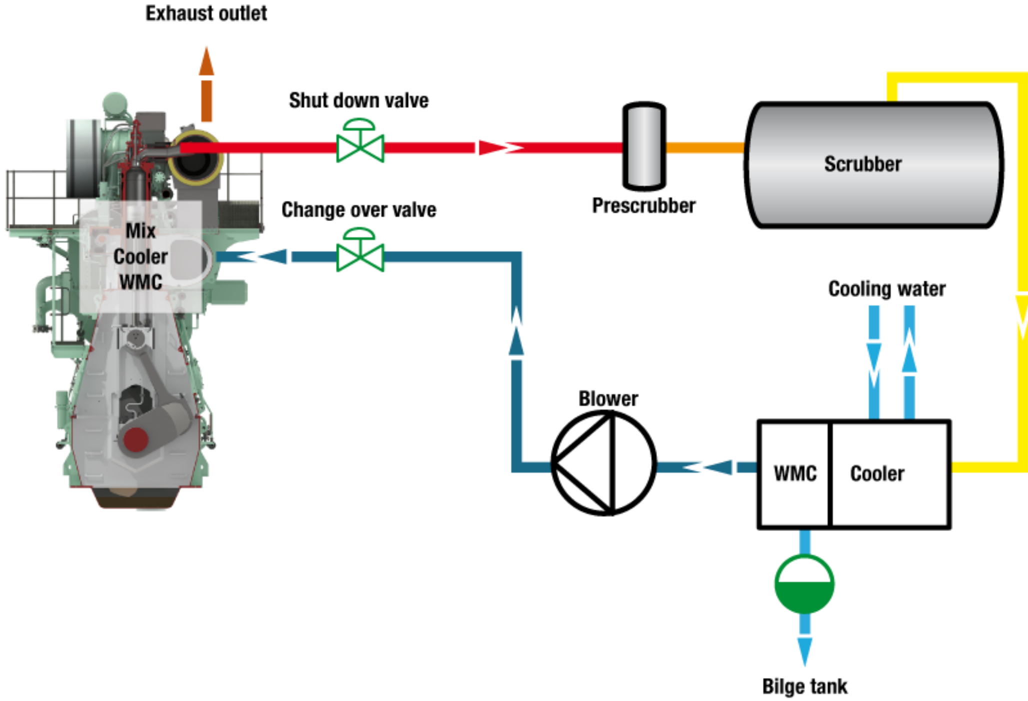
Exhaust Gas Recirculation

What is EGR?

- Recirculating a part of exh. gas as scav. air
  - More CO2 - higher specific heat capacity
  - Less O2 - slower combustion
  - Lower combustion temperature - less NOx
- A method **related with combustion process**

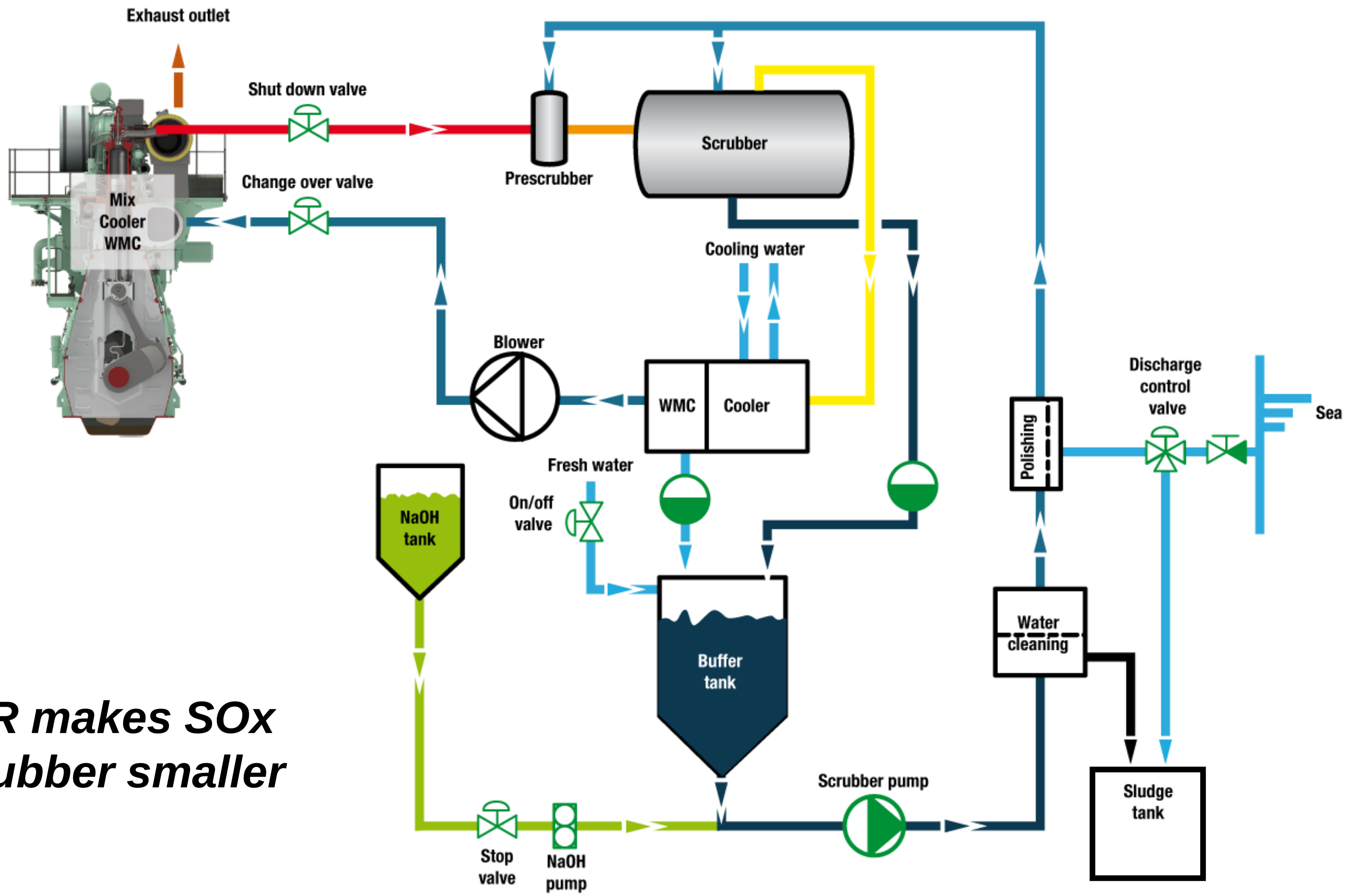


EGR system layout



Source: MDT

EGR system layout with auxiliary systems



- ✓ ***EGR makes SOx scrubber smaller***

Source: MDT

Tier III operation cost of 4T50ME-X with EGR1 - MDT

What does it cost:

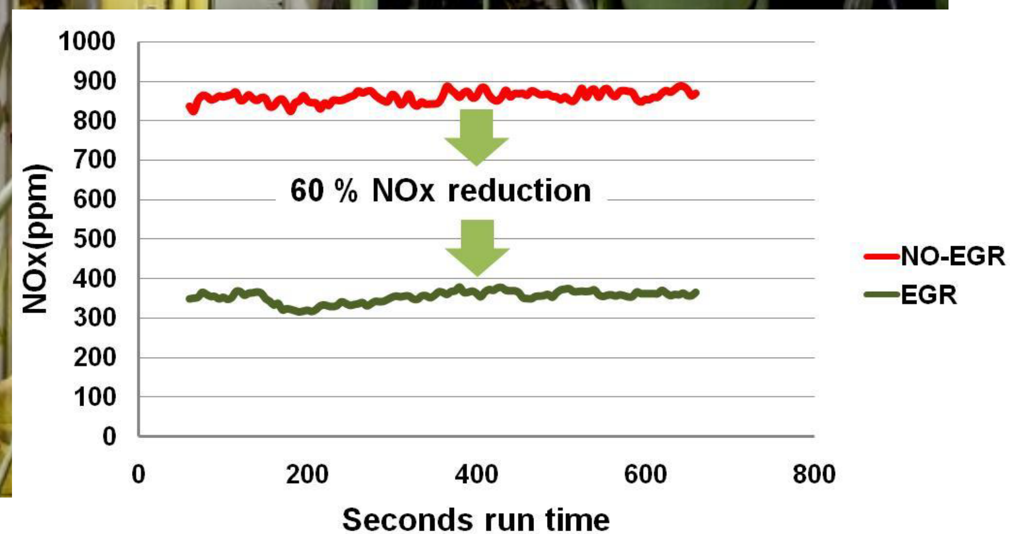
SFOC penalty:	0.5 – 1.0 % (+2 g/kWh for S80ME-C-EGR2) with fuel-saving measures
Additionally aux. power:	1.0 – 1.5 % of M/E power
NaOH consumption:	5 l/MWh (3%S, 50% solution)

Source: MDT

EGR Service Test on Alexander Maersk

7S50MC-C with 3% sulphur HFO

Currently more than 2000 running hours with EGR in operation is achieved and the crew onboard is operating the EGR system.



Service Experience 6S80ME-C9.2 EGR

- EGR shop test October 2012
- EGR test run on Sea-trial January 2013
- EGR Commissioning trial Marts 2013
- Approximately 700 EGR operational hours
- Only minor problem experienced
- Operated by Crew
- No influence on engine components

SCR

Selective Catalytic Reduction

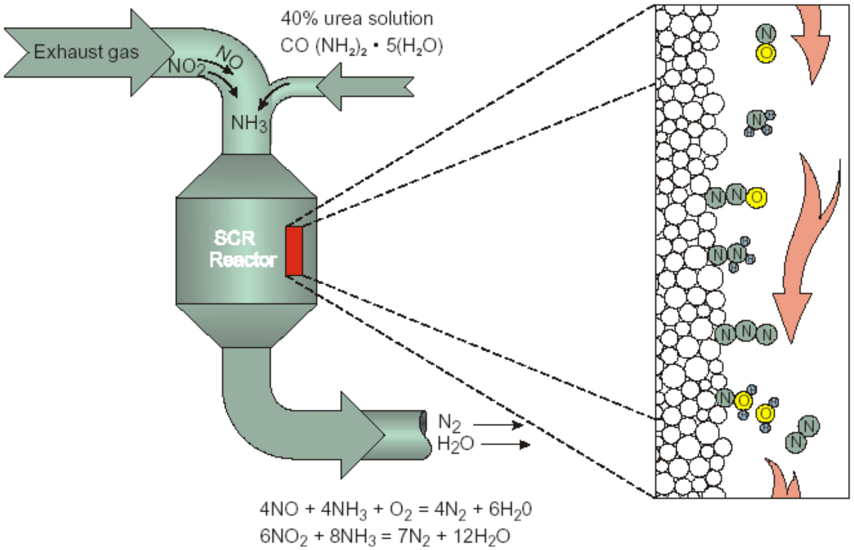
What is SCR?

- A **conventional/proven** method for stationary plants
- More than **90%** NOx reduction possible
- Not conventional for ships, especially for 2-strokes

- **After-treatment**, regardless of combustion process
  i.e. **free from 'Diesel Dilemma'**

- NOx --> **nitrogen and water**:
  - 4NO + 4NH3 + O2 --> 4N2 + 6H2O (Major)
  - 6NO2 + 8NH3 --> 7N2 + 12H2O (Minor)
  - NO + NO2 + 2NH3 --> 2N2 + 3H2O (Fast)

- **Urea** as reducing agent
  - (NH2)2CO --> NH3 + HCNO
  - HCNO + H2O --> NH3 + CO2



Hitz
Hitachi Zosen

FAQ: "SCR before or after?"

SCR after turbine 'Low Press SCR'	SCR before turbine 'High Press SCR'
Low pressure	**High pressure**
	● More active --> Compact
Low temp	**High temp**
● Gas temp: 210 - 280 degC ● SCR needs: 300 - 350 degC Heat up with burner	● Gas temp: 290 - 430 degC --> No heating, low CO_2

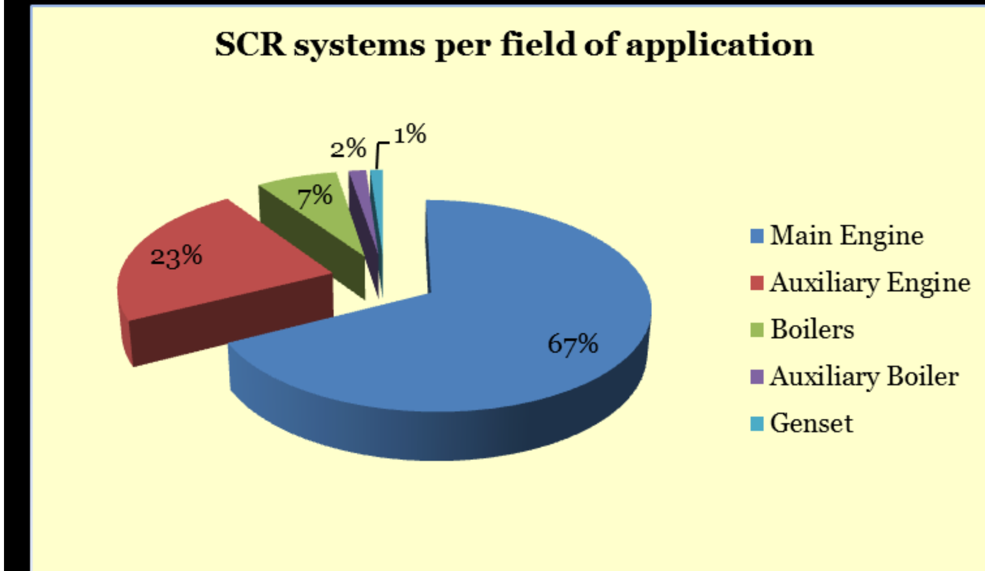
e.g. Burner = 100 C x 1 kJ/kg K x 10 kg/kWh / 42700 kJ/kg = 23 g/kWh !?

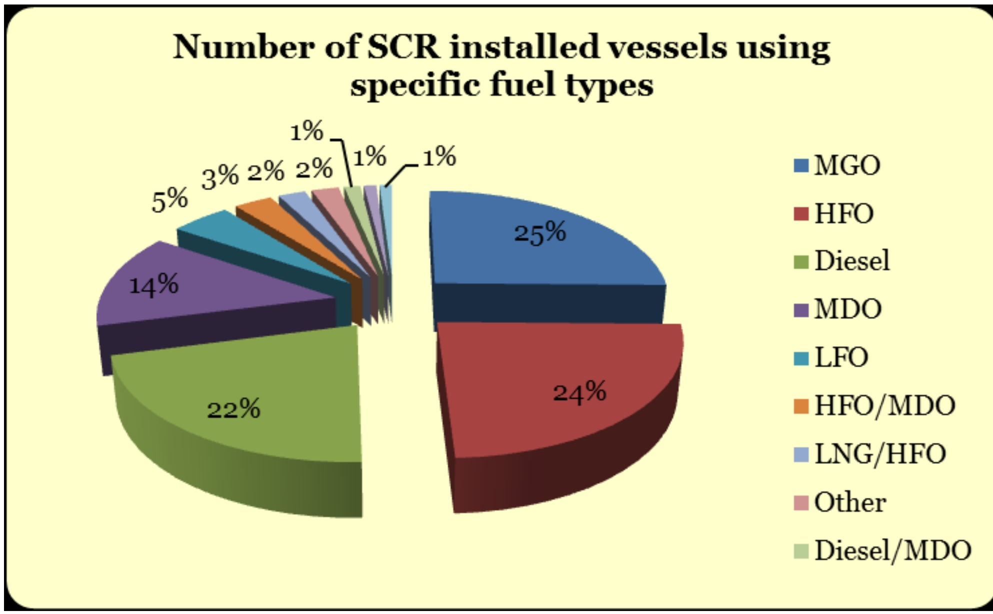
IACCSEA Database – Analysis

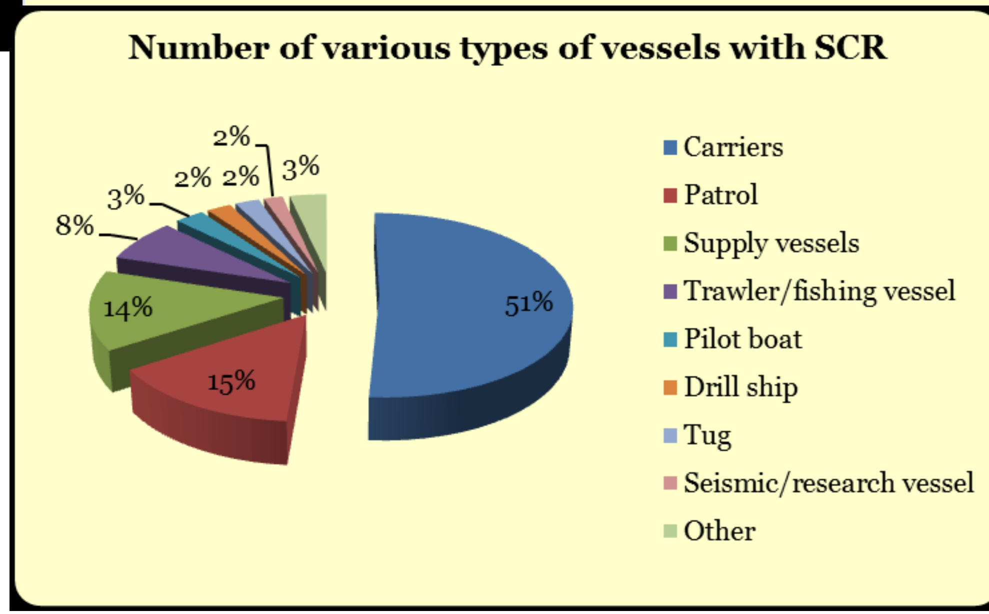
#	Ship Owner Operator	Ship Name	Ship Type	Fuel	Engine Model	Engine power (per engine)	NOx Redux Tech	Date of installation	Field of Application	Engine Manufacturer
1	HH-Ferries A/S	Mercandia VIII	RoPax		NTA-855-G2	295	SCR	1987		Cummins
2	USS-POSCO	M/V Pacific Success	Cargo		2stroke	7.9	SCR	1989	Main	
3	USS-POSCO	M/V Pittsburg	Cargo		2stroke	7.9	SCR	1989	Main	
4	HH-Ferries	Mervandia IV	RoPax		NTA-855-G2	295	SCR	1989		Cummins
5	Scandinavian Ferry Line	Aurora	Ferry Line	Diesel			SCR	1991		Wärtsilä
6	Scandinavian Ferry Line			Diesel			SCR, OXI	1991	Main engine	Wartsila
7	USS-POSCO	M/V Delta Pride	Cargo		2stroke	7.9	SCR	1991	Main	
8	USS-POSCO	M/V New Horizon	Cargo		2stroke	7.9	SCR	1992	Main	
9		Aurora of Helsingborg	Passenger/Ferry	MDO	WV6R32		SCR, OXI	1992	NA	Wärtsilä
10	National Maritime Administra	Scandica	Supply/Ice Breaker	Diesel			SCR	1994		SAAB, Hedem.
11	National Maritime Administration (Sweden?)			Diesel			SCR, OXI	1994	Main and aux eng	2 SAAB, 1 Hedem
12	Silja Line	M/S Serenade	Ferry		4stroke	3	SCR	1994	Aux	
13	Silja Line									
14	UK Royal Navy									
15	Nils Dacke - TT-									
16	Great Lakes Dr Ok Brook									
17	Swedish Navy									
18	Stena Line									
19	AESA 78									
20	AESA 79									
21	Stena RoRo II									
22										
23										
24	Viking Line									
25	Fosen Trafikkla									

502	Atlantic Offshore (Sartor)	Ocean Responce	AHTS			1500	SCR	2012		Wartsila
503	Eggesbø JB	Eros	Fishing vessel		8M32C	4000	SCR	2012		Cat
504	Saevik K	Kings Bay	Fishing vessel		8M32C	4000	SCR	2012		Cat
505	Larvik Shipping	Yara Embla	General Cargo Ship		6M25	1900	SCR	2012		MAK
506	Larvik Shipping	Yara Froya	General Cargo Ship		6M25	1900	SCR	2012		MAK
507	Solvtrans rederi as	Sølvtrans	Boat)		C25:33A	1900	SCR	2012		BE
508	KBV (Swedish Coast Guard)	KBV 033	Patrol Vessel		16V2000M60	802	SCR	2012		MTU
509	KBV (Swedish Coast Guard)	KBV 034	Patrol Vessel		16V2000M60	802	SCR	2012		MTU
510	Island Offshore	Island Contender	PSV		C25:33L6P	2000	SCR	2012		BE
511	Island Offshore	Island Crusader	PSV		C25:33L6P	2000	SCR	2012		BE
512	Atlantic Offshore (Sartor)	Ocean Pride	PSV		3512C	1765	SCR	2012		Cat
513	Sjoborg Supply (PF Supply)	Torsborg	PSV		12V4000M33S	1560	SCR	2012		MTU
514	Hull 110	Vestland Mira	PSV		3512C	1800	SCR	2012		Cat
515	Administration	Utvær	Special purpose		3516TA	1900	SCR	2012		Cat
516	Fiskebas AS	Fiskebas	Fishing vessel		C25-33L9P	2880	SCR	2013		BE
517	Island Offshore	STX Brevik H-1796	PSV		C25:33L6P	2000	SCR	2013		BE
518	Troms Offshore	Troms Sirius	PSV		3512C	1800	SCR	2013		Cat
519	Administration	Skomvær	Special purpose		3516TA	1900	SCR	2013		Cat
520		[illegible]	Purse Seiner				SCR		Main engine	NA
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]			MTU
[illegible]		[illegible]	[illegible]				[illegible]			[illegible]
523	Royal Danish Navy		6 Patrol Vessels		2 x MTU 2040 kW	x 2040 kW				MTU
524		Carrier M/V Norholm		MGO - MDO		3606 - 2030 kW	SCR retrofit			Caterpillar

More than 520 vessels equiped with SCR

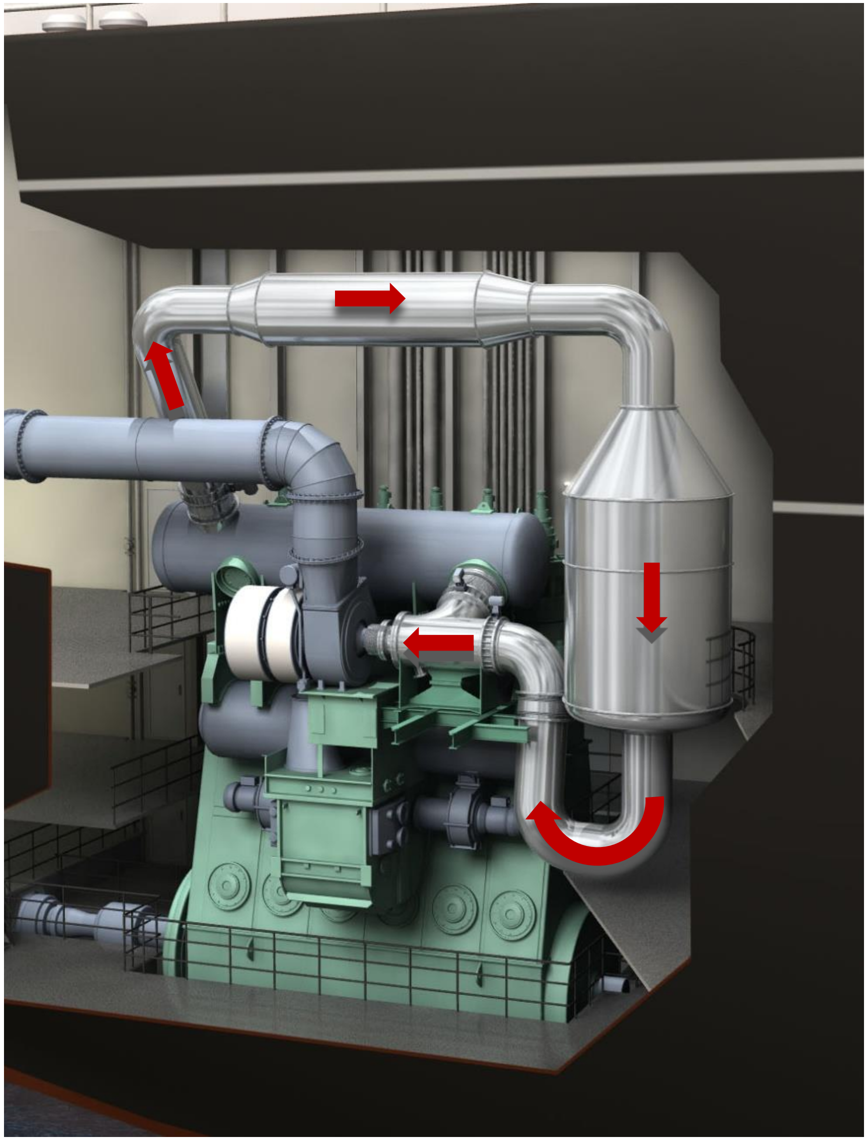






SCR-engine – SCR in use on 2 stroke engine

- **Exhaust gas flows to the SCR reactor**



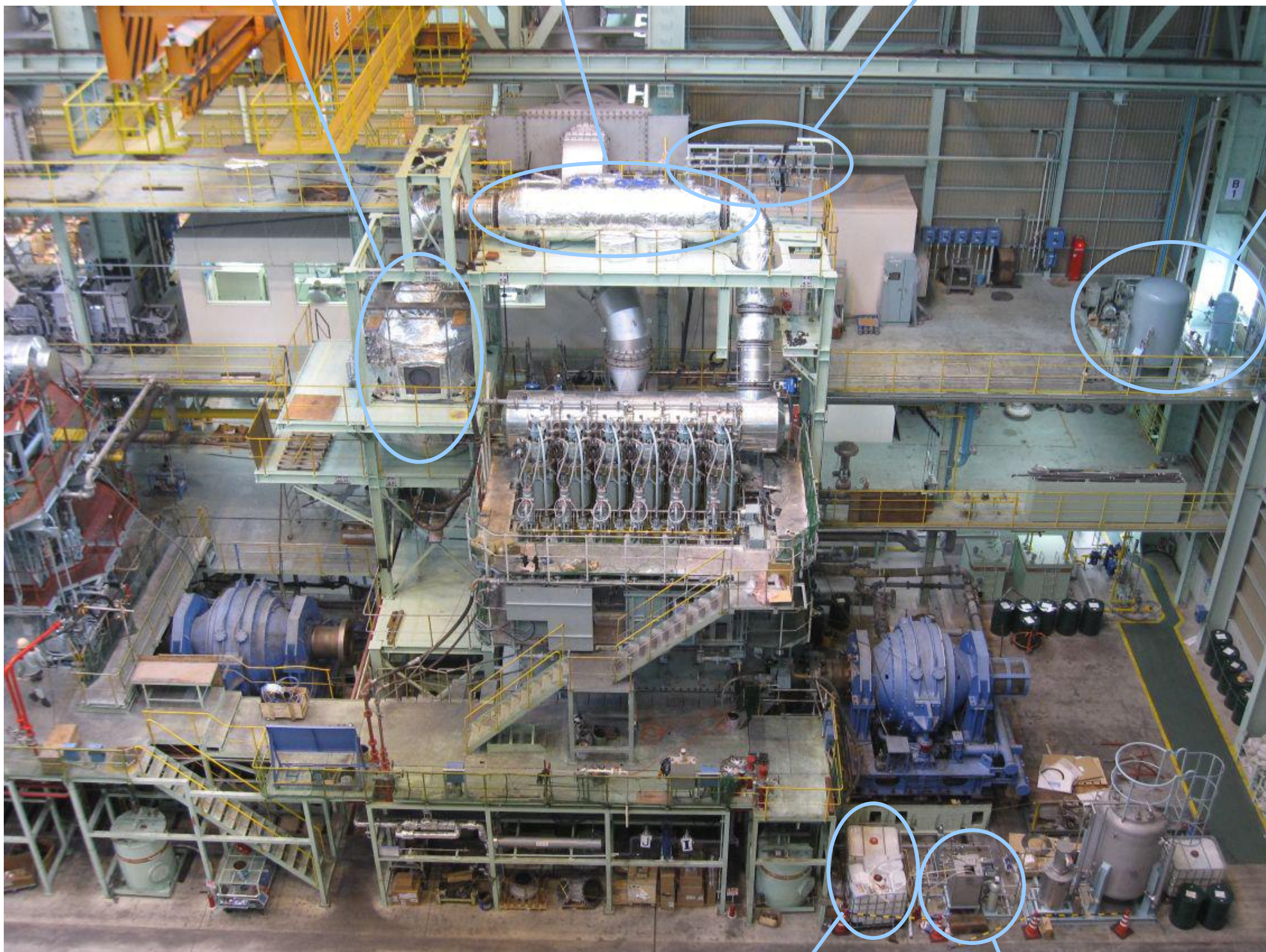
6S46MC-C-SCR on testbed

Reactor contain. catalysts & soot blower

Vaporizer & urea injection nozzle

Urea injection unit

Air compressor & air tanks



Urea solution tanks

Urea supply unit

Form 130

NIPPON KAIJI KYOKAI

STATEMNT OF FACT

No. KB11MM00301

Date: 1 November 2011

Engine Manufacture	Model Number	Serial Number	Test Cycle(s)	Rated Power (kW) and Speed (RPM)	NOx Reducing Device
Hitachi Zosen Corporation	6S46MC-C7	4306	E3	6780 kW 111 RPM	Selective Catalytic Reduction fitted

THIS IS TO CERTIFY:

1. That, at the request of Hitachi Zosen Corporation, Japan, NOx measurement for the above-mentioned marine diesel engine fitted with Selective Catalytic Reduction (SCR) was surveyed in accordance with Chapter 5 of NOx Technical Code 2008 at Hitachi Zosen Corporation, Japan, on 26 April 2011; and
2. That the NOx measurement result shows the following value less than the NOx Tier III emission limit of 3.4 g/kWh specified in paragraph 5.1, Regulation 13, MARPOL ANNEX VI.

NOx emission value: 2.8 (g/kWh)

Specification of the above-mentioned marine diesel engine fitted with SCR is as per the document "Technical File for NOx Certification", Drawing No. ES036111, examined on 1 November 2011.

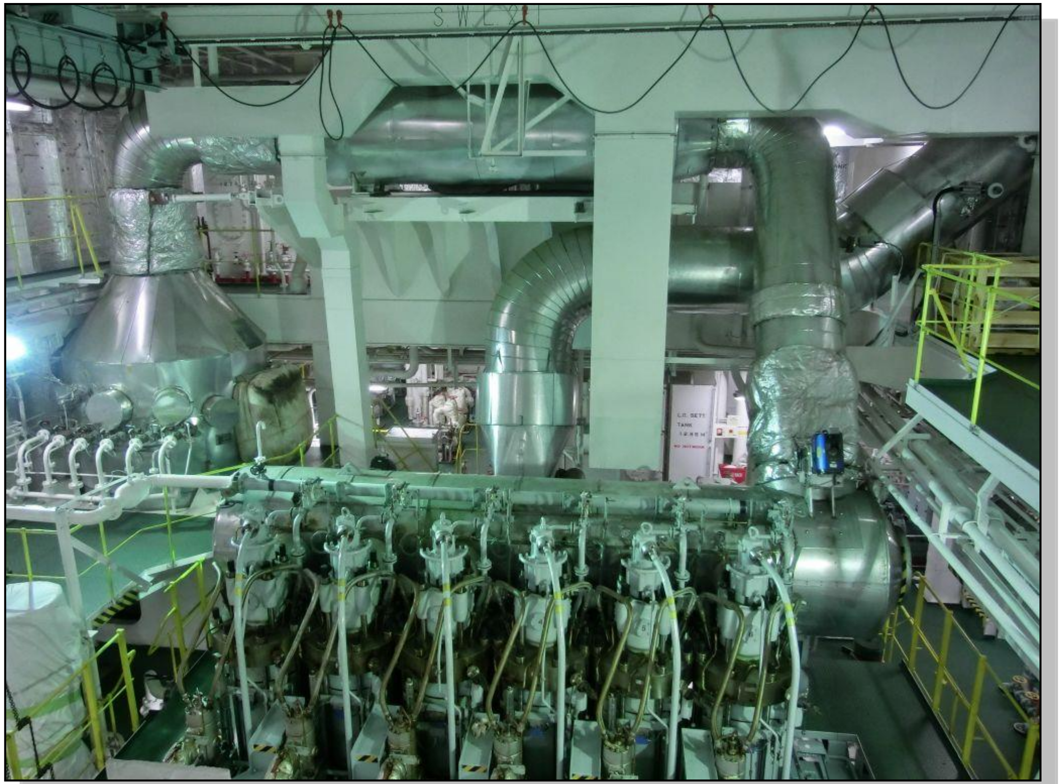
Remarks:
The following items are outside the scope of this certification.
a. Aged deterioration of SCR performance.
b. SCR bypass operations when the engine is under heating operation, low load operation, and transient speed change operation.

T. Narisawa
General Manager
Machinery Department
NIPPON KAIJI KYOKAI

Installation in engine room

- The same arrangement - engine, reactor, vaporizer, duct, fixation, …
  - ➢ Proved on the test-bed
  - ➢ Made the sea trial trouble-less

SCR in engine room



SCR on test-bed

Tier III operation cost of high pressure SCR

Hitz
Hitachi Zosen

What does it cost:

SFOC penalty:	Negligible (1% only at low load, Nil at other loads) without any fuel-saving measure
After-burner expense:	Nil
Urea consumption:	16 l/MWh (40% solution, deNOx 14.4 --> 3.4 g/kWh)

Summary

Summary

- **NOx reduction**
  - EGR can meet Tier 3
  - SCR can meet Tier 3

- **Cost**
  - CAPEX: SCR < EGR
  - OPEX: EGR < SCR
  - Total: depending on time for sailing in ECA

- **Size**
  - EGR: EGR2 integrated on engine (except auxiliary systems)
  - SCR: Compact SCR investigation ongoing

Conclusion

FAQ: "Which is available in 2016?"

Ans.: "Both are available"

New Question: "Which way to go after Tier III?"

Consider:

- More NOx reduction required in future?
- More CO2 reduction required in future?
- Gas?
- Who consumes HFO?
- Which way are auxiliary engines going?

Thank you for your attention!