YANMAR SCR Technology for IMO Tier III

12th Oct. 2018

YANMAR CO., LTD.

Agenda

- Introduction
- About YANMAR SCR system
  - -History of YANMAR SCR technology development
  - -Outline of YANMAR SCR system
  - -Certification of SCR System
  - -YANMAR SCR line up & delivery record
  - -SCR for main engine
- Summary

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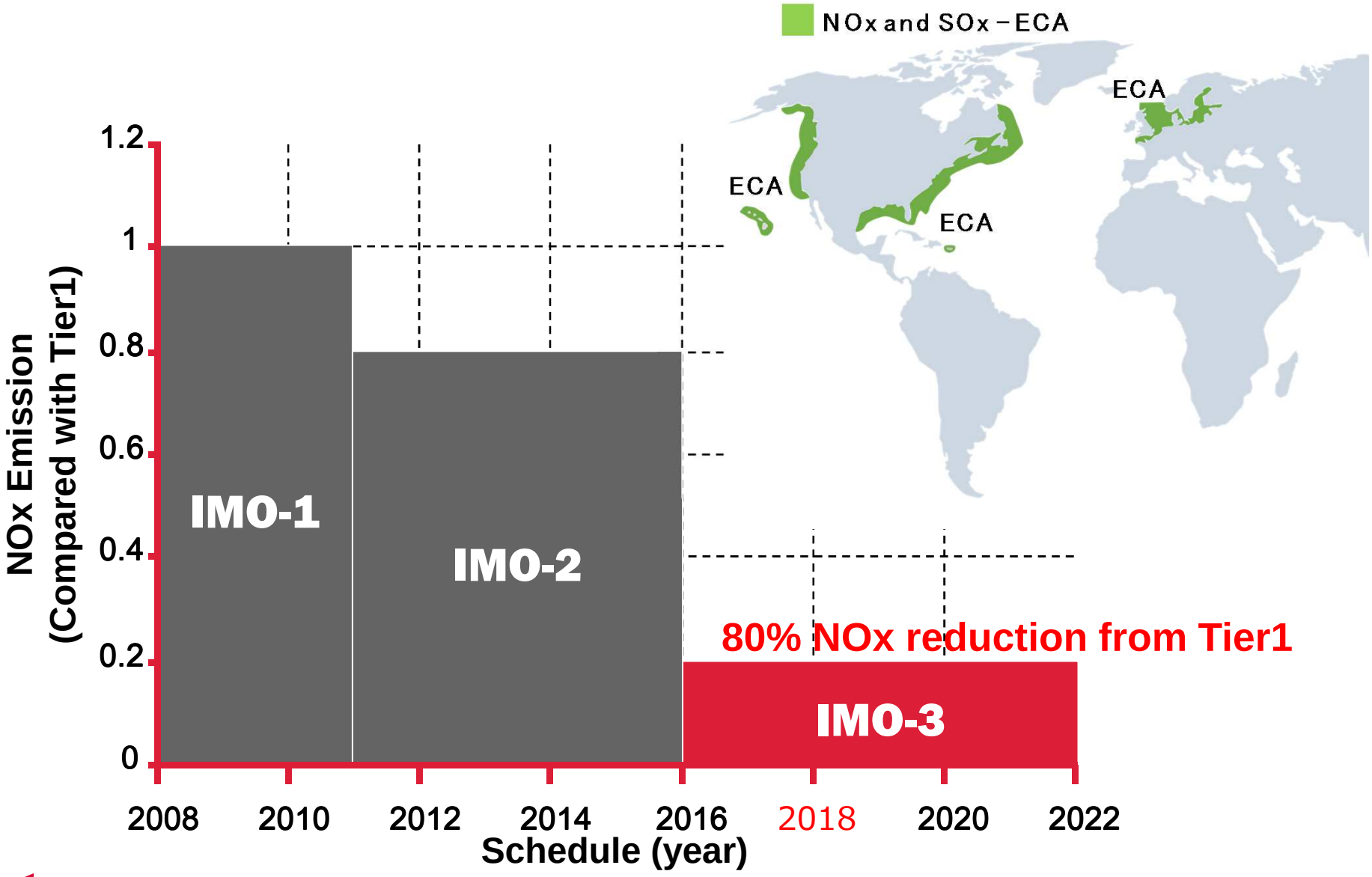
Introduction

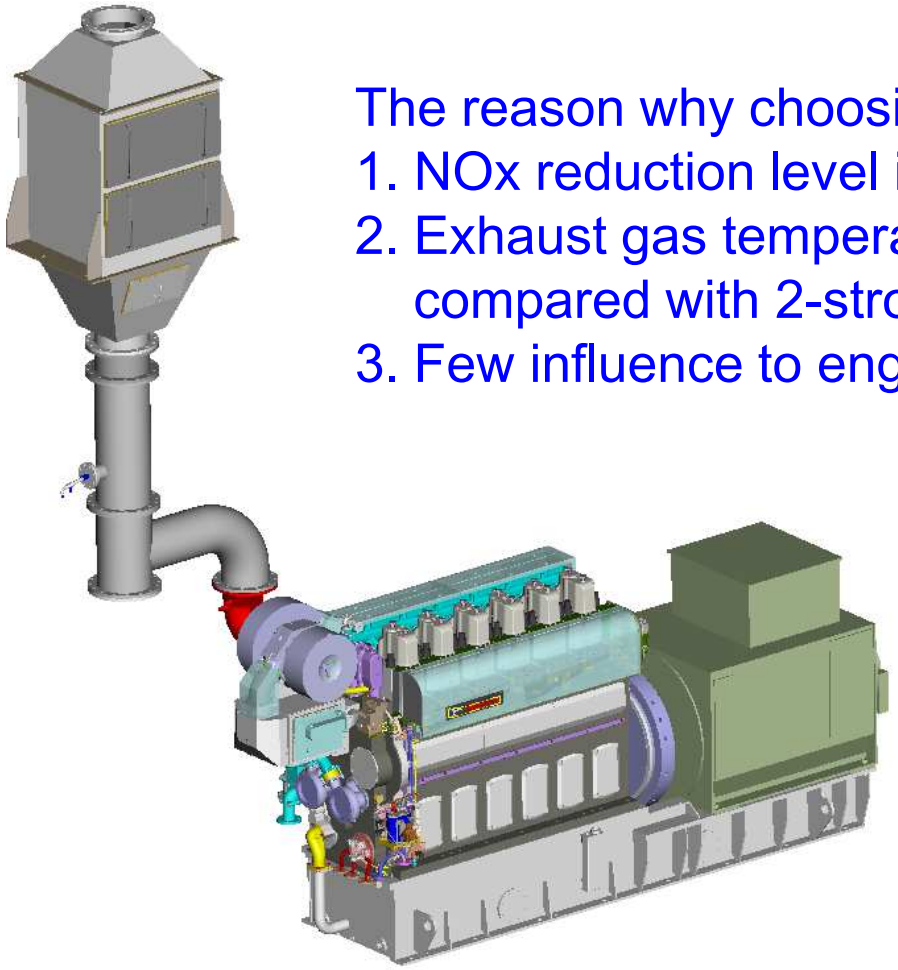
Transition of environmental regulations



Introduction

NOx reduction technology for IMO Tier3

YANMAR selected SCR technology to comply IMO Tier3



The reason why choosing SCR

1. NOx reduction level is the highest.
2. Exhaust gas temperature at engine outlet is higher compared with 2-stroke engine.
3. Few influence to engine performance.

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History of SCR technology development

2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017

Basic technology development

Endurance test (Phase 1)

Endurance test (Phase 2)

Endurance test (Phase 3)

Research results of Off-road Diesel

On-board test (Phase 1)

On-board test (Phase 2)

History of SCR technology development

We began developing base technologies of SCR since 2007.

We have experienced 3 times Endurance test and 2 times On-Board test.

Endurance test (on land)
Elemental technology development such as
catalyst deterioration and verification of control logic.

On-Board test
Demonstration of the durability of the whole system and the catalyst life.
Verification of SCR system operation method such as maintenance.

History of SCR technology development

On-board test of SCR system

225,000ton Cargo vessel

Install SCR to Gen. NO.1,2,3

SCR reactor

SCR operation sequence

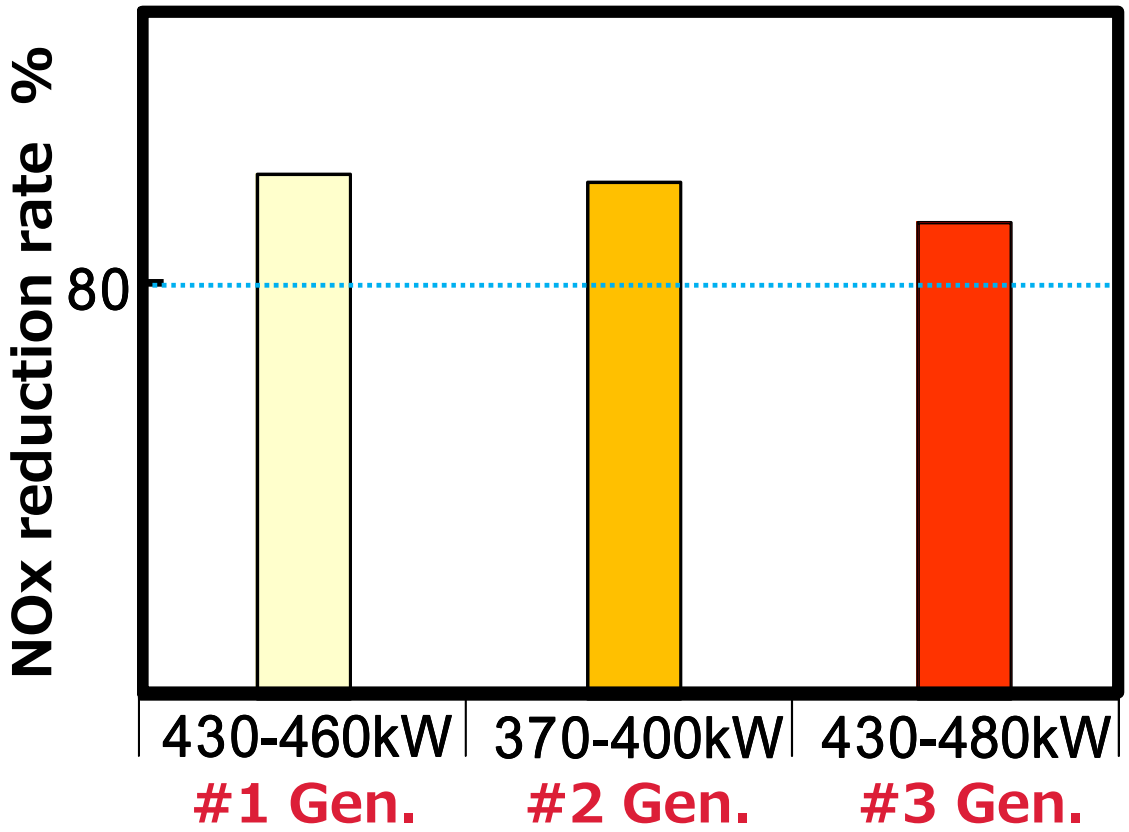
	Within supposed ECA	Without supposed ECA
Fuel (on MGO test)	MGO	HFO
Fuel (on HFO test)	HFO	HFO
IMO regulation	Tier3	Tier2
SCR operation	ON	OFF
Exhaust gas line	SCR	Bypass

Demonstration of the durability of the whole system and the catalyst life.
Verification of SCR system operation method such as maintenance.

History of SCR technology development

Onboard Test of SCR System

Performance at the end of the test
⇒ **NOx reduction rate > 80%**



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Reactor design concept

・SCR reactor was unitized from bypass branch to catalytic reactor. And Integration of catalytic reactor and bypass line.

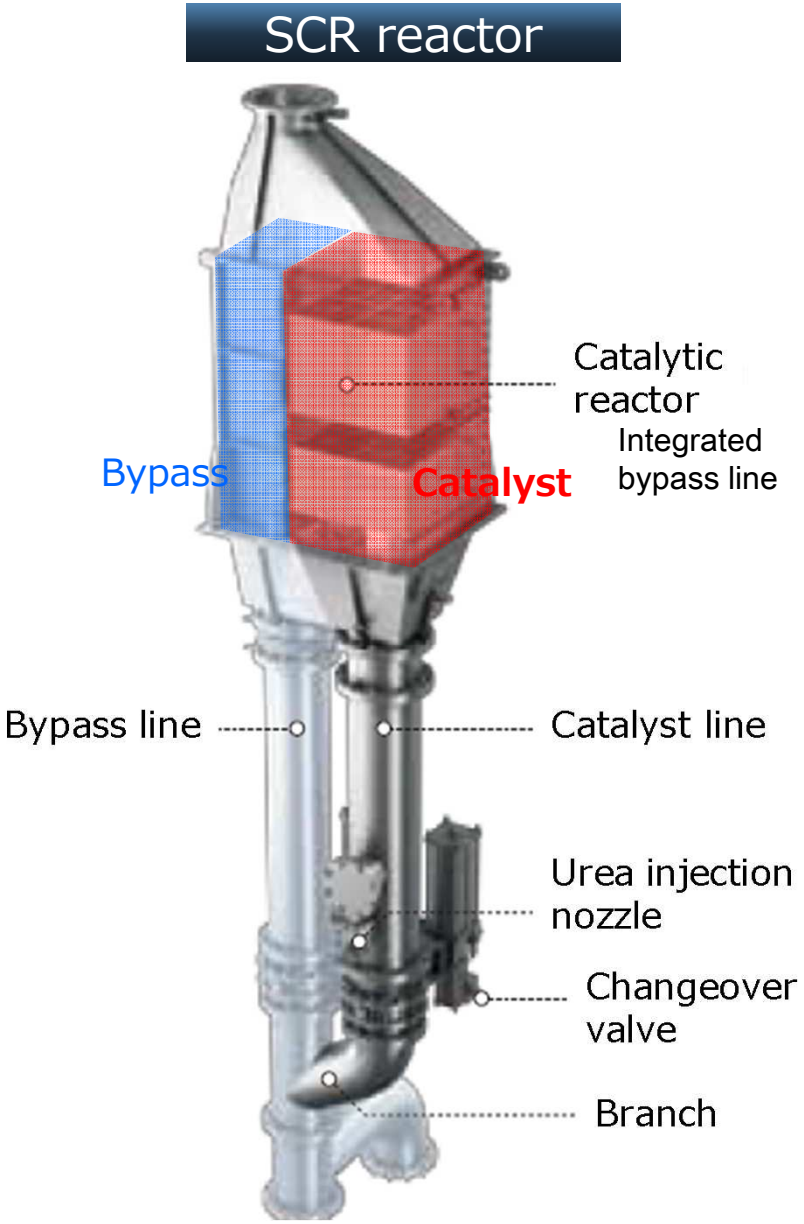
⇒ **No need for bypass line pipe space.**

・Urea injection nozzle is installed on the downstream of the branch to prevent Urea leak to the bypass side.

⇒ **More safety design for the crew.**

・The junction part of bypass line and catalyst line is designed to prevent deterioration of catalyst due to backflow of exhaust gas during bypass operation

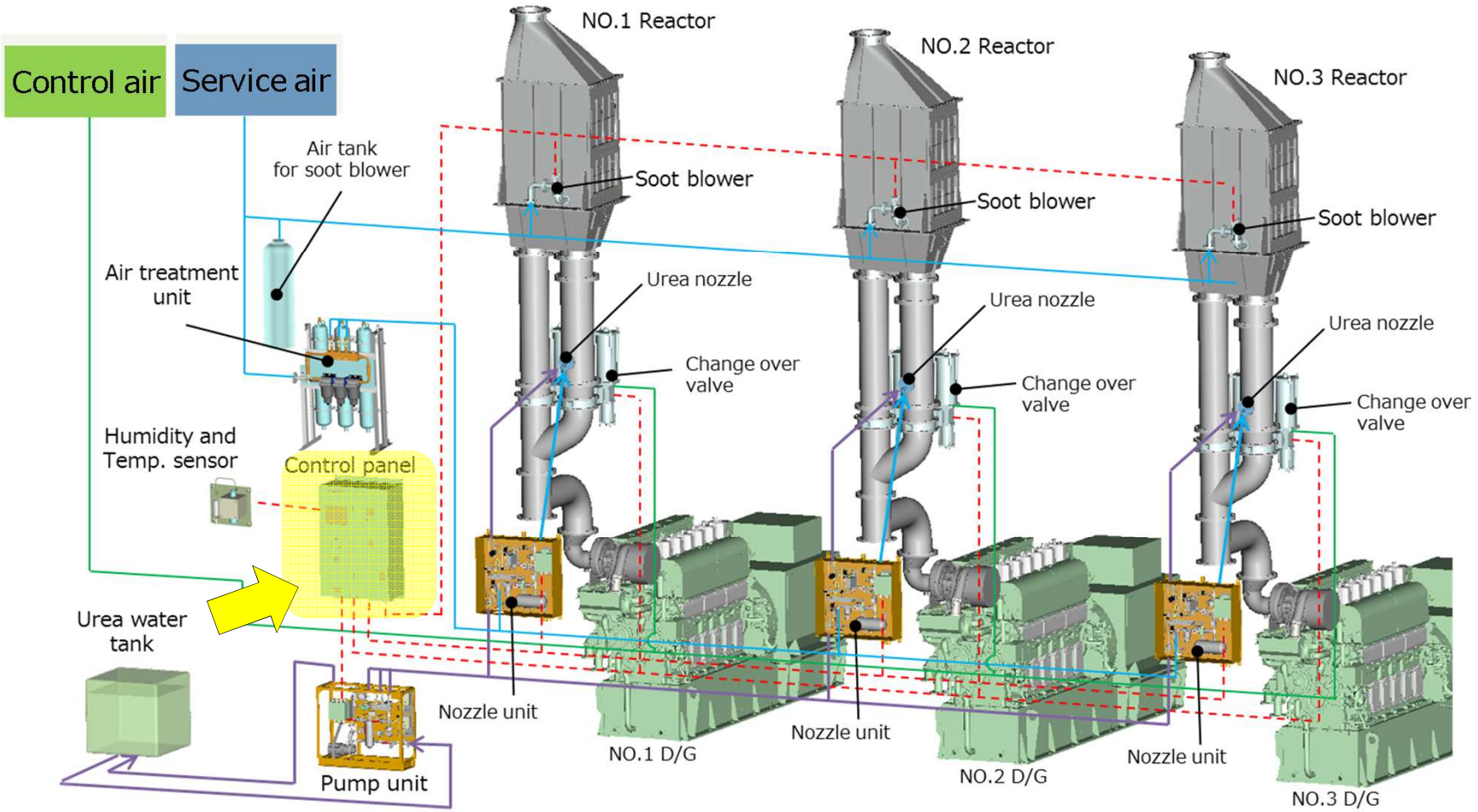
⇒ **Longer life of catalyst.**



Outline of YANMAR SCR system

Integrated control

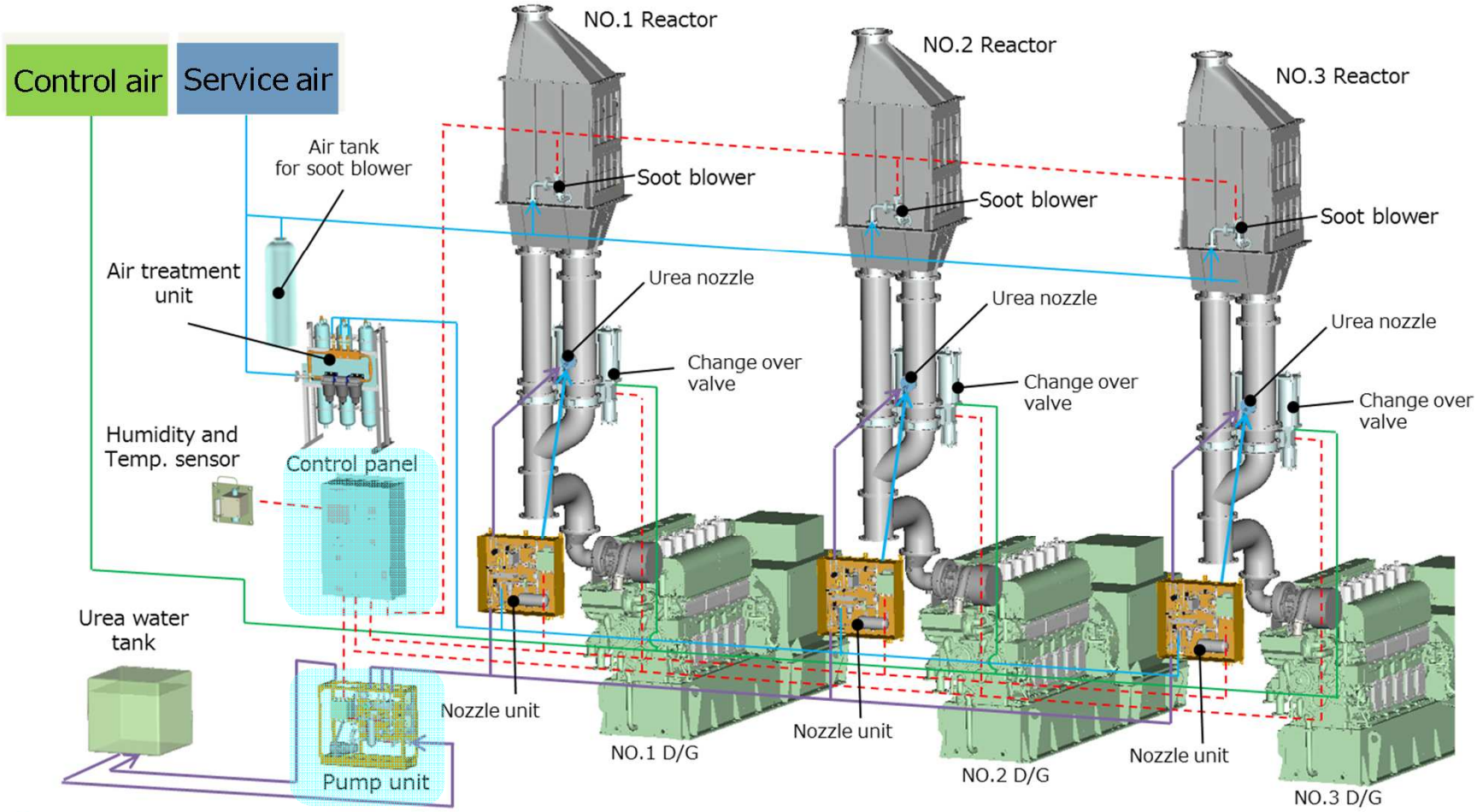
・All equipments including catalytic reactor are auto controlled integrally by control panel.



Outline of YANMAR SCR system

1 Control panel and 1 pump unit can operate multiple SCR

・SCR reactor and nozzle unit should be installed for each engine.
But 1 control panel and 1 pump unit are installed per 1 vessel.



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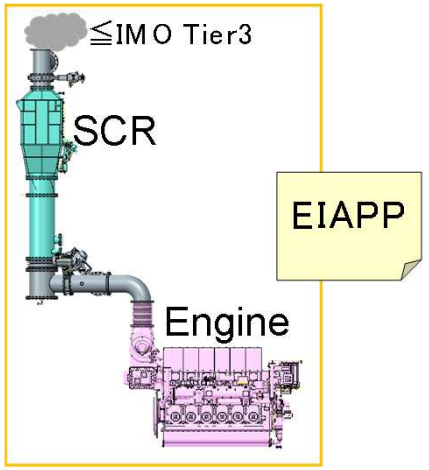
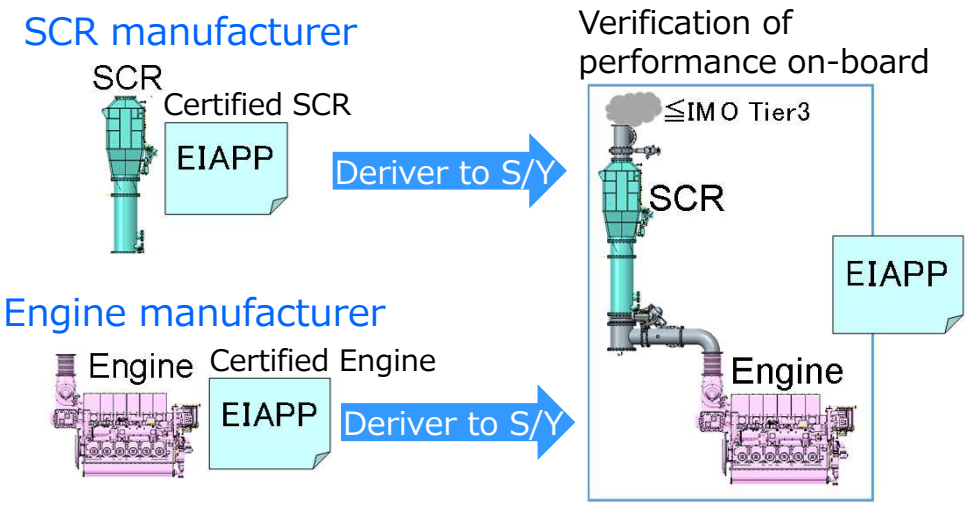
Certification of SCR system

In “Scheme A”, the engine and SCR system are tested for certification, as one unit, on the test bench.



In “Scheme B”, the engine and SCR are certified respectively.

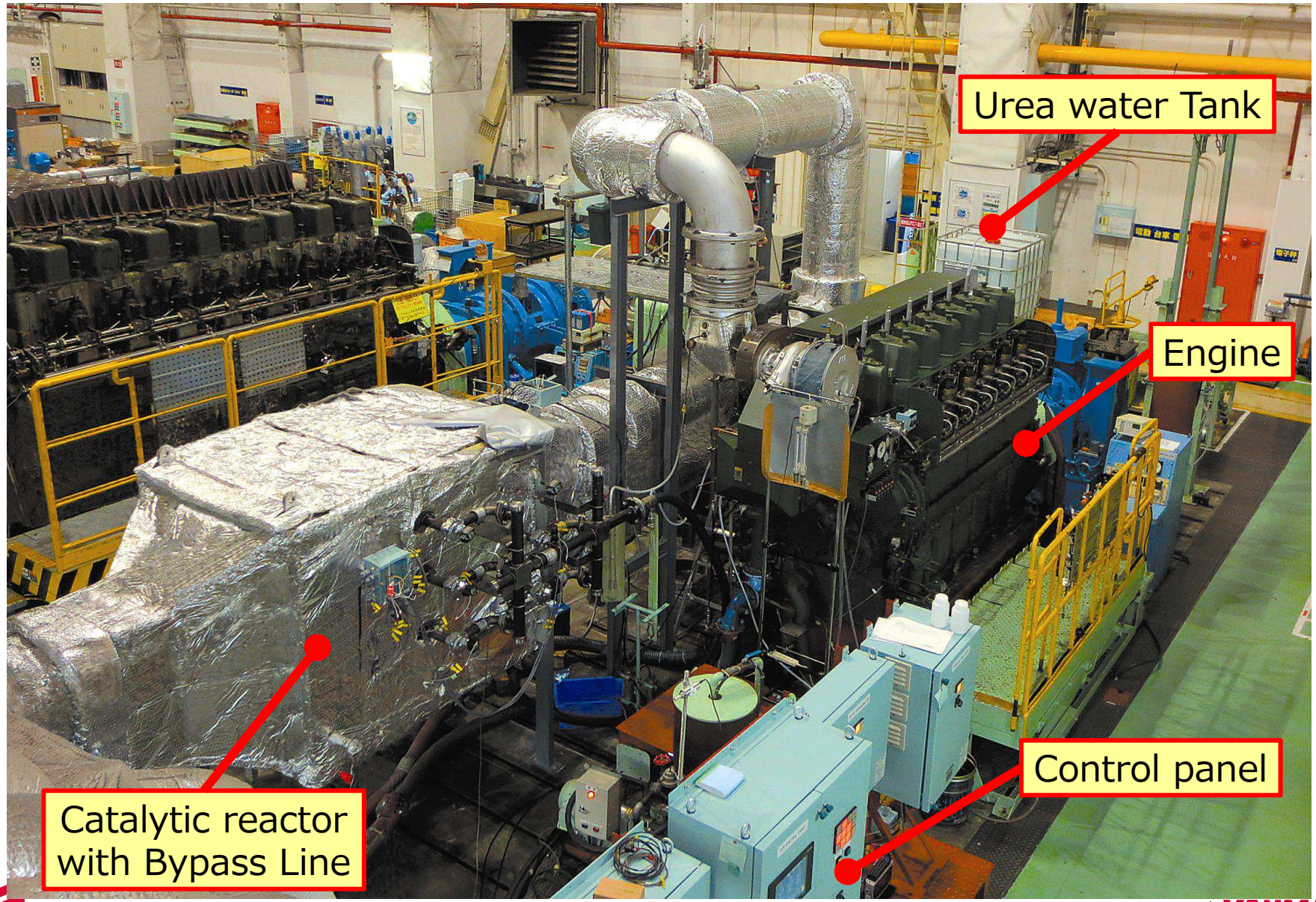
After that, SCR is fitted to engine, and the engine and SCR system is tested for verification on-board



YANMAR SCR system is certificated by Scheme A.
⇒ On-board performance is more reliable.

Certification of SCR system

Bench test of SCR system



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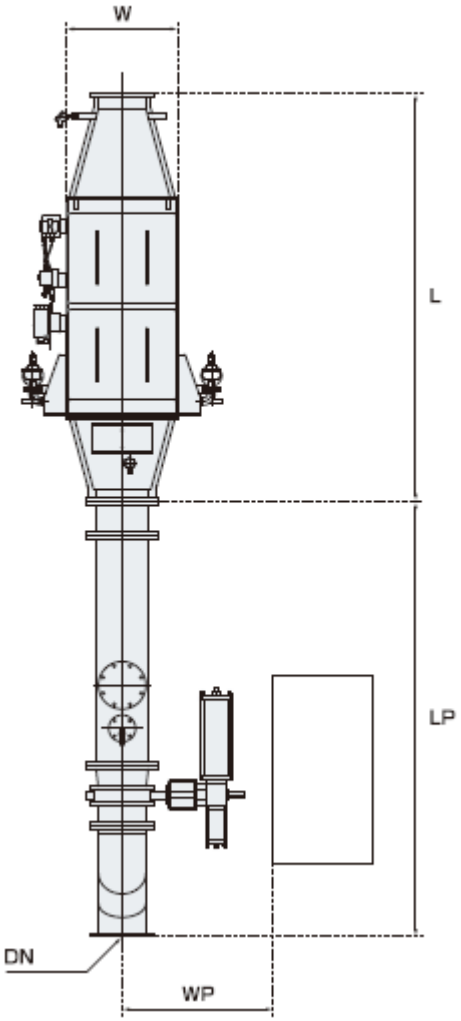
YANMAR SCR system line up (for Auxiliary engines)



For medium speed diesel engines with 355 to 4800 kW.

SCR model	Reactor size			Piping size		Engine model
	H	W	L	DN	LP	
Y16SCR-L	1080	750	2230	250A	2560	*6NY16LWS*
	1080	750	2380	250A	2560	
Y165SCR-L	1140	750	2600	300A	2530	*6N165LWS*
	1140	750	2750	300A	2530	
Y18SCR-(A)L	1140	750	2600	300A	2930	*6EY18(A)LWS*
	1140	750	2750	300A	2930	
Y22SCR-(A)L	1480	1100	2770	400A	3620	*6EY22(A)LWS*
	1480	1100	2920	400A	3620	
Y26SCR-6L	1700	1430	3490	500A	4300	*6EY26LWS*
Y26SCR-8L	1920	1430	3360	550A	4300	*8EY26LWS*
	1920	1430	3510	550A	4300	
Y33SCR-6L	2080	1750	3850	650A	5120	*6EY33LWS*
Y33SCR-8L	2430	1760	3900	750A	6100	*8EY33LWS*

※Please contact us for more details.

YANMAR SCR delivery record

Delivery record: **150** units
Number of orders in hand: **80** units scheduled for this year

Catalytic reactor

Shop test of Urea dosing system at Amagasaki factory

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SCR for main engine

We prepare SCR system not only for Auxiliary engine
but also for Main engine.

Our main engine is installed on following vessels mainly.

Offshore ships

Fishing Boat

Training ship

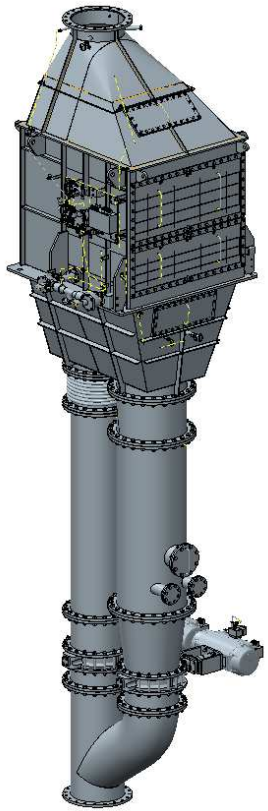
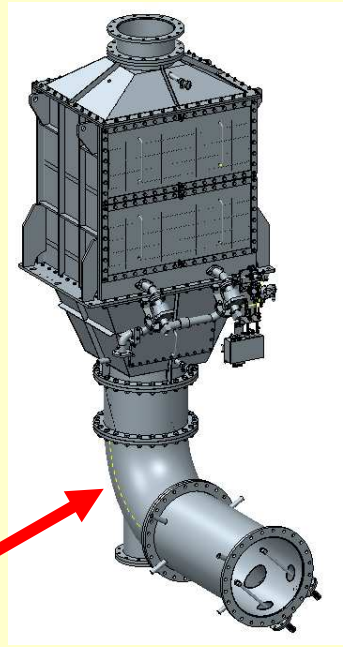
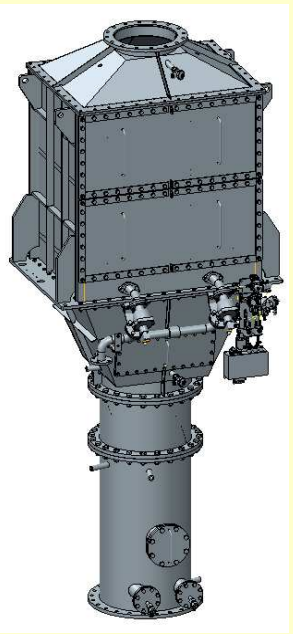
Patrol boat

The engine room of these vessels is smaller than the Ocean-going Vessel.

SCR for main engine

Difference of SCR reactor between auxiliary engine and main engine

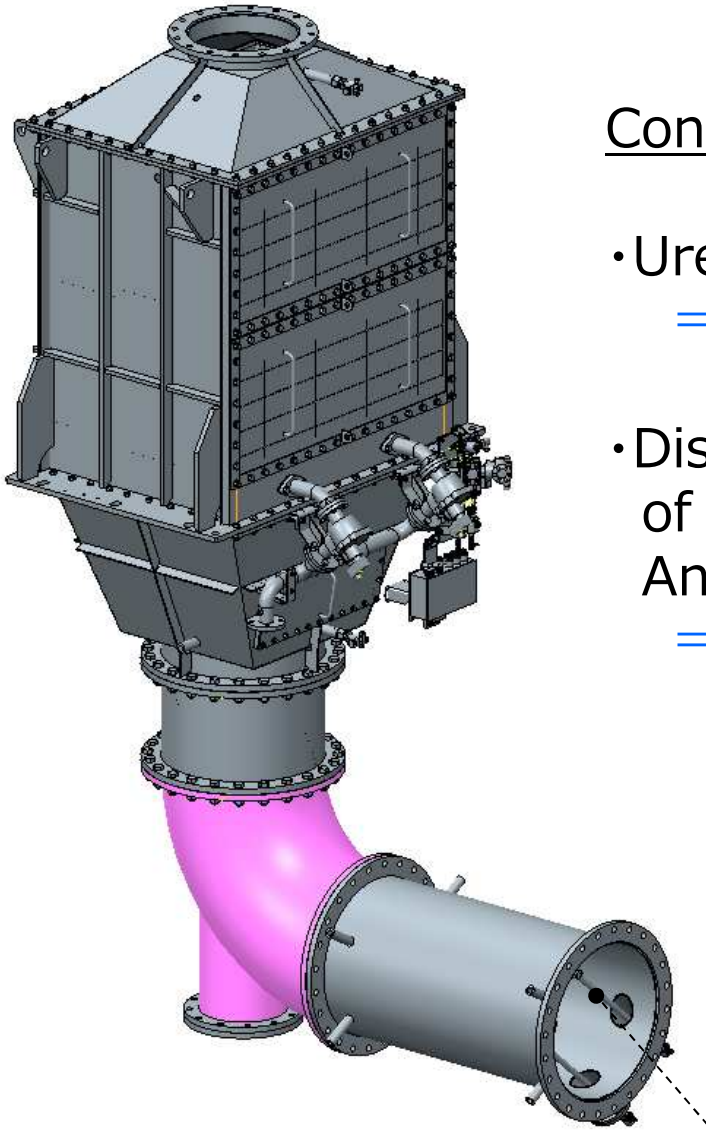
In the case of vessel with small engine room, flexibility of piping is required.

SCR reactor for Auxiliary engine (with bypass)		SCR reactor for Main engine (without bypass)	
・Longer catalyst life ・Redundancy ・Space saving with bypass pipe ・No change in back pressure outside the ECA		・Short size ・Flexibility of piping (1 bend allowing)	 

YANMAR

SCR for main engine

Bending pipe of SCR



Concern

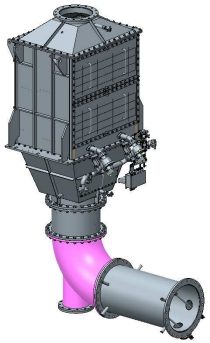
・Urea is deposited on the pipe surface
⇒Keep injection nozzle away from wall.

・Distribution of NH3 is biased at inlet of the catalyst.
And NOx reduction rate is decreased.
⇒Sufficient catalyst volume.

We are studying methods to predict these factors more accurately by using 3D model analysis.

SCR for main engine

Bending pipe of SCR



Concern

・Urea is deposited on the pipe surface
⇒Keep injection nozzle away from wall.

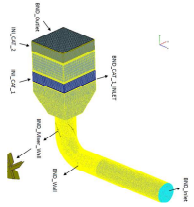
・Distribution of NH3 is biased at inlet of the catalyst and NOx reduction rate is decreased.
⇒Sufficient catalyst volume.

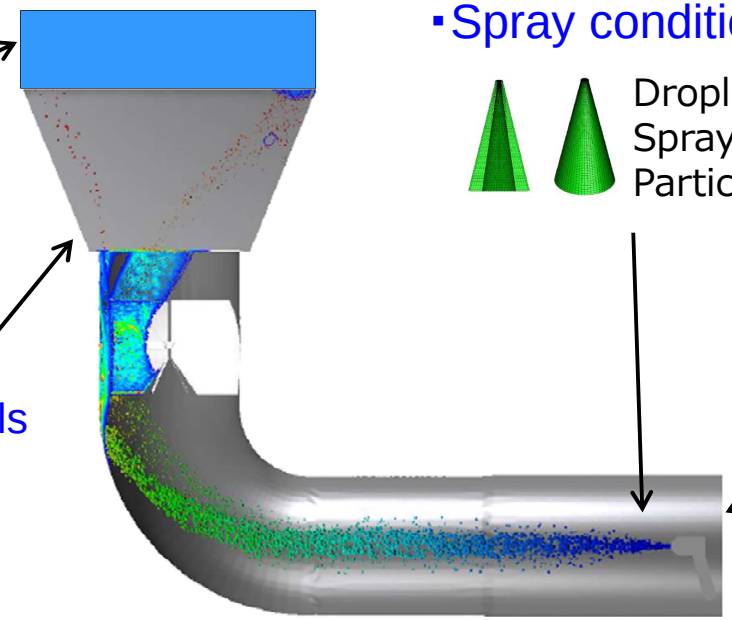
Prediction by using 3D model analysis (Software：FIRE v2017)

Input

▪Catalyst parameter
Size
CPSI
Pressure drop etc.

▪Dimensions and materials of reactor





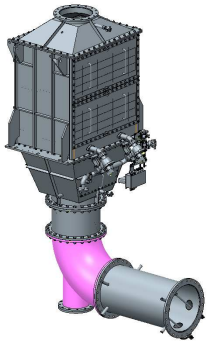
▪Spray conditions

Droplet velocity
Spray cone angle
Particles size distribution etc.

▪Exhaust gas conditions
Mass flow
Temperature
Pressure etc.

SCR for main engine

Bending pipe of SCR



Concern

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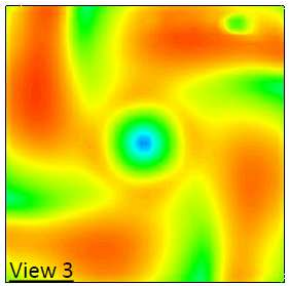
⇒Keep injection nozzle away from wall.

・Distribution of NH3 is biased at inlet of the catalyst and NOx reduction rate is decreased.
⇒Sufficient catalyst volume.

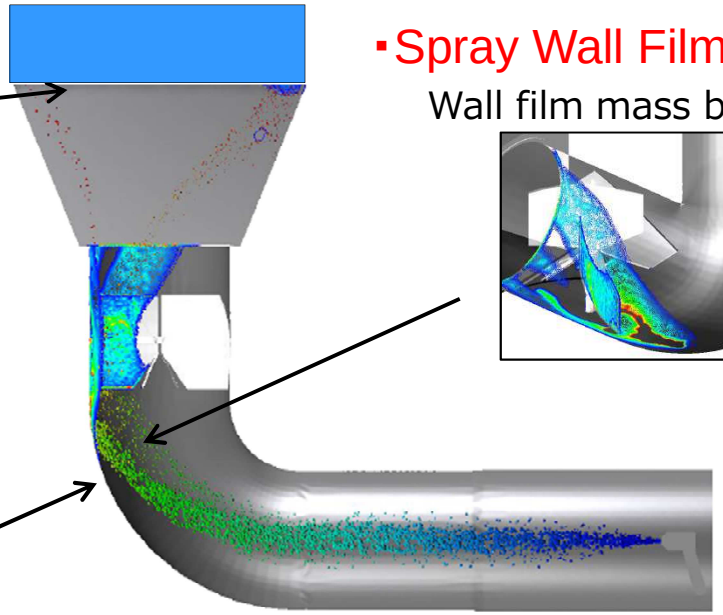
Prediction by using 3D model analysis (Software：FIRE v2017)

Output

・Catalyst inlet condition
NH3 uniformity etc.



・Wall temperature



・Spray Wall Film Formation
Wall film mass balance etc.

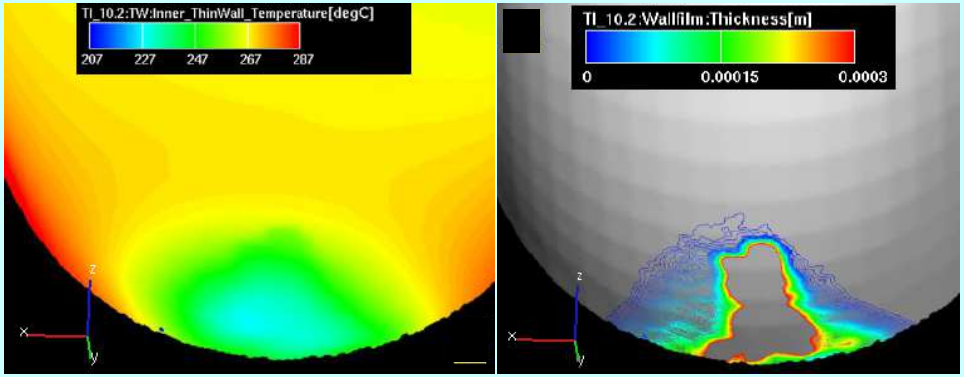
High possibility of deposition when wall film is formed and wall temperature is lower.

SCR for main engine

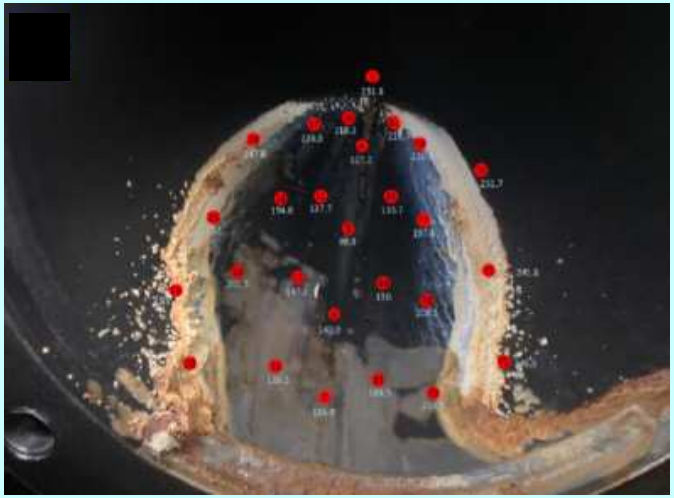
Bending pipe of SCR

We have improved analysis accuracy
by conducting verification test.

On verification test,
we increased the urea water injection quantity intentionally to deposit urea.



Wall temperature and Wall film formation of analysis

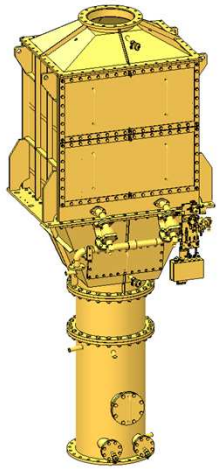
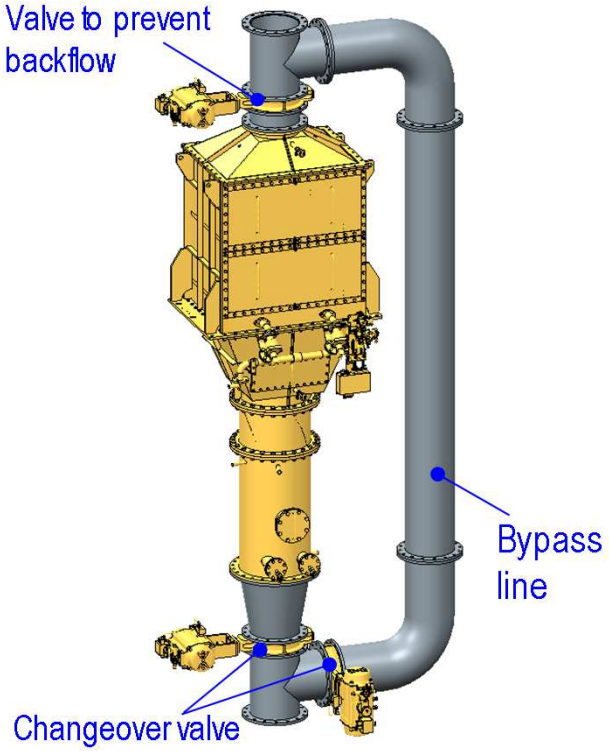
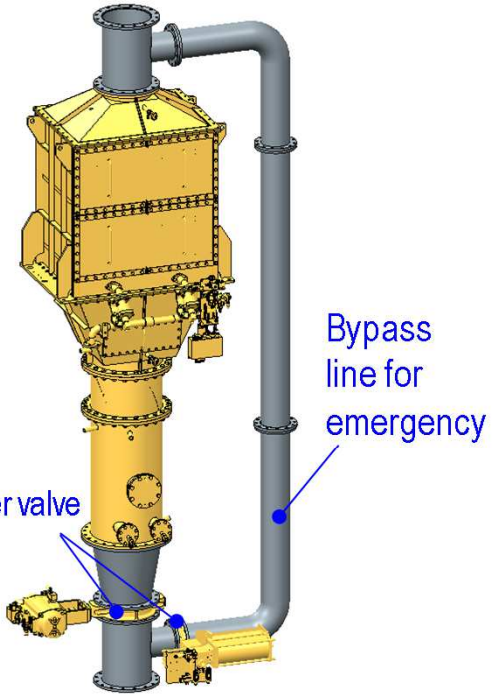


Actual deposit of Verification test

SCR for main engine

Variation of SCR reactor for main engine

Multiple types of reactor are available depending on usage

2 Engines-1 Shaft or 2 Engines-2 Shafts (provided redundancy)	1 Engine-1 Shaft (no redundancy)	
	Use SCR only within ECA	Always use SCR
Bypass-less	With bypass line	With emergency bypass line
		 Piping diameter of bypass line can be small depend on allowable back pressure for engine.

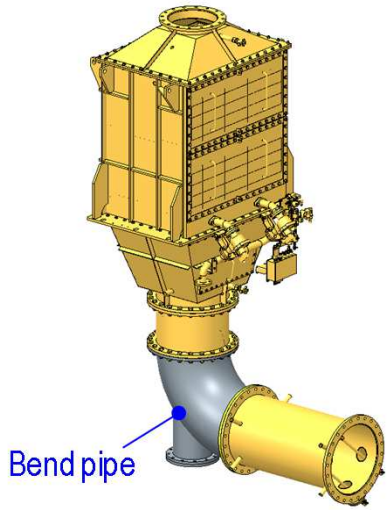
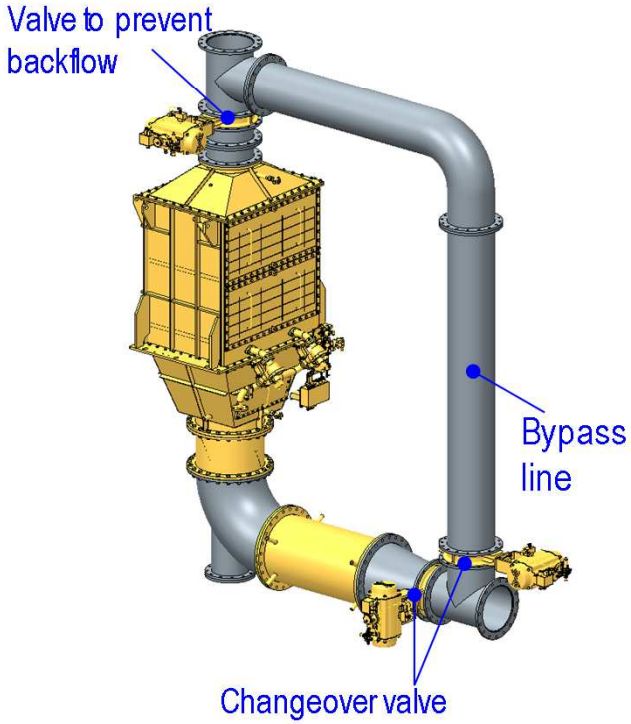
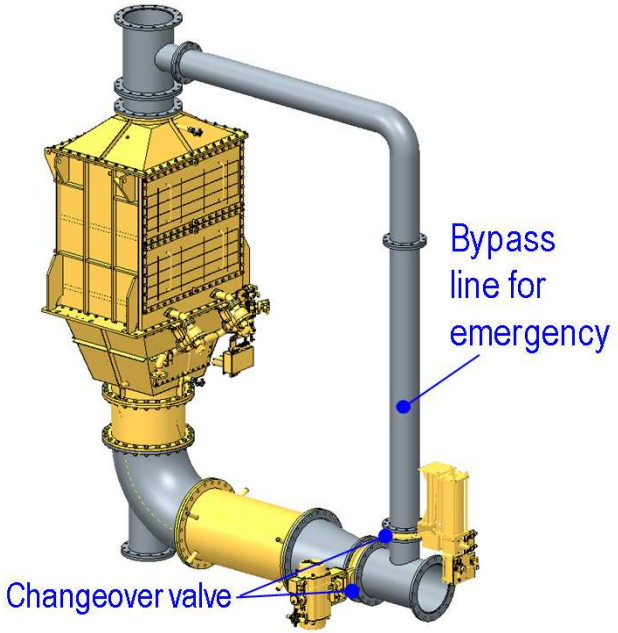
Yellow : Yanmar supply

SCR for main engine

Variation of SCR reactor for main engine

Multiple types of reactor are available depending on usage

Bending type is also the same as Straight type

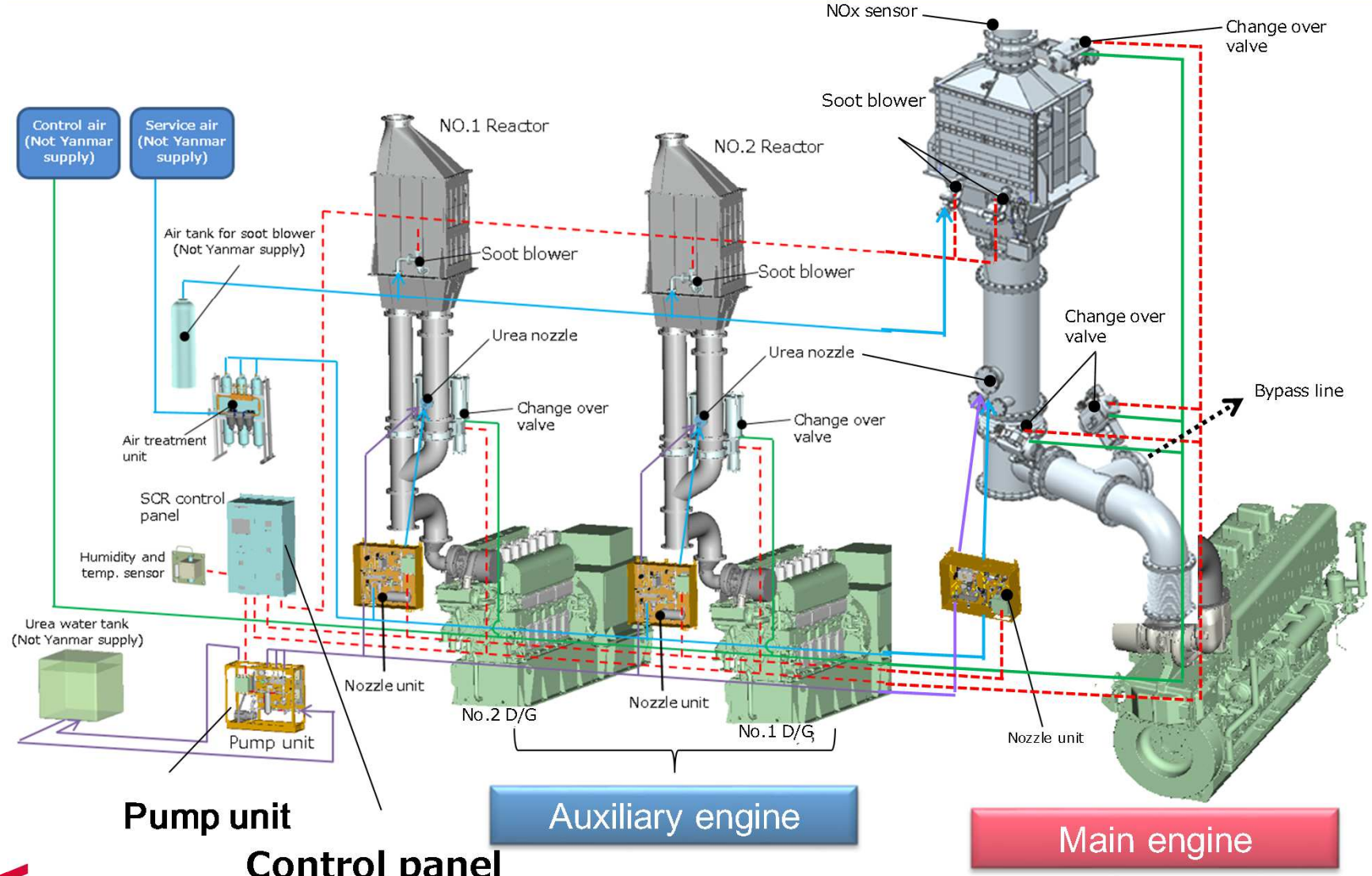
2 Engines-1 Shaft or 2 Engines-2 Shafts (provided redundancy)	1 Engine-1 Shaft (no redundancy)	
	Use SCR only within ECA	Always use SCR
Bypass-less	With bypass line	With emergency bypass line
		 Piping diameter of bypass line can be small depend on allowable back pressure for engine.

Yellow : Yanmar supply (※Bend pipe is shipyard supply)

SCR for main engine

1 Control panel and 1 pump unit can operate multiple SCR

Combination of main engine and auxiliary engine is also possible.



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Summary

In-house developed SCR system with high reliability and durability

SCR systems are best matched with
the respective engines.

One control panel and pump unit
integrate multiple devices.
It realized compact and simple system.

Engine and SCR system will be
certificated as IMO tierⅢ compliant
according to the Scheme A procedure .

Now developing SCR for main engine
based on customer's needs.