



WELCOME

WORKSHOP PROGRAMME



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Programme for Day 1 and Day 2

Compliance with NO_x Tier III standards

OBJECTIVES

- Strengthening knowledge of **technical aspects related to marine engines** and NO_x emission control measures
- Understanding the structure of **Regulation 13 and the NO_x Technical Code**, including **specific aspects** such as the 3-date criteria, the exemption regime, etc.
- Being able to describe the **framework supporting the implementation (Flag State) and enforcement (Port State)** of Reg.13 and Tier III emission limits

CONTENT

- 3 different Agenda Items will be covered through **4 sessions** (Day 1 full day and Day 2 morning only)
- Including **2 interactive sessions**, to review practical case studies and promote discussions, experience feedback, share views on barriers etc.



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REMPEC Consultant
Marie Caillerie

Agenda Item 2 – Compliance with NO_x Tier III standards

Part 1 – Technical aspects

Malta, 7-8 October 2026

Regional Expert Meeting on the Possible Designation of the Mediterranean, as a whole, as a NO_x ECA



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Agenda item 2 – Compliance with NO_x Tier III

Part 1 – Technical aspects

- **Introduction**
- **NO_x formation and internal combustion engines, key machinery components**
- **Tier III compliance methods**
 - Exhaust Gas Recirculation, Selective Catalytic Reduction
- **Perspective from Engine manufacturers and recent development**
- **Q&A and Conclusion**



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**Compliance with Tier III
Part 1**

October 2026



Introduction

MARPOL Annex VI, Regulation 13 – Application

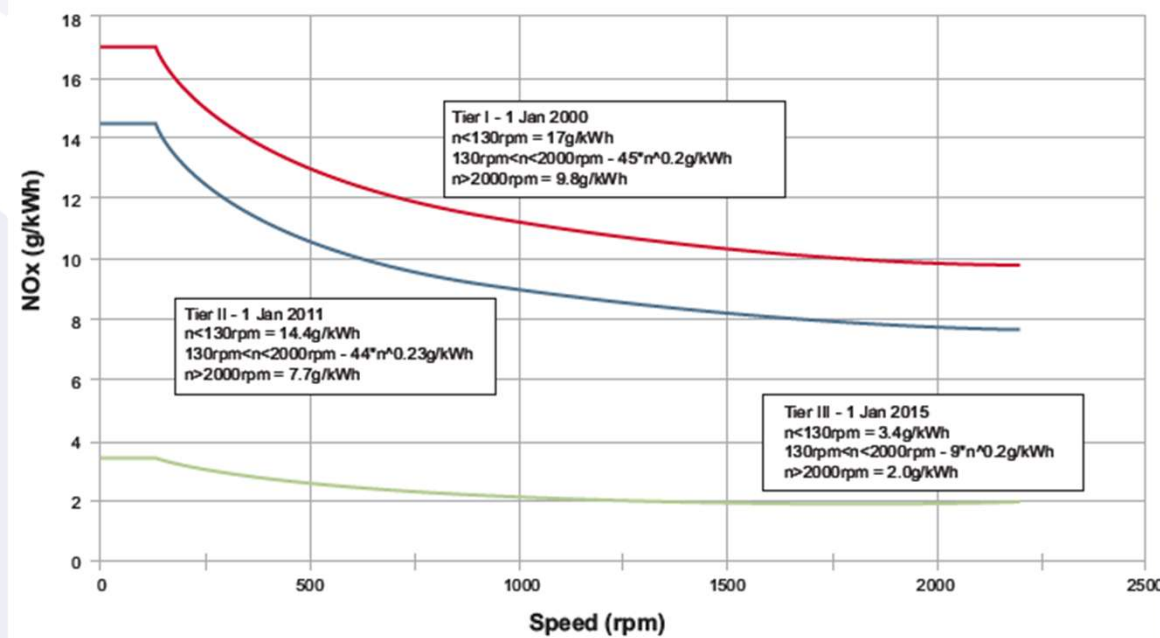
- NO_x limits apply to:

- **marine diesel engines**
- with an output **power over 130 kW**
- used for **propulsion** or **other services** onboard such as **power generation**.

- *Engines used solely for emergency purposes are excluded*
- *NOT for emergency generators, emergency fire pump, lifeboat engine...*

- Based on the ship **geographical area** of operation: ECA or not

IMO ANNEX VI NO_x LIMITS

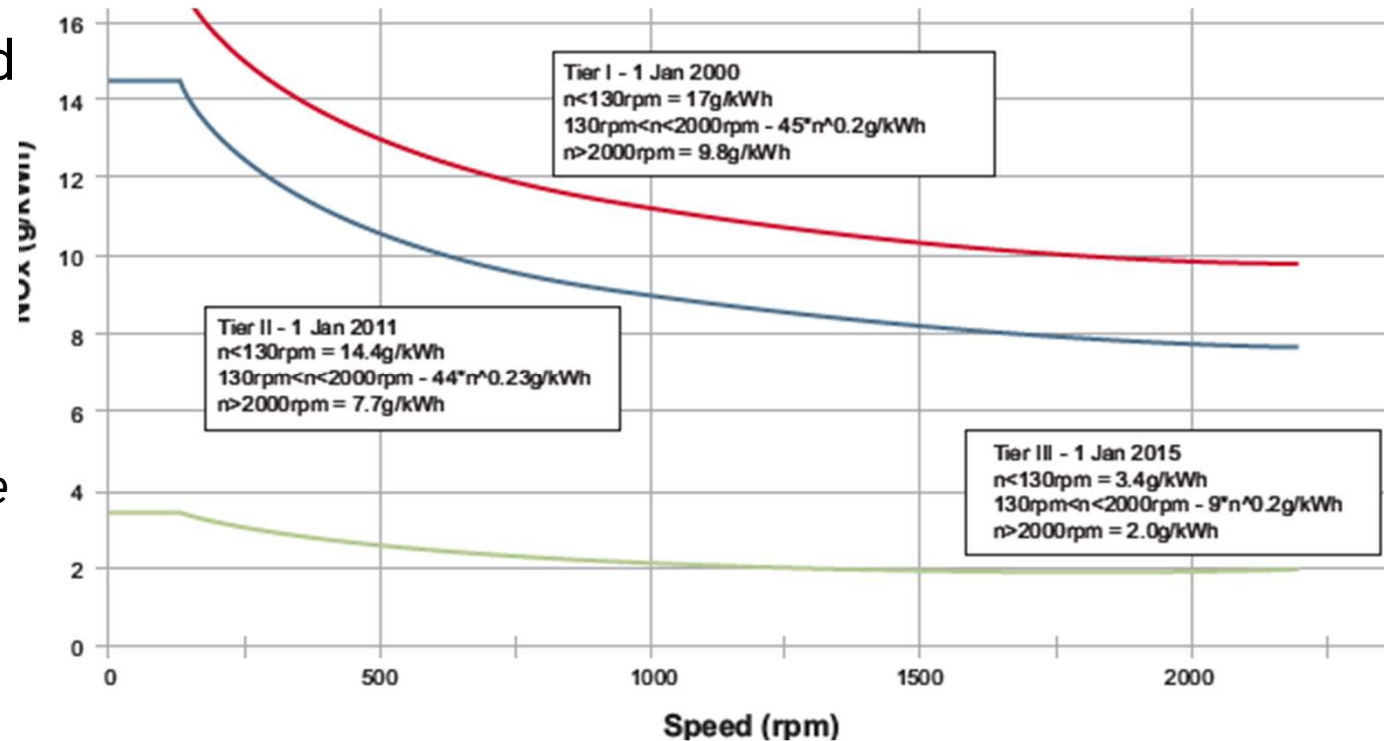


Today, Tier II limits are applicable globally by all ships constructed from 2011.
Except for ships covered by applicable Exemptions

MARPOL Annex VI, Regulation 13 – Application

The exact NO_x limit is determined for each engine based on:

- the **engine speed (rpm)**
 - A set limit or with Formula
- the **ship construction date**
 - For each ECAs; no retroactive application



Limits are expressed as

- a **maximum content of NO_x** , in **grams**, per **unit of power in kWh**
- based on **engine speed in rotation per minute (rpm)**: a fixed limit, or n in the formula.

Definitions (in reg. 2) – Marine diesel engine

“Marine diesel engine” means any **reciprocating internal combustion engine** operating on liquid or dual fuel, to which reg. 13 applies, including booster/compound systems if applied.

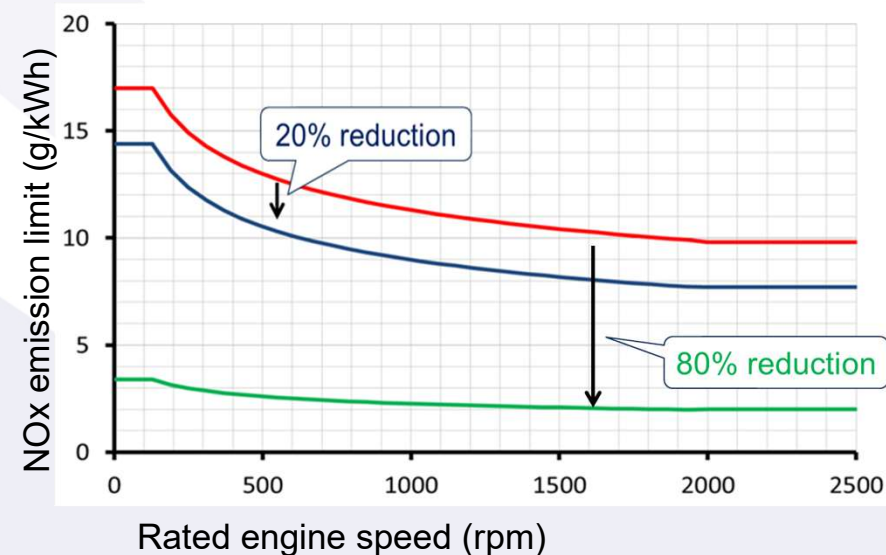
In addition, a **gas-fuelled engine** installed on a ship constructed after 1 March 2016 (...) is also considered as a marine diesel engine.

- ❑ Definition amended to ensure that **gas-fuelled engines** are covered by reg. 13.
- ❑ *Diesel engine* = any type of internal combustion engine (i.e. Diesel cycle or Otto cycle); and all types of liquid or gas fuels (gas-fuelled or dual fuel engines, for ships constructed > 1 March 2016)

Tiers I, II and III – Reg. 13

- ❑ **Tier II limits** are met by **optimizing** the engine design, to alter the combustion process.
 - ❑ Specific **engine parts or parameters can be modified** (FO injection system, piston and cylinder head, scavenging air temperature and pressure, etc.).
- ❑ **Tier III limits** can only be met with the **additional use of NO_x reducing technologies**, as “adds-on” to a conventional engine:
 - selective catalytic reduction **SCR**
 - exhaust gas recirculation **EGR**
 - Or the use of appropriate **alternative fuels** (i.e. LNG) can be a solution

The difference between Tier I and Tier III was considerable: 80% reduction of the NO_x emissions.



Tier I
Tier II
Tier III



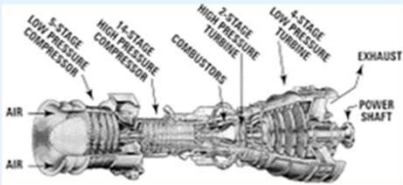
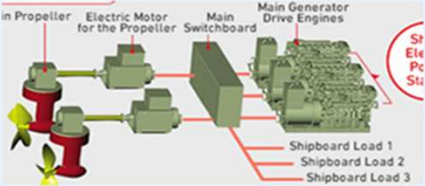
Marine engines – Technical details

Most ships use

Thermal engines = Internal combustion engines, with different design characteristics:

- **Diesel** cycle or **Otto** cycle: the type of combustion
- **4-stroke** or **2-stroke**: the number of piston strokes for one “active” cycle
- **Speed**: from slow, medium, high speed

Ships may use other engine types, but **only “marine diesel engines”** are covered by regulation 13.

Category	Combustion	Marine engine/application		Fuel
Thermal Engines	Internal combustion	Diesel cycle (2 stroke; 4 stroke) Or Otto Cycle (spark for ignition)		HFO LSFO MGO Gas
	External combustion	Steam turbine (with boiler) Gas turbine		Steam Natural gas
	Reaction engines (Jet)	None (aviation)		
Electrical Engines	Diesel engine/Turbine produce electricity; Electrical motor for propulsion	Diesel-Electric propulsion		



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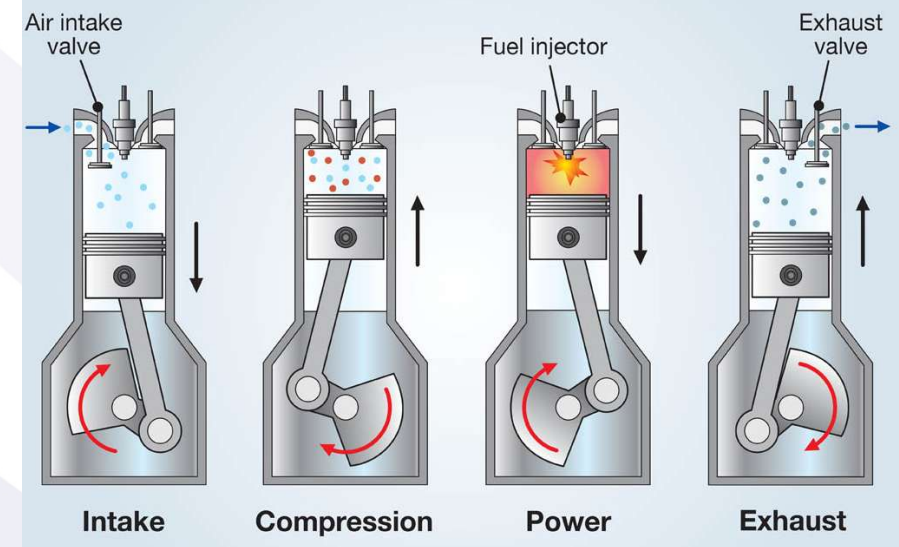


Description of a marine diesel engine

Main characteristics:

- Number of stroke (2 or 4)
- Type of combustion cycle (Otto or Diesel)
- Shaft Rotation speed (rpm)

4-stroke engine piston displacement Diesel cycle



1. **Intake:** Air into the cylinder through the air inlet valve. Piston moves down.
2. **Compression:** Piston moves up, compression of the air mixture, heats up. Fuel injected through the fuel nozzle.
3. **Power stroke:** As the air-fuel mixture ignites and burns, it pushes the piston down, driving the crankshaft.
4. **Exhaust:** Exhaust valve opens, gases are pushed out by the returning piston.

2-stroke engine: only 2 piston displacements for 1 power stroke. Different piston/cylinder head design.

Description of a marine diesel engine

Type of combustion cycle / Rotation speed

Diesel or Otto cycle ? It depends on the type of combustion

- **Otto cycle: Ignition** engine. The combustion is initiated using a spark plug or injection of **pilot fuel**.
- **Diesel cycle: Compression** engine. Fuel auto-ignition due to very high pressure obtained by compression.

Rotation speed - 3 categories (as in Reg. 13)

- **low-speed** engines **<300 rpm**: usually 2-stroke engines. For large ocean-going vessels.
- **medium-speed** engines **300–1,000 rpm**. Ferries.
- **high-speed** engines **>1,000 rpm**: 4-stroke engines. Tugs, service vessels.

Average efficiency of marine diesel engines

- 60-70%. Considered very good compared to other propulsion types (turbines, electrical)

Description of a marine diesel engine



Man Engine



Wartsilla Engine



Mitsubishi Engine



Caterpillar Engine



Cummins Engine



RollsRoyce Engine



Common Brands of Medium and high-speed engines

Largest 2-stroke, slow speed engine / Wärtsilä-Sulzer RTA96-C



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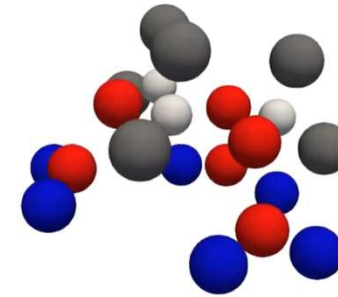
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Compliance with Tier III
Part 1

October 2026

Formation of NO_x

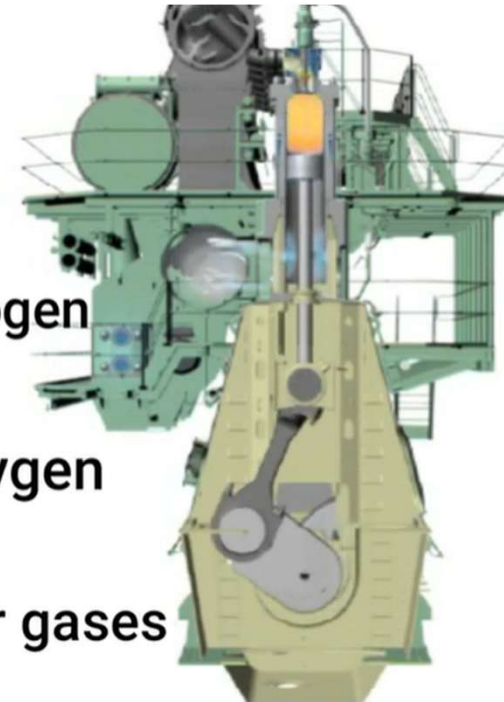
- Engine **intake air** is composed of Nitrogen and Oxygen.
- During the **fuel combustion process**, N remains largely unreacted; however, a small percentage **will be oxidized** with the O in excess, to form NO and NO₂,
- **Higher temperature** and longer exposure time
 - **higher** formation of NO_x
 - But...higher engine temperature (> 1300°C) = **more efficient engine** = but more NO_x ...
- A **slow-speed** diesel engine tends to have more NO_x formation than a high-speed engine.



about 78% - Nitrogen

about 21% - Oxygen

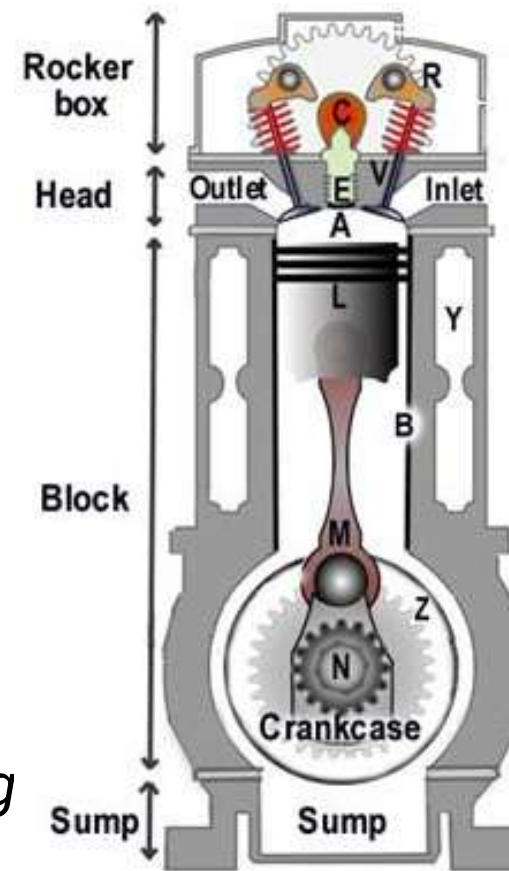
about 1% - other gases



Engine parts

Parts impacting NO_x formation

- **Fuel oil injection system** and injection pump
- **Injector valve/plunger**
 - *impacts injection pressure and injection rate*
- **Piston**
 - *involved in compression ratio*
- **Cylinder head**
 - *involved in compression ratio and mixing fuel/air*
- **Cam (camshaft)**
 - *regulates the timing of fuel injected*



Engine at TDC

A - Cylinder
B - Cylinder liner
C - Cam & cam shaft
E - Injector or spark plug
M - Connecting rod
N - Crankshaft
R - Rocker
V - Valve
Y - Water jacket
Z - Flywheel (external)



Original Wärtsilä
Cylinder
Head with valves

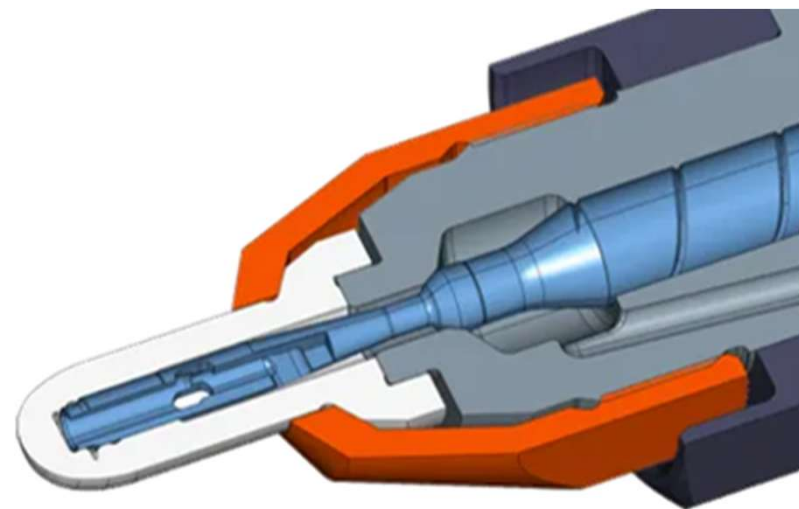
Mship.no

Engine parts

Parts impacting NO_x formation

- **Air cooler**
 - *affects air and cylinder temperatures*
- **Turbo charger**
 - *controls pressure and amount of inlet air*

All those parts are considered “**critical**” and are referenced in the **Engine NO_x Technical File** (see Session 2).



Prolonged injector needle and adapted nozzle atomizer, on a Wärtsilä FAST fuel injector. Source: Wärtsilä

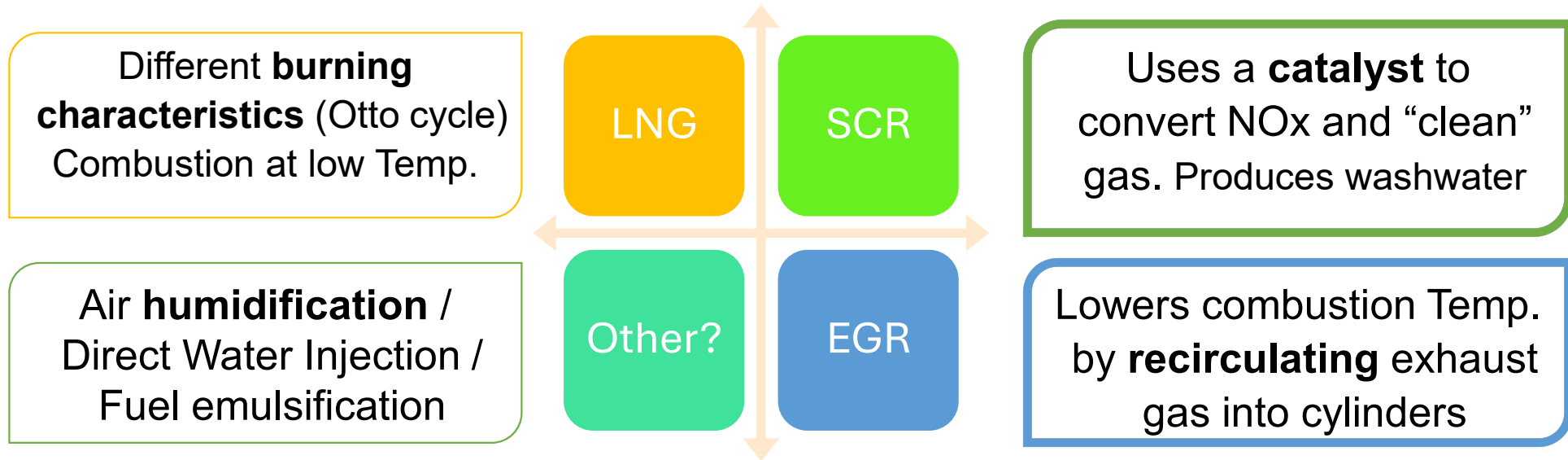


ABB Turbocharger



Tier III Compliance methods

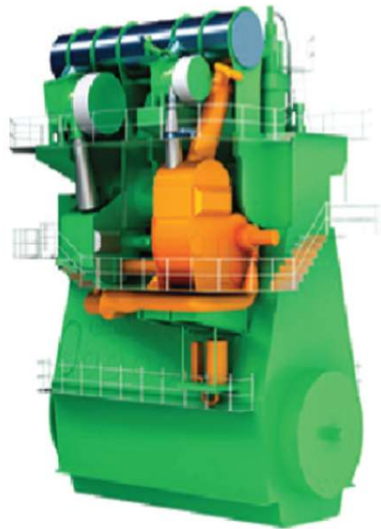
Different approaches to reduce NO_x emissions



- Selective Catalytic Reduction **SCR**
- Exhaust Gas Recirculation **EGR**
- Using **gas LNG/bioLNG** as fuel
- **Other** options but less developed

EGR and SCR solutions

- Exhaust Gas Recirculation **EGR** (low and high pressure options here)
- Selective Catalytic Reduction **SCR**



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Examples of Tier III engine – EGR, HP SCR and LP SCR solutions

Source: Everllence B&W Two-stroke Marine Engines, Emission Project Guide, for Marpol Annex VI Regulations, Copyright © 2026 Everllence



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Selective Catalytic Reduction (SCR)

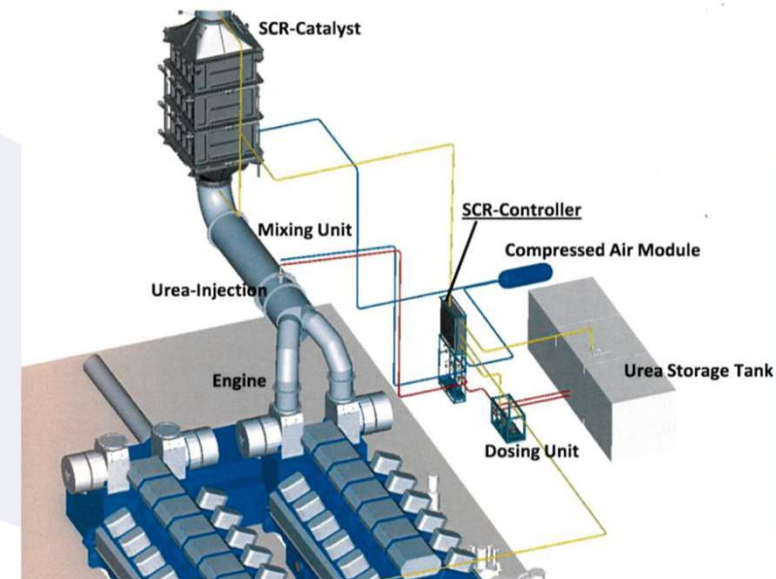
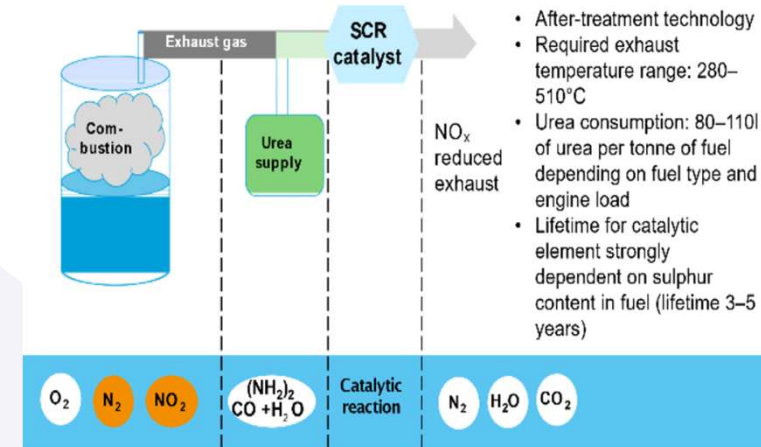
Installed in/around the exhaust funnel.

A **urea-water solution is injected into the exhaust gas stream**, where it reacts with a **catalyst** unit.

- Reducing agent : **ammonia** in the form of urea solution
- Chemical reactions take place on the **catalyst**:
 - ammonia reacts with NO_x to produce nitrogen and **water**.
- Requires **urea tank on board**

The **exhaust gas temperature affects** the catalyst's performance.

Source: ABS Advisory on NO_x Tier III compliance; and CIMAC 2025 Congress paper by Fabian Kock, DNV



Source: MEPC 66/INF.4 Euromot

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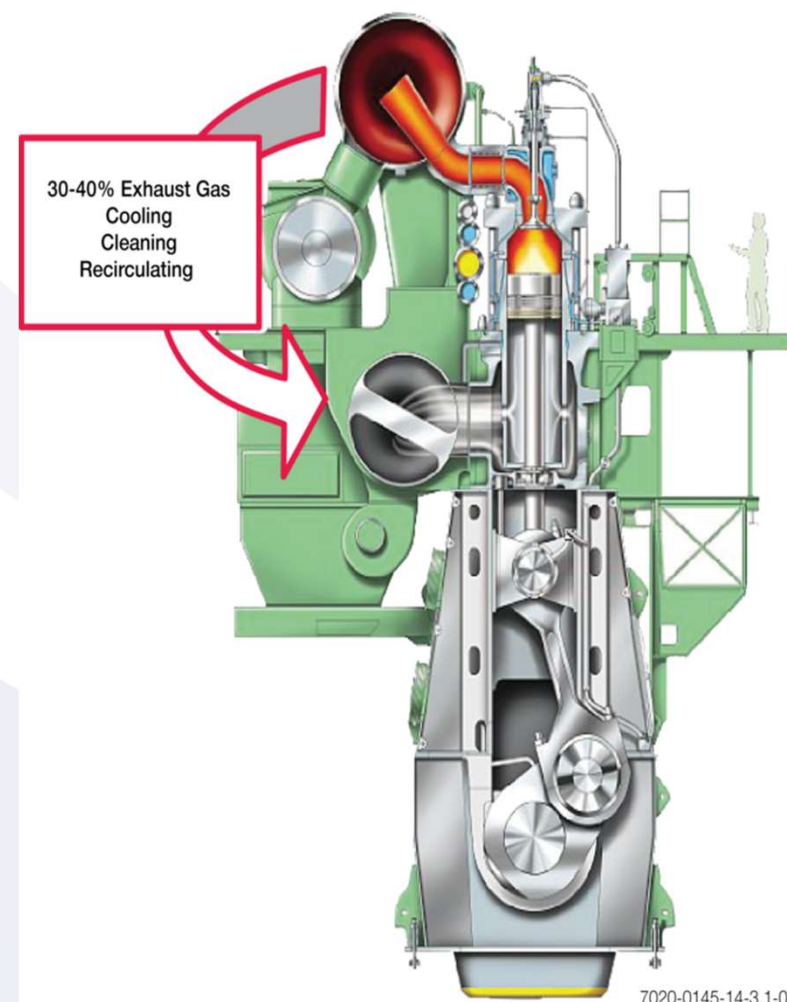
Exhaust Gas Recirculation (EGR)

A portion of the **gases** (30-40%) is redirected to the **intake** side of the engine and **re-enters** the cylinders:

- **Reduces** the amount of O₂ and **increases** CO₂ in the air used for combustion
- peak **combustion temperature** **reduces** significantly
- **reduced** NO_x formation

Drawbacks of EGR

- reduced combustion **efficiency**
- increased **PM** emissions
- recirculated gases need to be **cleaned** and **cooled** (by fresh water = washwater needs to be stored or treated). Source: ABS Advisory on NOx Tier III compliance



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Principle of EGR. Source: Source: Everllence B&W Two-stroke Marine Engines, Emission Project Guide, for Marpol Annex VI Regulations, Copyright © 2026 Everllence

Alternative fuels for NO_x Tier III compliance

Fuel type	Tier III compliance possible?
Methanol	NO - Methanol produces 50% less NO_x than FO . Need to combine with SCR. (Source: Wartsila https://www.wartsila.com/marine/decarbonisation/adopting-methanol-as-marine-fuel)
Ammonia	NO - Ammonia combustion naturally lowers NO _x emissions by 40% to 50% compared to traditional diesel operation. Need to combine with SCR (Source: Ammonia Energy association).
LNG in dual fuel or gas engines	YES – But when engine is operated in 100% gas mode only. Need to install a SCR equipment for Tier III compliance due to the use of pilot fuel oil .
Note on the Use of Otto Cycle with different fuels	<i>Dual Fuel engines using the “lean burn” Otto cycle to burn natural gas or alternative fuels such as methanol, ethanol, LPG or dimethyl ether (DME) have much lower NO_x emissions than those using the diesel combustion cycle, as the combustion Temp. is lower. Otto cycle gas engines can meet the Tier III limits without emissions abatement equipment – but the use of pilot fuel (FO, MDO) will generate NO_x and SCR could be required for this reason.</i>



Let's pause and reflect!

True or False – Poll with your mobile

Q1 - Compliance with Tier III limit can be achieved by using new generations of low carbon fuels such as biomethanol or zero carbon fuels such as ammonia.



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TEEQTFF

Display results: <https://app.wooclap.com/events/TEEQTFF/live-session>



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True or False as a poll with mobile

Q1 - Compliance with Tier III can be achieved by using new generations of low carbon fuels such as biomethanol or zero carbon fuels such as ammonia

- **NO - FALSE**
- Methanol, ammonia will require the addition of a SCR system – LNG or other liquid gas could reach Tier III if the engine operates on an Otto cycle, but the use of pilot fuel (to initiate ignition) could be problematic.
- Display results: <https://app.wooclap.com/events/TEEQTFF/live-session>

True or False as a poll with mobile

Q2 - A Selective Catalytic Reduction SCR system is designed to prevent NO_x formation when the fuel burns inside the engine combustion chamber.



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True or False as a poll with mobile

- **Q2 - A Selective Catalytic Reduction system is designed to prevent NOx formation when the fuel burns inside the engine combustion chamber**
 - **NO - FALSE**
- It is an “add-on” equipment, fitted outside the engine to collect and clean the exhaust gas produced by combustion. In contrast, EGR involved internal recirculation of the exhaust gas.

Display results: <https://app.wooclap.com/events/TEEQTFF/live-session>

True or False as a poll with mobile

- **Q3 - A slow-speed diesel engine is likely to generate greater volumes of NOx than a high-speed engine.**



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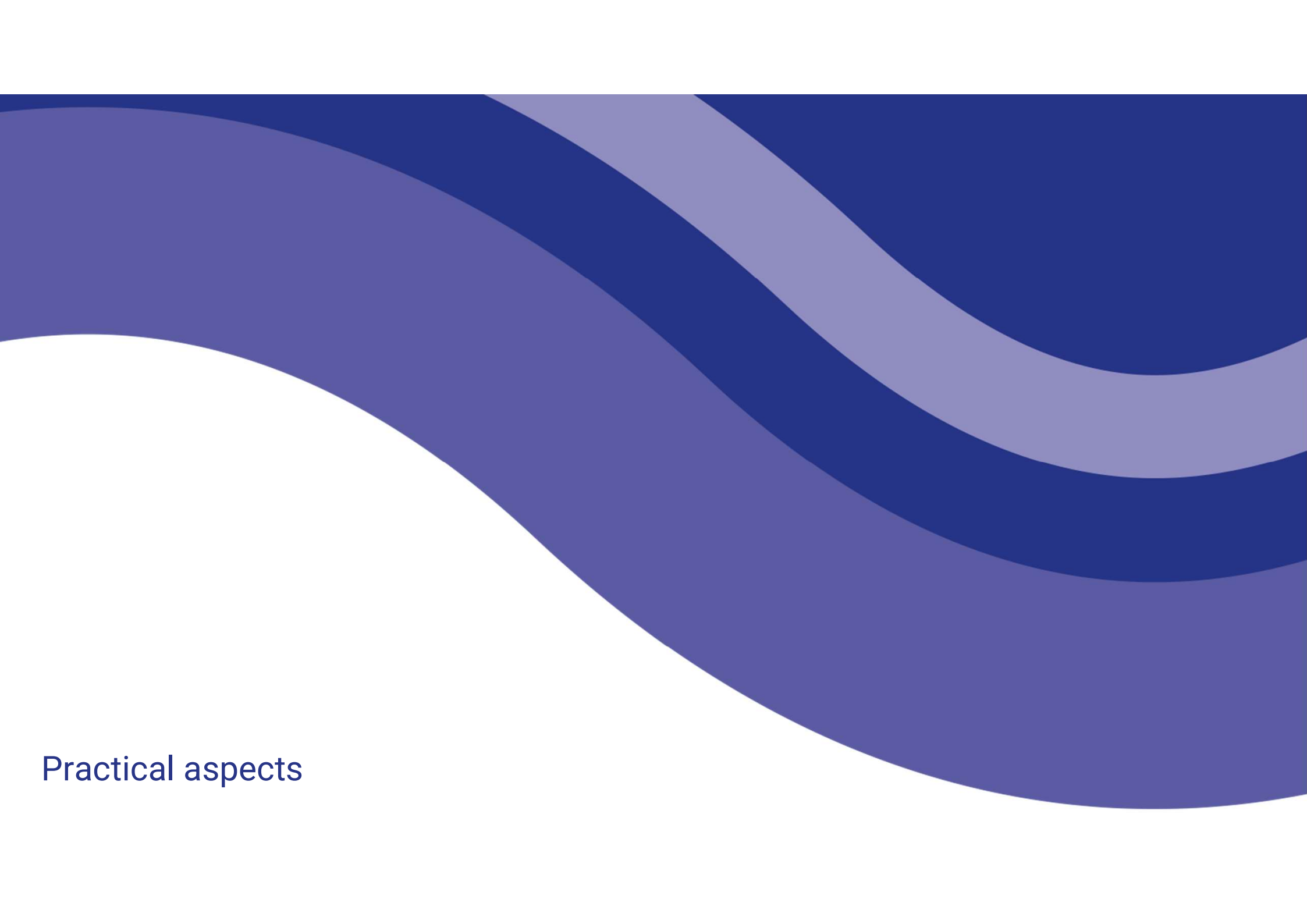
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True or False as a poll with mobile

- **Q3 - A slow-speed diesel engine is likely to generate greater volumes of NO_x than a high-speed engine**
 - **YES - TRUE**
- Generally, 2-stroke engine at 60–120 rpm. Longer combustion duration and higher cylinder Pressure and Temperature.

True or False as a poll with mobile

- **Compliance with Tier III NO_x limit can be achieved for marine diesel engines by using new generations of low carbon fuels such as biomethanol or zero carbon fuels such as ammonia**
 - **NO**
 - Methanol, ammonia will require the addition of a SCR system – LNG or other liquid gas could reach Tier III if the engine operates on an Otto cycle, but the use of pilot fuel (to initiate ignition) could be problematic
- **A Selective Catalytic Reduction system is designed to prevent NO_x formation as the fuel burns inside the engine combustion chamber**
 - **NO**
 - It is an “add-on” equipment, fitted outside the engine to collect and clean the exhaust gas produced by combustion. In contrast, EGR involved internal recirculation of the exhaust gas.
- **A slow-speed diesel engine is likely to generate greater volumes of NO_x than a high-speed engine**
 - **YES**
 - Generally, 2-stroke engine at 60–120 rpm. Longer combustion duration and higher cylinder P and T



Practical aspects

Practical aspects – dual-Tier engines

One engine may have two Tier modes

Most Tier III engines have the ability to operate under **two** modes - called the “**dual-tier approach**”:

- **Tier III** when they enter an **ECA**
- **Tier II** for the rest of the time

Why ? For saving purposes

The ability to “pause” SCR or EGR minimizes their use, the associated **costs** including **energy consumption**

- When **EGR** is operative, the specific **fuel oil consumption** (SFOC) will increase due to changes in the combustion process.
- With **SCR**, when “off”, it saves on the consumables (urea).

Since the engine has **two emission cycle operating modes**, compliance shall be demonstrated for each operating modes, Tier II and Tier III.

And the ship must monitor when Tier III mode is engaged or not.

- **Mandatory records of the Tier and on/off status of each marine diesel engines while the ship is a NECA (Reg.13, para 5.3) in logbook or ERB.**

Practical aspects – MEOP

Multiple Engine Operational profiles - MEOP

The Engine operational profile is a particular **group of settings** applied, influencing the NO_x emission performance. For ex. fuel injection, inlet and exhaust valves operation, charge air management, or exhaust after-treatment controls. It is a defined **combination of engine operating parameters/settings** under which the engine is certified.

Modern engines can have sophisticated **electronic control systems** and manufacturers can create **different combinations** of fuel injection and valves timing; injection pressure; turbocharger settings; etc.

And therefore, different NO_x emission characteristics.

Operational Profile	Purpose
Profile A	Normal operation in open seas
Profile B	Operation in harbour or restricted waters
Profile C	Other operating condition (heavy weather)

Multiple engine operational profiles means that **more than one profile is available** and may be selected on the engine. It allows an engine to switch between multiple software or mechanical operational modes.

MEOP Formally recognized in 2025 through amendments to the NTC 2008.



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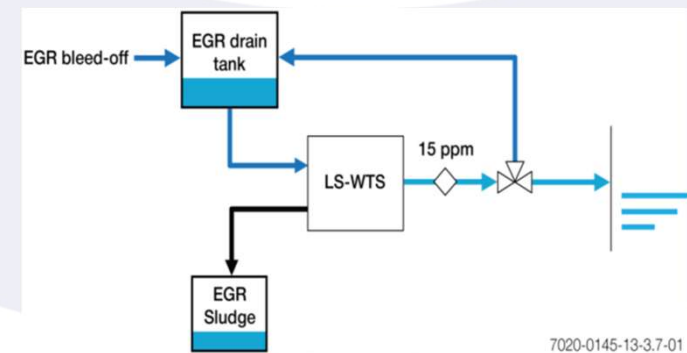
Practical aspects – Sulphur and water

Influence of sulphur

- In addition to meet the Tier III NO_x requirement, ships sailing in a **combined NO_x and SO_x ECA** must **either run on low-sulphur fuel** or use an exhaust gas cleaning process (EGCS, i.e. scrubber)
- When planning the Tier III installation, these conditions must be taken into account. For ex, manufacturer Everllence states that:
“The EGR system and the SCR system **cannot be used for high sulphur fuel** on two-stroke engines = low sulphur fuels **MUST** be used, as adding a scrubber is not an option (Source: Everllence 2026 Guide)

Discharge of the bleed-off water from an Exhaust Gas Recirculation system

- The bleed-off water **accumulated in the EGR drain tank** must comply with the **15 ppm** criteria before discharge – as per the 2015 Guidelines for exhaust gas cleaning systems (MEPC.259(68))





Conclusion

**Any question or
clarification,
please ask!**

End of

**Compliance with NOx Tier III
standards**

Part 1 – Technical aspects

And now

**Part 2 – Implementation and
enforcement**



**Compliance with Tier III
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