Selective Catalytic Reduction FAQ

WIN GD
Simply a better different

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1. Why select SCR for low-speed engines?

1.1. Why WinGD is promoting SCR for low-speed engines?

SCR is a well-proven and consolidated technology

Selective catalytic reduction (SCR) is a proven technology launched more than 40 years ago, for cleaning NO_X from exhaust gas emitted by internal combustion engines.

During the past decade, the automotive industry has largely replaced exhaust gas recirculation (EGR) technology with SCR to achieve the lowest NO_X limits required by regulations.

SCR is the marine industry standard for medium and high speed engines

SCR is the industry standard and the most used technology for removing NO_X from exhaust gas of four-stroke main and auxiliary engines in marine and stationary applications.

WinGD has extensive and broad experience with SCR systems, with over 600 units ordered/installed in a large variety of engines and applications:

- Diesel and high-pressure (HP) gas engines
- Marine and stationary applications
- four and two-stroke engine applications

1.2. What are the benefits of SCR compared to EGR?

SCR has a lower initial investment cost than EGR

The investment cost of a Tier III solution for a low-speed engine depends on the type of engine and ship, the power of the engine, the amount of exhaust gas to clean, etc.

For most ship segments, the initial investment cost of the SCR is lower than that of EGR.

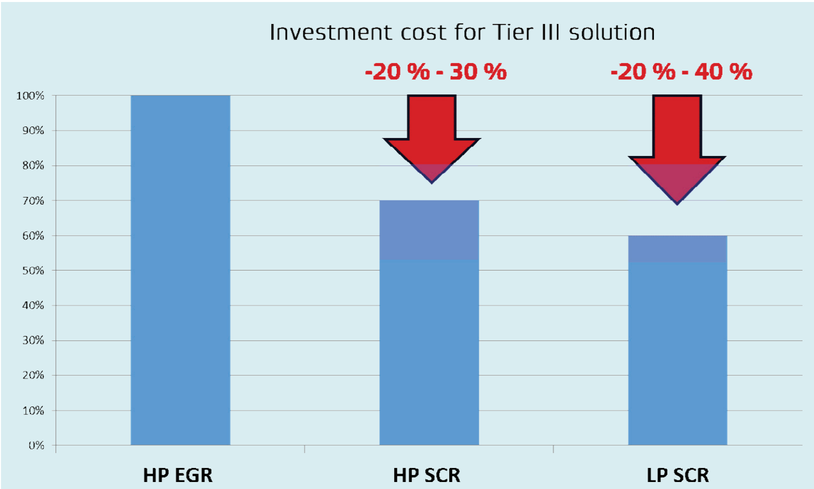


Figure 1: Indicative initial investment cost comparison for HP EGR, HP SCR and LP SCR.

SCR and EGR have similar total consumable costs

Both SCR and EGR create operational costs when cleaning NO_X from exhaust gas. The source of the operational costs are different as shown in the table below. The total operational costs for SCR and EGR are similar.

HP SCR	HP EGR
Urea consumption (average about 18 g/kWh)	NaOH consumption
Fuel penalty is up to 2 g/kWh at low engine load only	Fuel penalty for EGR is between 3-8 g/kWh (across the entire engine power range)
Negligible energy consumption for the ancillary systems, such as the urea system and soot blowing	High energy consumption for the water treatment system, blower, additional cooling water and sludge
No second pollutant is created	EGR produces a second pollutant discharged against a fee

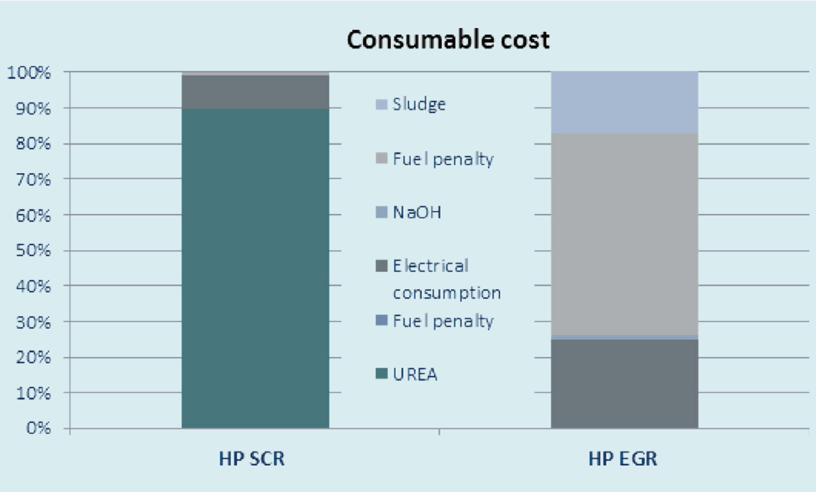


Figure 2: Indicative consumable cost comparison for HP EGR and HP SCR.

SCR is a less complex system to install and maintain than EGR

The following table shows the main components of HP SCR and HP EGR

HP SCR	HP EGR
SCR on/off valves and control	**Exhaust Gas Recirculation system:** cylinder bypass, EGR on/off valves, EGR blower, EGR cooler and control
SCR reactor and catalyst elements	**Scrubbing system:** Scrubber, fresh water production, tank, pump, filter and injection system
Urea system: tank, pump, filter and injection	**Caustic soda:** tank, pump, filter and mixing unit
Soot blowing system: bottles, filter, injectors	**Black water treatment:** Pumps, filter, sludge filter, air compressor, drain & sludge tank

SCR has no impact on steam production

With SCR in operation, it is still possible to generate steam using the exhaust gas economizer which produces the same steam production power. With EGR, steam production is reduced by about 40% due to exhaust gas recirculation.

SCR does not impact piston running and combustion behaviour

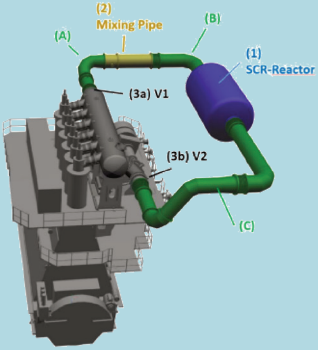
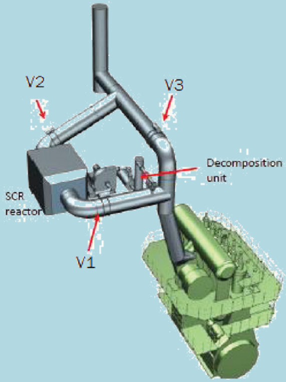
SCR is a post-combustion system and causes no change to the in-cylinder air and piston running. EGR may have an impact on piston running behaviour because of the changed combustion and Sulphur content in the recirculated gas.

2. SCR Concept & design

2.1. What are the differences between high-pressure (HP) and low-pressure (LP) SCR?

There are several differences between HP and LP SCR. Below are the most important:

Reactor position

HP SCR	LP SCR
The reactor is before the turbocharger. The exhaust gas in the reactor has a higher pressure (max 4 bar(g)) and temperature.	The reactor is after the turbocharger. The exhaust gas in the reactor has a relatively lower pressure (about 0.6 bar(g)) and temperature.
 An HP SCR system has 3 main design features. The SCR reactor (1), a pipe section, known as the Evaporation or Mixing Pipe for urea injection and evaporation (2), and the interface valves to the engine (3a/3b)	 An LP SCR system has the following design features: the SCR reactor, the decomposition unit for ammonia generation and the control valves (V1, V2, V3)

The HP SCR reactor is typically installed in the engine room. The ship designer has the choice to position the reactor in a horizontal or vertical position according to the engine room layout and available space.

The LP SCR reactor is typically installed outside the engine room in the stack. This provides more flexibility for the ship designer. However additional components such as the fuel burner and blower must also be integrated in the ship design.

Ammonia generation

HP SCR	LP SCR
Urea is injected into the mixed piping with high temperature exhaust gas, no energy consumption	Through ammonia generation using a fuel oil burner

Minimum working temperature

HP SCR	LP SCR
Exhaust gas temperature before turbocharger: • 310°C for fuel <0.1%S	Exhaust gas temperature after turbocharger: • 230°C for fuel <0.1%S

Fuel penalties

HP SCR	LP SCR
≈ 0-3 g/kWh between 25-40% of engine power	≈ 0-3 g/kWh between 25-50% of engine power ≈ 0-2 g/kWh between 50-80% of engine power

Engine interfaces

HP SCR	LP SCR
Engine mechanical modifications: • Exhaust gas manifold • Engine gallery • Turbocharger connections	No engine modification
SCR bypass valves controlled by the engine control system	SCR bypass valves controlled by the SCR system control

SCR components

HP SCR	LP SCR
Urea Tank	Urea Tank
Compressed air bottle tank	Compressed air bottle tank
Compressed air system	Compressed air system
Urea supply	Urea supply
Soot blowing system	Soot blowing system
SCR valves	SCR valves
-	Burner
-	Blower

2.2. Which parties are involved in the supply of SCR systems and what are their responsibilities?

The engine manufacturer, the engine designer (WinGD), the SCR supplier and the shipyard are all involved in SCR project developments.

WinGD's responsibility and tasks

WinGD defines the mandatory technical requirements and the system design guidelines for the SCR system and the engine tuning.

In addition, WinGD designs the engines' mechanical and electrical interfaces to the HP SCR system. As a licensor, WinGD is responsible for engine performance and delivers the engine design and tuning optimised for Tier III compliance.

In the case of HP SCR, WinGD also delivers the SCR valve control system.

Engine manufacturer

The engine manufacturer produces the engine in accordance to WinGD's design and includes the mechanical and automation interfaces (in the case of HP SCR).

The engine manufacturer is responsible for the IMO Tier III NO_X certification.

SCR supplier

The SCR supplier designs and manufactures the key SCR elements.
The reactor, mixing pipe, ammonia generator, the catalyst element with appropriate size and volume, urea injection system, soot blowing system, urea dosing system, etc.

The SCR supplier provides detailed interface and mounting specifications to the engine manufacturer and shipyards.

Shipyard

The shipyard designs the structural support for the reactor housing and ducting, and arranges the SCR system on the ship.

The shipyard designs, procures and manufactures the connecting piping, compensator, flanges etc. and carries out the final assembly of the SCR system on the ship.

2.3. Is SCR applicable for engines with more than one turbocharger?

Both LP and HP SCR are possible solutions for engines with more than one (1) turbocharger application. WinGD has developed several configuration solutions that are available on demand.

3. SCR and engine operation

3.1. What engine tunings are possible with SCR?

All the available tunings for WinGD's low-speed engines are applicable for both, HP and LP SCR.

Available engine tunings	Tuning Options	
	HP SCR	LP SCR
Standard: high load tuning, Tier II compliant, optimised for engine loads above 90%. (not recommended for current operating scenarios)	✓	✓
Delta: part load tuning, Tier II compliant, optimised for engine loads between 75% – 90%. – electronic tuning of the engine	✓	✓
Delta Bypass: part load tuning with a lower BSFC below 50% engine load, Tier II compliant, optimised for increasing steam production above 50% engine load and reduced fuel consumption below 50% engine load.	✓	✓
Low load: Tier II compliant, optimised for engine loads below 75%.	✓	✓

The tuning options "HP SCR" and "LP SCR" will ensure that the exhaust gas temperature is always above the minimum required temperature for reliable operation of the SCR system. In case the exhaust gas temperature goes below this minimum required temperature, the engine control system reacts and adequately increases the temperature.

3.2. Does low ambient temperature affect the SCR system?

Cold external conditions have no impact on the SCR system because the engine's Tier III tuning will control the exhaust gas temperature so that it stays above the minimum required low temperature.

3.3. What is the acceptable back pressure for HP SCR and LP SCR?

HP SCR back pressure

The maximum acceptable pressure drop for the entire HP SCR system over its lifetime must be kept below a maximum acceptable limit.

A proper pre-calculation and piping system design must ensure that the pressure drop of the SCR system including the piping (without the bypass valves) does not exceed 70 mbar.

An "SCR Valve Control System" monitors the pressure drop values across the main components. It will trigger an alarm and set up counter-measures should the pressure drop exceed the set values.

LP SCR back pressure

The maximum allowed back pressure created by the LP SCR system is 300 mm WC. In combination with the economizer, silencer and other piping, the maximum back pressure is 600 mm WC on a new installation.

3.4. What is the purpose of the soot blowing system? How does the soot blowing system operate?

The accumulation of deposits, like soot and ash, is very likely to occur on the surface of the catalytic elements. The soot blowing system regularly removes such deposits with a dedicated soot blowing line provided for each catalyst layer in the reactor.

The soot blowing is controlled and enforced by the SCR control system. Typically, the soot blowing is operated automatically and sequentially at a pressure of 8 bar(g).

3.5. Is reactor trace heating needed?

The SCR supplier will decide whether reactor trace heating is required and will supply the relevant specifications.

Currently, there are no regulations that require the installation of trace heating. This may depend on the customer's operational profile and individual requirements.

How much power is needed for trace heating?

The energy required depends on how fast the customer would like to heat the catalyst element and on the volume of the catalyst elements. According to our experience and current projects, the pre-heater power is well below 50 kW.

How is trace heating for the HP SCR's reactor used in an ECA port?

If the ship's port stay is short, the catalyst elements will still be hot after the engine has been switched off. Therefore the pre-heater (if switched on at this moment) will provide a small amount of energy to compensate for the thermal dissipations of the reactor, and will keep the catalyst element at the right temperature.

How long does it take to pre-heat the HP SCR's reactor when the ship enters an ECA area?

In the case of the ship entering an ECA area, the catalyst elements are heated by partially opening the SCR valves according to a specific heating procedure.

Before the SCR system is switched on, the catalyst elements need to be heated to the minimum SCR operational temperature before any reducing agent is injected.

3.6. Is thermal shock to the catalyst elements a concern when starting up under cold ambient conditions?

Thermal shock to the catalyst elements is avoided by taking into consideration the thermal gradient recommendation from the catalyst element supplier.

The catalyst elements are heated according to a given time-temperature law; both the traced heater and the SCR valve control system will take into account the heating gradient parameters during the heating procedure.

4. Catalyst element

4.1. What is the lifetime of catalyst elements in an SCR system?

It is common practice to assume that the lifetime of the catalyst elements is 5 years, i.e. the time corresponding to the ship's dry-docking schedule.

The proper maintenance of the catalyst elements is the key to extended life and a well-functioning SCR installation. As well as soot blowing and the ammonia bi-sulphate (ABS) regeneration measures, manual maintenance is also important.

4.2. How many running hours (RH) do the catalyst elements in an SCR system last?

The maximum number of running hours (RH) for the catalyst elements depends on the design of the SCR system (e.g. the volume of the catalyst element, flow velocity, layers, fuel type, engine operating profile, etc.).

Therefore, the maximum RH of catalyst elements is the result of the SCR supplier's design, taking into account the customer's operating profile for a lifetime of 5 years, and the need to keep the reactor size within reasonable dimensions.

4.3. What are the typical weight and dimensions of a catalyst block inside the SCR reactor?

The catalyst element blocks are designed so that they can be dismounted and removed without any special tools. The typical catalyst element block measures 300x300x500 mm and weighs 24 kg.

4.4. How can the used elements of a catalyst block be disposed of?

Metal from the canisters/frames/cassettes is recycled as normal metal. Local disposal of the catalyst blocks is managed through recycling waste disposal companies. The supplier of the catalyst can provide advice regarding disposal globally.

5. UREA handling

5.1. Why is urea used for SCR and what is the required grade of urea?

The chemical element required for the reaction of NO_X to water and Nitrogen is Ammonia (NH_4). However, ammonia is difficult to store and handle on a ship and is therefore generated from urea. Urea is stored and transformed into ammonia after injection into the exhaust before entering the reactor. Urea is injected into the exhaust gas stream mixed with compressed air or fresh water.

The standard Aqueous Urea Solution (AUS) for marine applications is 40% urea in water (Marine urea/AUS40). The appropriate quality requirements for the urea solution are presented in ISO 22241. On board the vessel, a ready urea water mixture can be bunkered or stored. Urea can also be stored on board in powder or pellet form and can be mixed with purified water when needed.

5.2. What are the chemical and physical characteristics of urea?

AUS 40 urea has the following characteristics:

- Colourless liquid
- Not flammable
- Not classified as harmful by the class societies rules or other applicable rules.
- Not recorded as hazardous waste. Recovery possible through use as fertilizer
- Light ammoniac odour, the ammoniac content is less than 0.1%
- Density: 1.1 - 1.15 ton/m^3
- Decomposition/boiling temperature at 105°C at 1 bara

5.3. How should urea be stored on board a ship?

The general guidelines for urea handling and storage are prescribed in ISO 18622-3:2014.

The storage procedures of urea AUS40 are provided by the original SCR or urea supplier.

Urea (AUS40) must be stored at a temperature between 5°C and 35°C to avoid decomposition or salt deposits.

The storage time for urea solution is temperature dependent. A storage temperature of less than 35°C will keep the urea solution usable for more than a year. For example, at a temperature of about 20°C, urea can be stored for up to 2 years.

Urea tanks are to be kept clear from fire or high temperature sources to avoid evaporation. Urea is corrosive on carbon steels, nickel and non-ferrous metals (copper, zinc, etc.). Therefore, the urea tanks must be suitably coated or made of stainless steel or selected plastics. Furthermore, the recommendations from the class societies must be considered when designing the urea tank.

6. Rules and certification

6.1. Who is responsible for arranging the Tier III engine certification and who is the SCR system supplied to?

The approved SCR supplier delivers the SCR system to the engine manufacturer (only for the parent engine). The engine manufacturer needs to ensure that the parent engine with SCR meets Tier III NO_X emissions levels during shoptest. The Tier III certification is issued by the Classification Society, according to IMO scheme "A" test procedure.

For member engines, the SCR system is delivered directly to the shipyard

6.2. Is on board NO_X monitoring mandatory in ECA areas?

NO_X monitoring system is not mandatory and is not explicitly requested by the applicable rules in force.

6.3. How long does it take to carry out the Scheme B test on board?

Discussions regarding the various test procedures are ongoing and are not yet finalised. WinGD is actively participating in these discussions, which also include the test procedures according to scheme B, with IACS (and IMO).

Winterthur Gas & Diesel Ltd. (WinGD) is a leading developer of two-stroke low-speed gas and diesel engines used for propulsion power in merchant shipping.

WinGD sets the industry standard for reliability, efficiency and environmental sustainability. WinGD provides designs, training and technical support to engine manufacturers, shipbuilders and ship operators worldwide.

WinGD is headquartered in Winterthur, Switzerland, where, as one of the earliest developers of diesel technology, it started the design of large internal combustion engines in 1893 under the "Sulzer" name.

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