

The Nitrogen Oxides Reducer

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The latest proposals for reducing NO_x emissions from ships stipulate that by 2016, emission levels will be some 80% lower than at present. Wärtsilä is in the forefront of providing a feasible solution to this challenge.

Legislation

Since the year 2000 the IMO and other legislative bodies, including national authorities, have been concerned about nitrogen oxide (NO_x) emissions from ships. In 2005, the first global legislation from the IMO came into force covering all new ships built after the year 2000. This legislation was the first step, but due to the increase in sea traffic and the rise in general concern for the environment, new measures were demanded.

During 2008 new rules have been proposed that are expected to be ratified before the end of the year (Figure 1).

The proposal suggests that further NO_x reductions from ships be introduced in two steps. The first step, known as Tier II will introduce a reduction of about 25% from the Tier I level and will cover all seas. This Tier II limit will enter into force in 2011. The second step, Tier III, will further reduce NO_x emissions by about 80% of the Tier I level. Tier III will enter into force in 2016 but will be limited to certain sea regions, known as NECA.

The designation of these NECA areas involves a complex process that is being handled by the IMO. The procedure will start with the request from local authorities, and will involve an evaluation of ship traffic pollution and the potential benefits to the area arising from this exclusive action. It is expected that this procedure will take from 3 to 5 years to complete.

Possible NO_x abatement methods

With the above in mind, Wärtsilä has positioned itself to be able to offer its customers a sound solution.

For Tier I, engine-related methods are by far the most viable since they do not require additional equipment onboard.

However, it is a completely different situation as regards the Tier II emission level. New technologies developed during recent years have demonstrated the ability to reach a maximum NO_x abatement of 60% from Tier I levels. While these technologies may be further developed to reach the Tier III target, they will require fairly substantial development before they become ready for marine use. This could result in a mismatch between the legislation entering into force and the technology development schedules. Another important point is the focus on CO₂ emissions and engine efficiency. The primary methods generally result in a decrease in engine efficiency, which means higher fuel consumption and higher CO₂ emissions.

CO₂ emissions are already targeted for limitation because of their impact on the greenhouse effect. Controlling fuel consumption is a primary consideration to any shipowner. The solution, therefore, is the SCR.

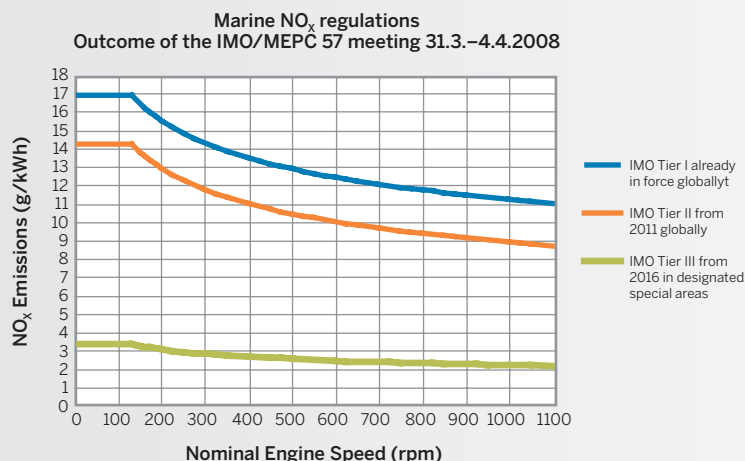
The Selective Catalytic Reactor (SCR) is a chemical reactor totally separated from the engine (Figure 2). The SCR is able to achieve substantial reductions in NO_x, usually in the range of 80-90%, with even greater reductions possible. The fact that the SCR is very powerful and its behaviour is not directly related to the engine set up, allows the benefit of having the highest possible engine efficiency with the lowest NO_x emissions.

This technology was developed during the 1970s, and has been widely utilized in several industries, including the marine industry, since then. It is a mature technology that has already proven its capability in meeting the goals for which it was developed.

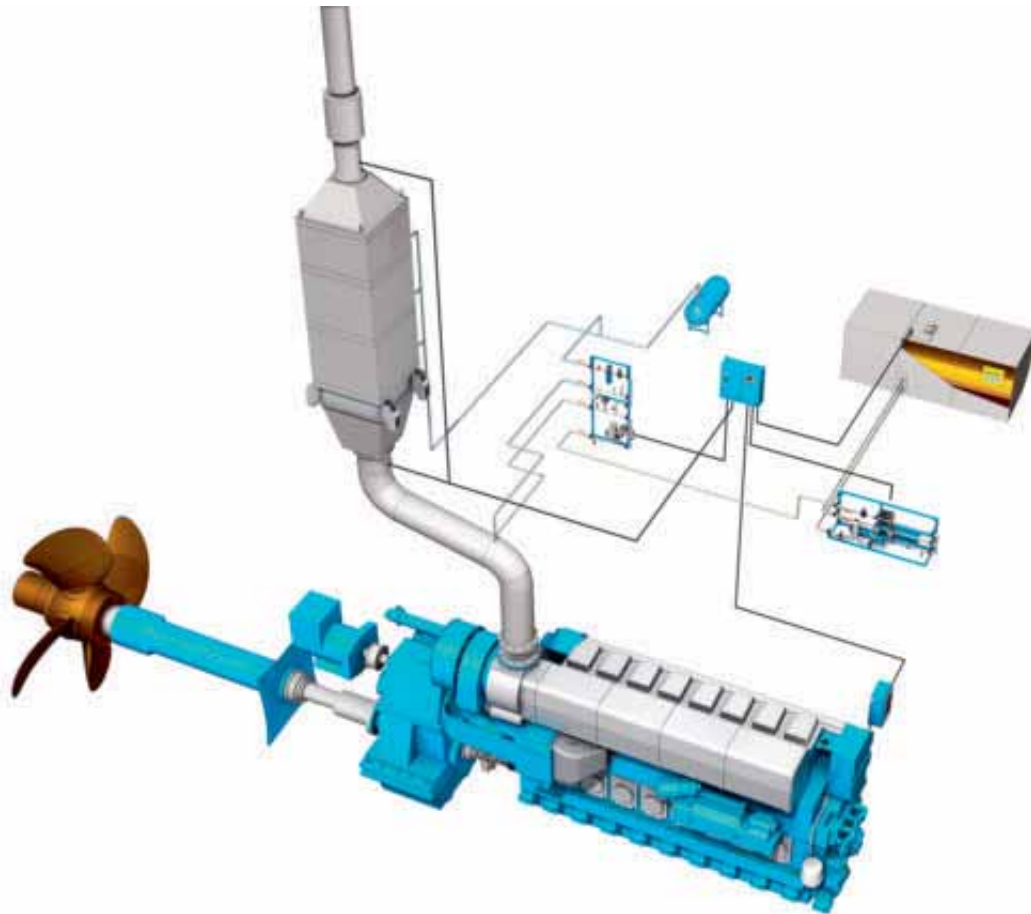
How a SCR works

Reaction description

The generation of NO_x occurs inside a diesel engine during the combustion phase in the spots where high temperatures are generated by the combustion of the fuel. In these spots a secondary reaction between the atmospheric nitrogen and



■ Fig. 1 – IMO proposal curves.



■ Fig. 2 – SCR general plant.

the oxygen occurs, thereby generating NO_x . The formation reaction should be reversible, meaning that the NO_x should decompose back to the basic elements when the temperature is reduced. Unfortunately, because of the fast temperature reduction in the cycle, this does not occur. The NO_x generated at high temperatures are frozen and remain present at relatively low temperatures.

It is possible to reverse this reaction also at low temperatures, but catalyst material and an additional reagent would be needed. In the SCR, the catalyst material is vanadium pent oxide. On its surface, the NO_x molecules react with the additional reagent, ammonia, and form back into nitrogen and water. The new compounds mix with the gas stream and leave the catalyst surface.

Ammonia is not present in the engines' exhaust gases so it has to be added. In the maritime industry, urea is preferred over ammonia for safety reasons. Ammonia is highly toxic, and

should a leakage occur aboard ship, it could be extremely hazardous.

Urea, on the other hand, is a harmless compound that can be handled directly without any special precautions. It comes in the form of small white crystals. Usually it is not handled in solid form but is instead used in a 40% urea: 60% water solution. The solution is much easier to pump and dose into the NO_x abatement system.

Once the urea solution is injected into the exhaust gases, first the water evaporates and secondly the urea goes through its own thermolysis. Thanks to the high temperature of the exhaust gases, the urea molecule breaks up into ammonia and carbon dioxides.

SCR components

The system is made up of several parts, which perform the different actions required by the process to reduce the NO_x (Figure 3).

The main components are:

- the catalyst
- the reactor
- the soot blowing system
- the pumping unit
- the dosing unit
- the injection system
- the control unit.

The catalyst.

The catalyst is in the shape of ceramic bricks, with a honeycomb structure inside so as to maximize the available surface to be exposed to the gases. The catalyst material is deposited on a ceramic support.

The reactor.

There is a reactor for every engine. It is usually made of iron, and its main function is to contain the catalyst.

The soot blowing system.

On the reactor there is also the soot blowing system. This function prevents the catalyst from being clogged by the →

soot present in the engine exhaust flow. It operates on a timing basis and blows the soot deposits away from the catalyst inlet.

The air used to operate the soot blowing system comes usually from the ship's service air system.

The pumping unit.

One pumping unit can serve several engines. This unit pumps the urea from the tank into the other components of the system and raises its pressure to the right level for injection into the exhaust gas stream.

The dosing unit.

A dosing unit should be installed for each reactor. The dosing unit provides the correct flow rate to the urea solution for injection. The flow rate is regulated via a dosing valve. The dosing unit also ensures that the pressurized air is at the correct pressure for injection.

The injection unit.

The urea is injected with the help of compressed air. The injector consists of

a mounting flange, a lance, and a nozzle. The flange is directly mounted onto the exhaust gas duct. The lance consists of two coaxial pipes; the inner one for the urea solution, and the external one for the compressed air. The lance must be long enough for the nozzle to be located in the middle of the duct. The two media mix in the nozzle, with the compressed air ensuring that the urea solution is finely sprayed into the exhaust gas stream.

A certain length is necessary in order to achieve complete water vaporization and the decaying of the urea into ammonia.

The control system.

The control system is mounted in a steel cabinet. The control system receives engine-load and NO_x-signals from the engine and calculates the amount of urea to be injected. Dosing, soot blowing, and tank heating are incorporated into the control system.

Limitations

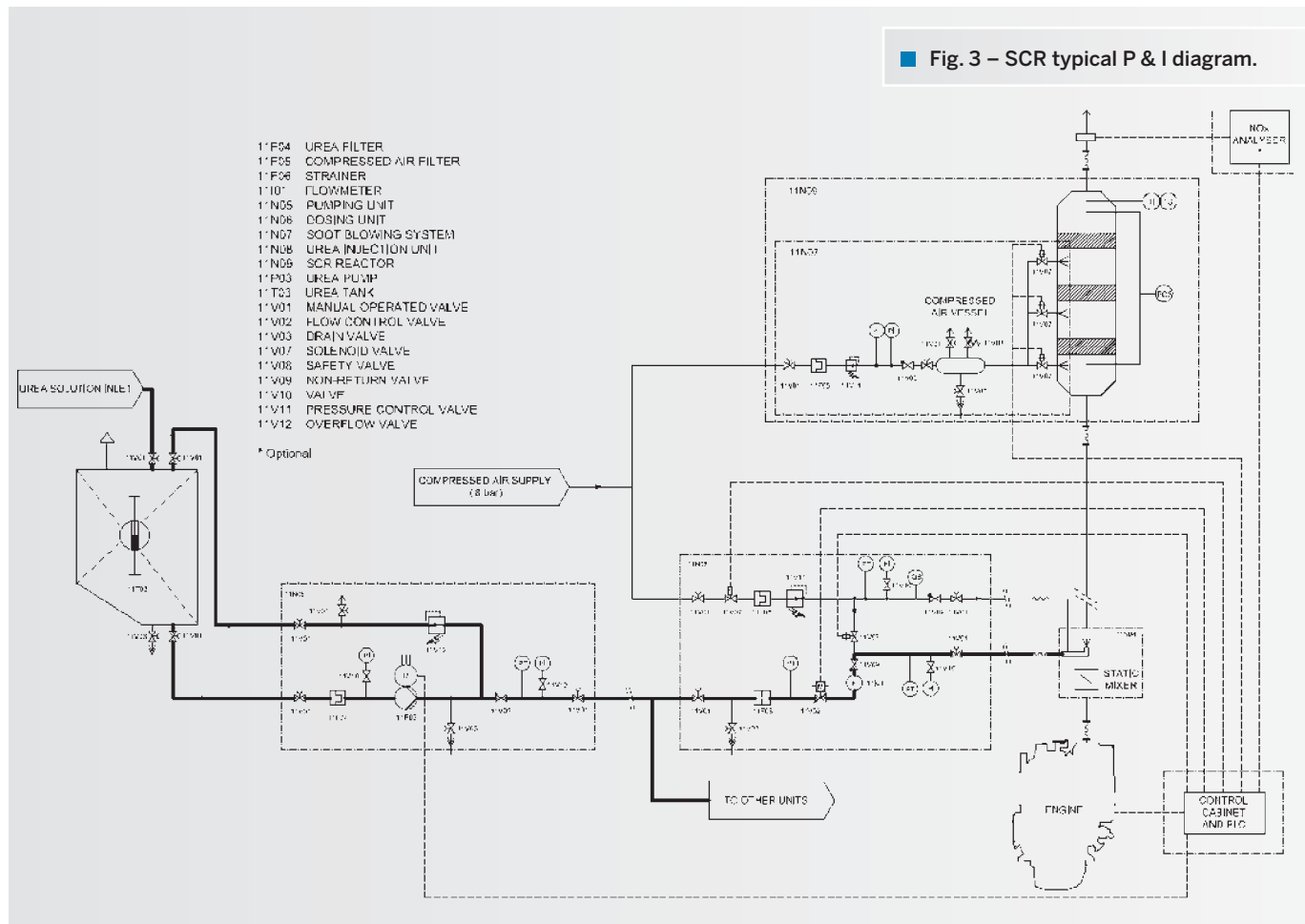
The working temperature of the SCR

system varies between 250 °C and 500 °C. Above 500 °C the ceramic support burns off and becomes ineffective. There are also two low temperature limitations. Firstly, low temperatures can limit the catalyst's efficiency by reducing the conversion factor. Secondly, at low temperatures a secondary reaction between the sulphur oxides and the ammonia occurs. The product is ammonia bisulphate (ABS), a sticky compound that can clog the catalyst. Figure 4 shows the trade off between the minimum recommended exhaust gas temperature and the sulphur content in used fuel.

In the case of ABS formation, it is still possible to remedy the situation if detected before the SCR is completely clogged. Increasing the exhaust gas temperature (by increasing the engine load, for example) will cause the ABS to be simply burned off, thus freeing the clogged channels.

The NOR design concept

Since the 1990s, Wärtsilä has supplied more than 100 engines equipped

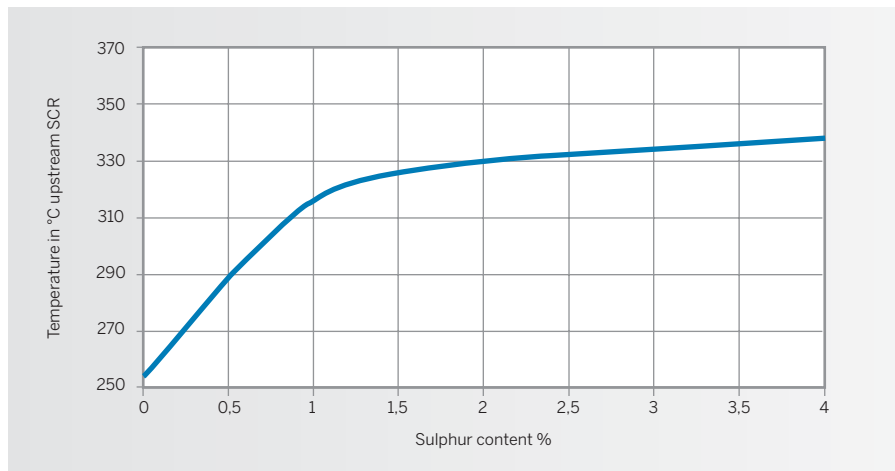


with SCR. In recent years Wärtsilä has noted a growing demand from its customers for this equipment.

As a result, Wärtsilä decided to develop a first class SCR portfolio to cover its 4-stroke engine portfolio. The name selected for this is the Nitrogen Oxides Reducer (NOR). In order to achieve this, Wärtsilä has signed agreements with its main sub suppliers. This allows Wärtsilä to be in full control of the know-how applied to its products, and to guarantee that top class technology will always be utilized.

Entering into a new market with new technology to offer its customers was not sufficient for Wärtsilä. Instead, it has been decided to enter the market with a high quality product that is, nevertheless, highly competitive also on the price level.

The company's purchasing organization has contributed to this goal by associating the SCR business with other businesses so as to generate volume in order to abate costs. At the same time, in order to reduce costs the equipment has been highly



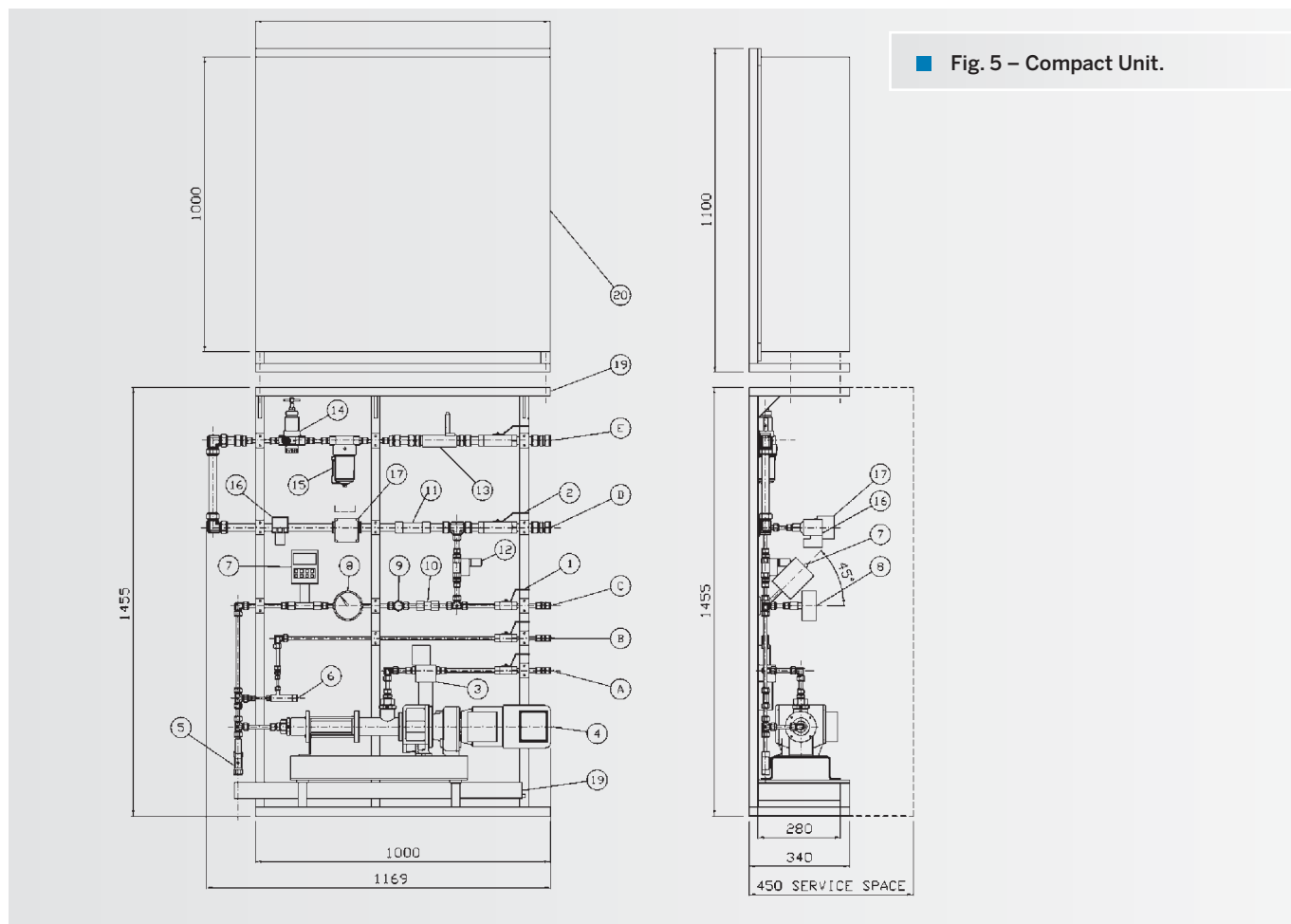
■ Fig. 4 – Sulphur vs. min. exhaust gas temperature.

standardized in order to limit the number of different components used. In addition to lowering costs, this also shortens delivery time. In certain conditions, the equipment can even be purchased on speculation.

Applications

Wärtsilä SCR can be utilized in all marine industry applications where a 4-stroke engine is installed. It can operate with different fuel types, from gas to heavy fuels.

Particular care has been taken in reducing the need for additional →



equipment, combining everything on a single skid or building directly onto the reactor. Wärtsilä has developed a unique solution where the urea pumping and dosing are combined with the SCR control system in a single unit. This solution has been named the Compact Unit (Figure 5), so as to differentiate it from the traditional solution having the control system, pumping, and dosing units separate.

The standard equipment will be delivered already connected and commissioned, thereby reducing the shipyard work for assembly and avoiding equipment commissioning onboard.

The fact that it has been developed specifically for marine applications does not mean that its possible applications are limited to this sector. It can also be utilized in power plants and can be supplied both for existing and new applications when its characteristics match the requirements for particular projects.

NOR Portfolio

The SCR's have been divided into 6 groups with each group relating to a number of Wärtsilä 4-stroke engines. For each SCR there is a selection of standard auxiliary equipment.

The SCR is selected according to engine type and number of cylinders. This is sufficient to define the SCR size and the auxiliaries required (see Figure 6). Our standard offer includes the reactor, with the catalyst and soot-blowing system, the compact unit, and the injection unit. The urea pumping unit and the urea dosing units can be offered as options.

The reactor has four feet, but there are eight possible positions where they can be located in order to match the space available onboard.

The air supply is taken from the ship's service air system and the urea tank is usually obtained from a ballast water tank, so there is no need for special vessels.

Available options

A number of different options are available on demand. In certain applications the customer may prefer to split the auxiliary equipment as has been the earlier tradition. The possibility to have a separate control system, pumping unit and dosing unit, is available.

The NO_x emission monitoring device is another available option. It has been kept as an option because currently it is seldom required.

If preferred, Wärtsilä can offer an air compression station to serve the SCR. Shock absorbers, exhaust bellows, and flexible hoses are also options available to the customer if his particular application involves vibration that may affect the SCR.

Serviceability

The above design strategy also has a positive impact on servicing the equipment. The high standardization of components translates into high availability of service parts since stocks will be readily available. ●

■ Fig. 6 – SCR portfolio.

Engine	W20	W26	W26	W32	W38	W32	W26	W38	W46	W50DF	W32	W38	W46	W50DF	W38	W46	W50DF	W64	
Cyl Config	4-8	6-8	9-12	6-8	6	9-12	16	9	6	6	16-18	12	8-9	8-9	16	12-18	12-18	6-9	
Reactor size	1		2			3					4			5					
Urea Pumping System						1					2								
Urea dosing System						1					2								
Compact Unit											1								
Urea Injection System	1		2			3					4			5					
Control System	1																		

