SO_x scrubbing of marine exhaust gases

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New legislation governing SO_x emissions of ships affects ship design and operation. If the vessel operates in areas where SO_x emissions are controlled, compliance can be achieved by using low sulphur fuel, or by cleaning exhaust gases using SO_x scrubbers, or by a combination of both.

For the commercial implementation of marine scrubbers to become viable, there are a number of challenges to be faced. These include the return on investment with fuel prices as they are at present, the need to clarify rules relating to the discharge of wash water, the certification process, and the absence of reference installations. Wärtsilä has combined it's long experience of developing and delivering SO_x scrubbers for stationary diesel power plants with it's specific expertise in marine system design, and has now produced in-depth feasibility studies for several selected ship types.

Existing SO_x emission regulations

Currently, the most important legislation, particularly for ship operation in Europe, is covered by the Marpol Annex VI Act and the new EU directive. Table 1 shows a rough summary of these regulations.

Additionally, the California Air Resources Board (CARB), for example, has adopted regulations for auxiliary diesel engines and diesel-electric engines in ocean-going vessels within regulated California waters (24 nautical miles from California). The limits are 0.5% of sulphur in the fuel from 1.1.2007, and 0.1% of sulphur from 1.1.2010. Exhaust gas abatement is an alternative.

Locally, ports and local authorities for example in Sweden, offer reductions in port and fairway fees depending on the sulphur content in the fuel being used.

Future regulations under discussion

The clear goal of the IMO and EU is to further curb the emission of sulphur oxides. The work on revising MARPOL Annex VI is actively being pursued at the IMO, and an expert group has been nominated. Decisions are expected during 2008.

Six alternatives are presently being discussed. Four of them include more stringent requirements for certain regions, while the other two alternatives focus on unified SO_x-limits that would be applicable globally on all seas.

One option is to use distillate quality everywhere. However, while this would certainly simplify many things, it has met with considerable objections based upon its drastic impact on shipping and the oil industry, and the increased CO_2-emissions at refineries.

The five remaining alternatives are more "goal-setting", specifying the required emission performance, but leaving the solutions to the industry. In these scenarios, exhaust gas cleaning is also considered as being an economically feasible alternative to using much more expensive fuel. The low-sulphur fuel price premium is expected to grow due to reduced sulphur limits and to the fact that regions with more stringent requirements are being geographically extended.

When	Ship type	Area	%	Act
19.5.2006	All	Baltic SECA	1.5	Marpol
11.8.2006	All	Baltic SECA	1.5	EU
11.8.2006	Passenger ships	All EU	1.5	EU
11.8.2007	All	North Sea + English Channel SECA	1.5	EU
22.11.2007	All	North Sea + English Channel SECA	1.5	Marpol
1.1.2010	All	All EU ports	0.1	EU
1.1.2010	Inland waterway vessels	All EU inland waterways	0.1	EU
1.1.2012	16 Greek ferries	Greek ports	0.1	EU

Table 1. – A summary of existing SO_x emission regulations.

SO_x SCUBBER REGULATIONS

The IMO and the EU are being urged to produce a consolidated approach to reasonable wash water discharge criteria and a unified geographical definition.

The development of legislation is presently considered to be the most important means of ensuring the successful introduction of exhaust gas cleaning on ships. Here again decisions are expected during 2008.

IMO scrubber certification

There are already some regulations stipulating performance, verification, and certification issues for SO_x-scrubbers.

IMO Resolution MEPC.130(53) requires a SECA Compliance Plan (SCP) describing methodology for compliance by each ship using scrubbers rather than low-sulphur fuel.

Similarly to the NO_x regulation requirements for engines, the scrubber (Exhaust Gas Cleaning System-SO_x, or EGCS) shall be delivered with a technical document, the EGCS-SO_x Technical Manual (ETM), outlining the nominal capacity, type of combustion units, operating limits (gas temperature, sea water alkalinity etc.), maintenance, and survey procedures to ensure proper operation etc. Upon successful approval of the ETM and demonstration of performance, a SECA Compliance →

Certificate (SCC) will be issued.

During operation, scrubber maintenance should be recorded in a dedicated "EGCS-SO_x record book", or alternatively in a Planned Maintenance System. Maintenance and survey procedures of monitoring systems are documented in an "Onboard Monitoring Manual (OMM)".

IMO wash water requirements

Marpol Annex VI stipulates that "waste streams shall have no adverse impact on ecosystems based on criteria of port State". While this may sound obvious, countries have been slow in defining their criteria. This is soon expected to change, as IMO Wash Water Guidelines will be available (approval expected in 2008).

EU regulations

EU Marine Fuels Sulphur Directive (2005/33/EC) includes provisions for the testing and installation of emission abatement technologies.

The European Commission is responsible for establishing criteria for the use of scrubbers in enclosed areas. Similarly, ships utilizing scrubbers are required to be fitted with continuous emission monitoring equipment. It is hoped that the EU will harmonize this requirement with the provisions of IMO Resolution MEPC.130(53), which offers both unit approval (scheme A) and continuous monitoring (scheme B).

National regulations

For authorities it is difficult to get a full picture of the composition and quantity of scrubber wash water, and what is "effluent" and what is "residue". This is fully understandable, as little information is publicly available, and several scrubber technologies exist with considerable variation in this respect.

Some countries adjacent to SECA areas have then defined certain coastal zones, within which the discharge of scrubber wash water is currently not permitted (in contrast to the discharge from inert gas scrubbers on tankers).

ALKALINITY, PH AND SALINITY

The driving factor for sulphur acid neutralization, and therefore SO_2-reduction, is the water alkalinity.

Such alkalinity is to some extent available in sea water, but it can also be added artificially in the

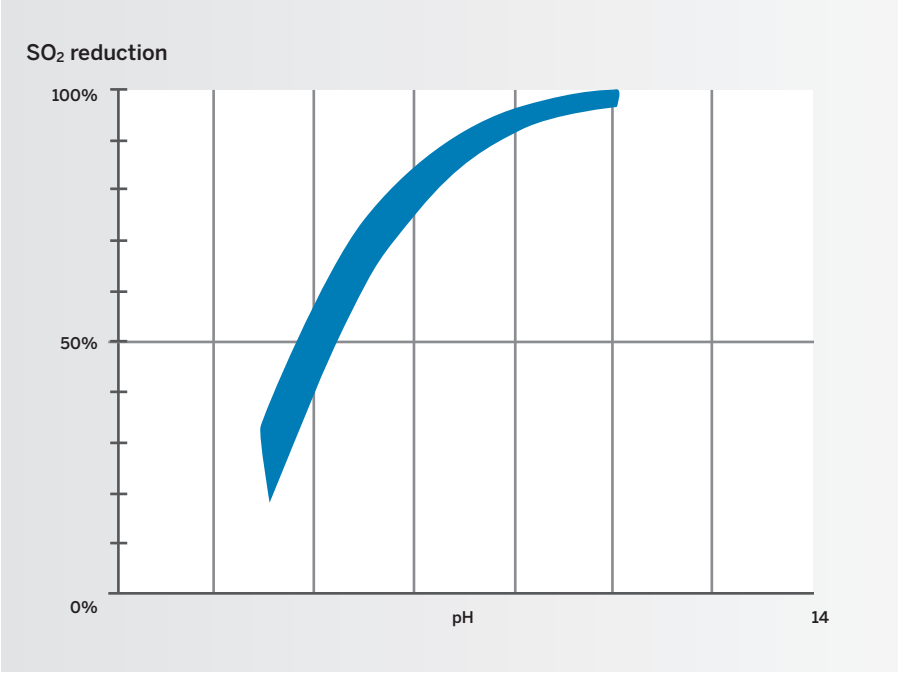

Fig 1. – Scrubber SO_x-reduction versus pH of the scrubbing water.

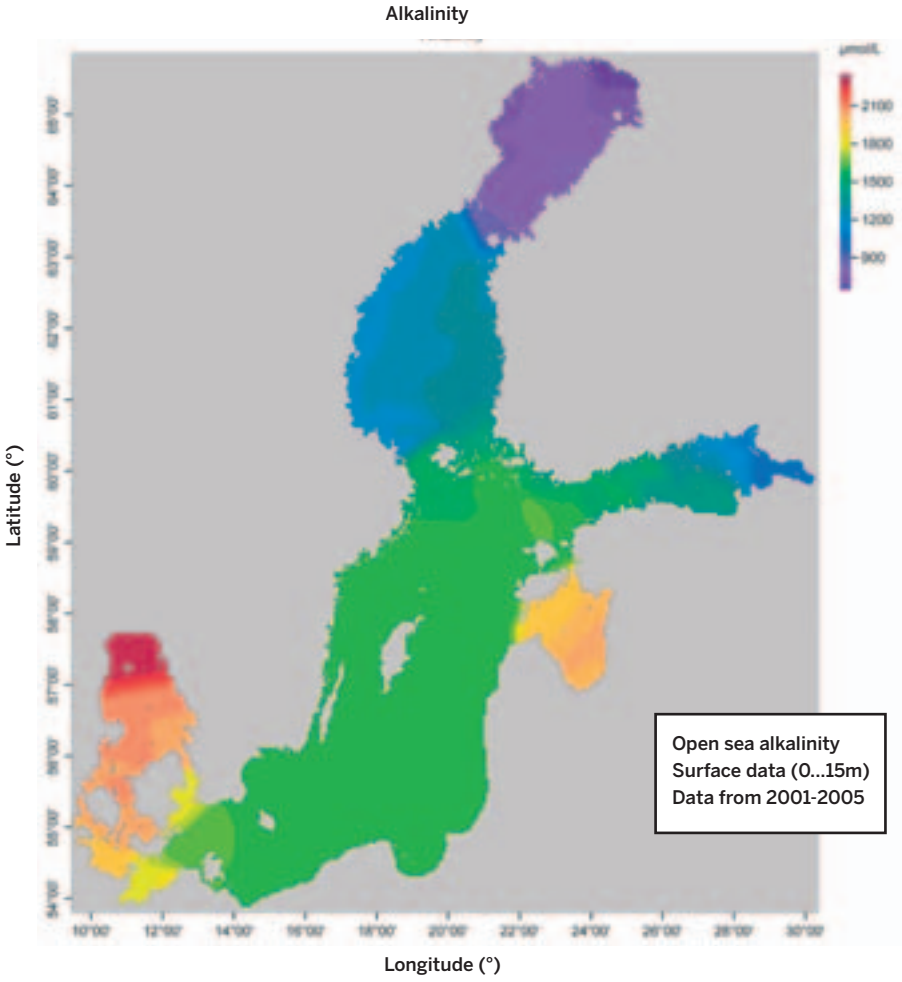

Fig 2. – Alkalinity of the Baltic Sea.

form of an alkaline chemical.

Alkalinity does not refer simply to pH, but to the ability of water to resist changes in pH. Buffering materials are primarily bicarbonate, carbonate, but also consist of hydroxide, borates, silicates, phosphates, ammonium, sulphides, and organic compounds. Total alkalinity, AT, is the sum of all these.

Salinity describes the salt content of water. The salinity of ocean water is approximately 3.5%-weight. Water can have high alkalinity and zero salinity depending on the calcium concentration.

Alkalinity in nature

Ocean alkalinity is usually constant and high; approximately 2200-2300 µmol/l.

Alkalinity in coastal areas, ports, rivers and estuaries is mainly affected by the different drainage areas of the inflowing rivers, resulting in large variations in the chemical quality. Rivers running through soil rich in carbonates will be high in alkalinity. For example, the northern rivers of the Baltic Sea run through granite bedrock resulting in low alkalinity, while the southern rivers run through calcite bedrock resulting in high carbonate concentrations with consequently high alkalinity (see Figure 2).

In general, the alkalinity in the Baltic Sea is lower than normally in sea areas because of the minimal exchange of water through the Danish straits.

At low alkalinity levels the seawater scrubber can still operate, but it leads to lower cleaning efficiency and to low effluent pH figures.

SO_x scrubbing technologies for marine applications

Wärtsilä has an impressive reference list of delivered SO_x-scrubbers for stationary plants, and has consequently accumulated vast experience of scrubbing technology. Based on this background, Wärtsilä has concluded that there are two different technologies worth further development for marine applications, namely sea water ("open loop") scrubbing, and fresh water ("closed loop") scrubbing with an added chemical (typically caustic soda).

As ships have sea water available in unlimited quantities, sea water scrubbing may appear to be the obvious choice. There are, however, some limitations involved in this concept, which will be discussed below.

SEA WATER SCRUBBING

The main benefit of a seawater scrubber is simplicity; it requires neither additional chemicals nor fresh water for operation. Instead seawater alkalinity, or buffering capacity, is used to neutralize the exhaust gas sulphur. In order to maintain high efficiency, a seawater scrubber needs a high flow of seawater with an adequate level of alkalinity.

FRESH WATER SCRUBBING

The fresh water scrubber is a good alternative if high efficiency cleaning is needed, or as a means of avoiding seawater alkalinity issues. In such scrubbers, a caustic soda (NaOH) solution is used to neutralize sulphur compound.

Fresh water scrubber cleaning efficiency is typically higher than 90%. A figure as high as 97% can be specified for generator engines to reach an equivalent of 0.1% fuel sulphur, as will be required in, for example, EU ports and California (see Table 1). Thus, engines will always be able to run on conventional HFO.

The power demand for pumps is very low, between 0.5 and 1% of the engine in question.

System layout

The fresh water scrubber system layout is shown in Figure 3. The main principle is as follows:

The washing solution is pumped from the process tank through a system cooler to the scrubber. From the scrubber the washing solution returns to the process tank by gravity.

NaOH is fed to the system via a small feed pump. Topping-up of fresh water is needed to the extent that the evaporated or discharged water is not fully compensated by the humidity in the exhaust gases (from engine combustion).

A small portion (the "bleed-off") of the scrubbing water flow is directed to the treatment unit. The treated effluent is either discharged overboard or collected in a clean bilge water tank or other suitable holding tank. This feature is unique, as the system can periodically be operated in a "Zero Discharge Mode" i. e. with no discharge of wash water overboard.

The captured contaminants (sludge) are transferred to the existing vessel's sludge tank.

The process tank can be large enough to temporarily hold some bleed-off for periods when the scrubber is running but the treatment plant is not, or vice versa.

Caustic soda

The typical commercial solution is a liquid with a concentration of 50%. It has a density of 1.52 t/m^3 and a pH of 14. It solidifies at 12°C, and is typically transported warm.

The caustic soda can be bunkered →

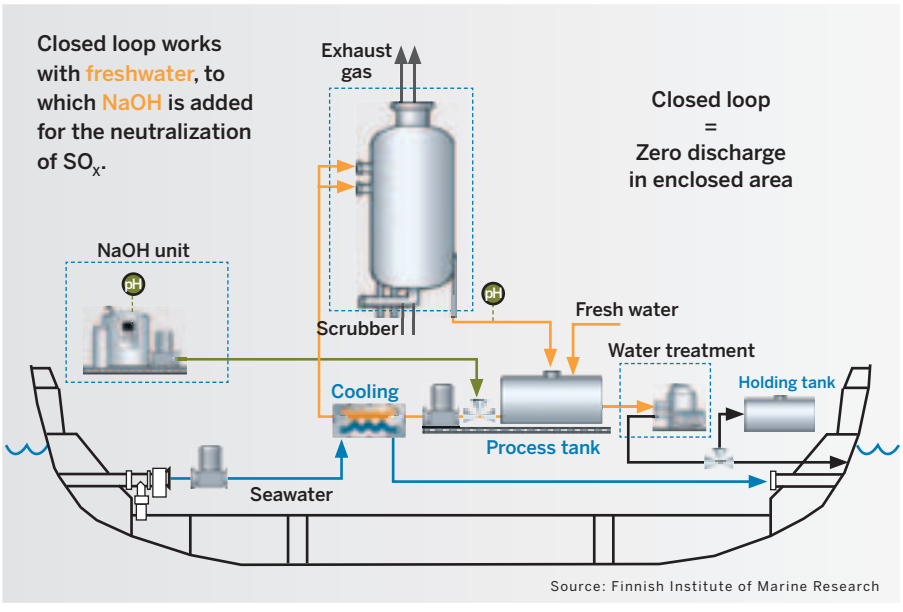

Fig 3. – Sulphur removal from exhaust gas by fresh water scrubbing, Wärtsilä scrubber system layout.

[MARINE / IN DETAIL]

from trucks via filling connections in the bunker stations. The storage tank can be of normal shipbuilding steel.

Based on price fluctuations of caustic soda during the last 20 years, the cost is between 0.5 and 4% of the fuel costs.

Exhaust gas

The exhaust gas plume in traditional wet scrubbers has a high relative humidity. Wärtsilä's marine scrubber includes a feature to minimize the water vapour of the plume, as well as the water lost to the atmosphere and, therefore, the need for topping-up water.

As the scrubber provides noise attenuation, it can replace the existing silencer. Attenuation of high frequencies is inherent in the scrubber design, while lower frequencies are taken care of by a suitable geometry considering the emission spectrum of the engine in question.

As a separate silencer is not needed, the overall back pressure of the exhaust gas system can be maintained within acceptable limits.

Retrofits and newbuilds

Scrubbers can be fitted on newbuildings as well as on existing ships.

On newbuildings there is full freedom to locate components. It is also possible to specify a "readiness for later retrofit of scrubbers". Wärtsilä can provide information relating to matters such as space allocation etc. (see Figures 4 and 5).

On existing ships the funnel may not be large enough. In such cases the funnel geometry can be modified, but it is also possible to fit the scrubber itself outside the funnel, with the other equipment inside.

As an example, a scrubber for an 8400 kW engine is 8.0 meters high, 2.9 meters in diameter, and the weight in operation is 13.4 tons.

CONCLUSION

With more stringent regulations looming in the future, SO_x-scrubbing is being seen as an increasingly attractive way of minimizing operational costs by using HFO in an environmentally sound way. The interest of shipping companies is steadily increasing, and authorities are working actively to develop corresponding regulations.

NOTE: For more information, please contact us at scrubber@wartsila.com

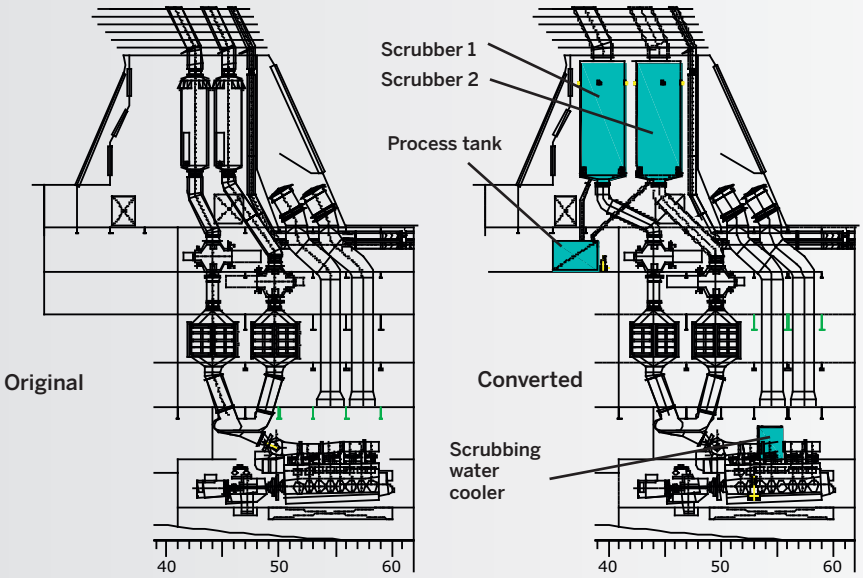

Fig 4. – Wärtsilä scrubbers in a RoPax (longitudinal section).

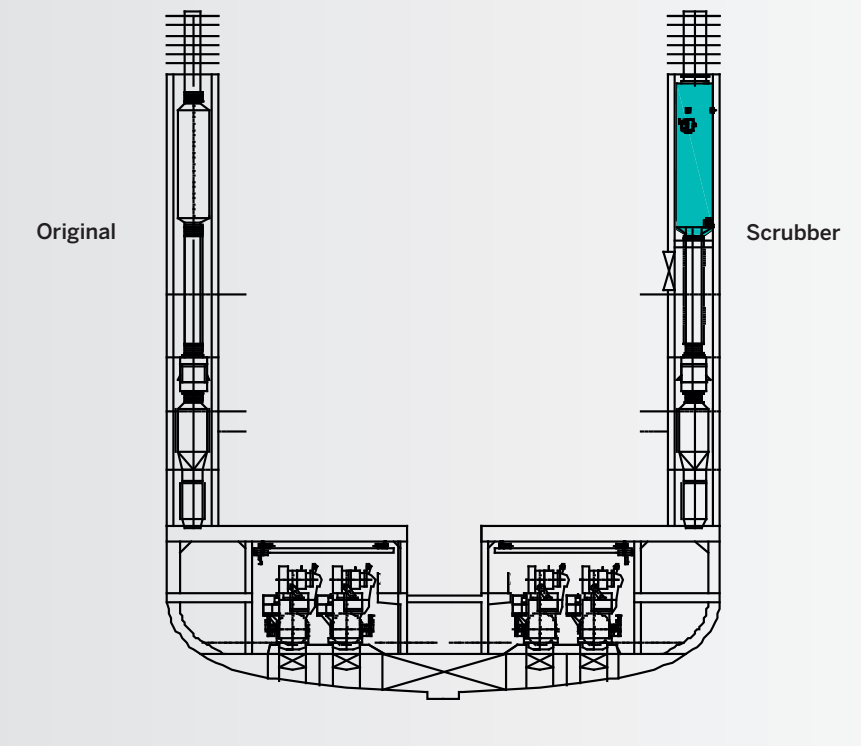

Fig 5. – Wärtsilä scrubbers in a RoPax (transverse section).