Icelandic Transport Authority

Project of Exhaust Gas Cleaning

From Marine Diesel Engines in the Arctic Region

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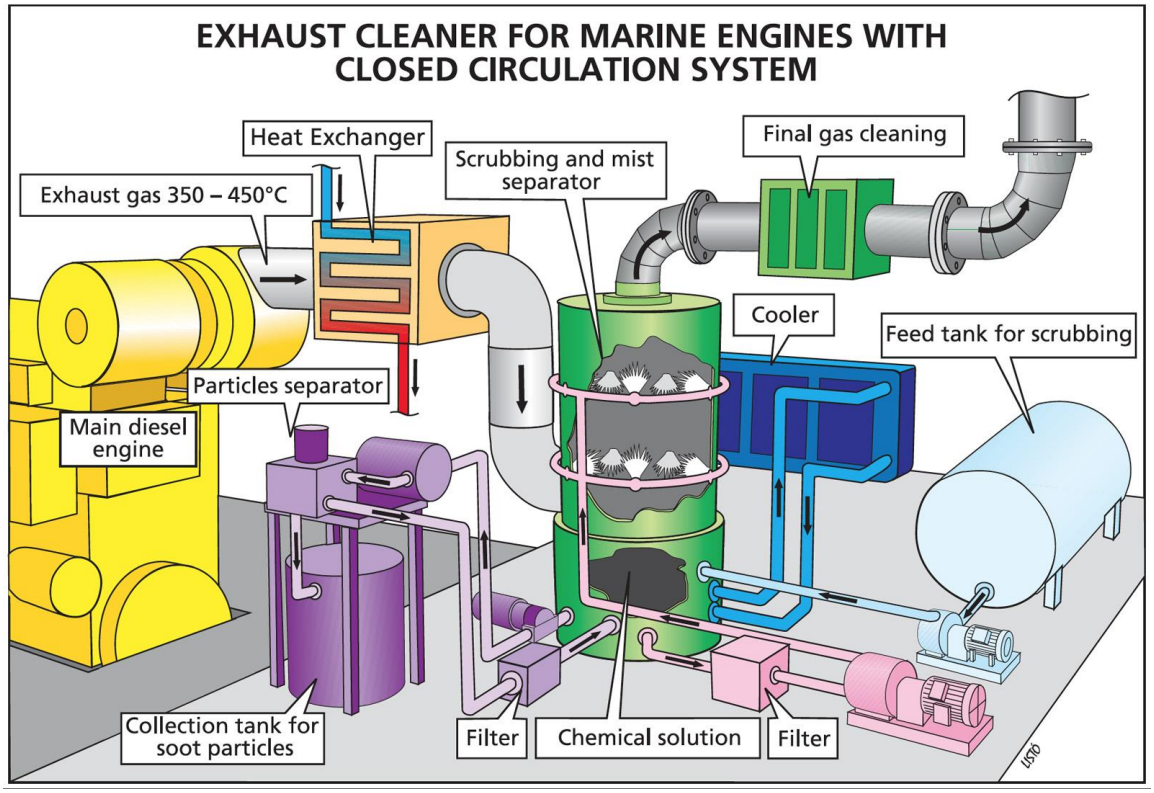
Project background

A great majority of engines used for vessel propulsion are driven by fossil diesel oil. Smaller vessels and smaller engines are generally powered by Marine Diesel Oil (MDO). For larger engines, Heavy Fuel Oil (HFO) is the fossil diesel used as it has greater viscosity than the former. HFO is less refined and cheaper than MDO and is therefore the favoured choice among owners of larger vessels. The combustion of any type of fossil diesel creates numerous exhaust gases which are harmful to the environment and human health.

Research on possible means by which to reduce the amount of harmful gases emitted by vessel engines has been ongoing for some time. Though various solutions have been tried throughout the past decades, two methods of exhaust gas treatment are notable: Wet Scrubbing of exhaust gas and Water in Oil Emulsion, the emulsification of oil and water prior to entering the engine combustion. These methods have proven successful in removing a large proportion of harmful gases from the exhaust gas.

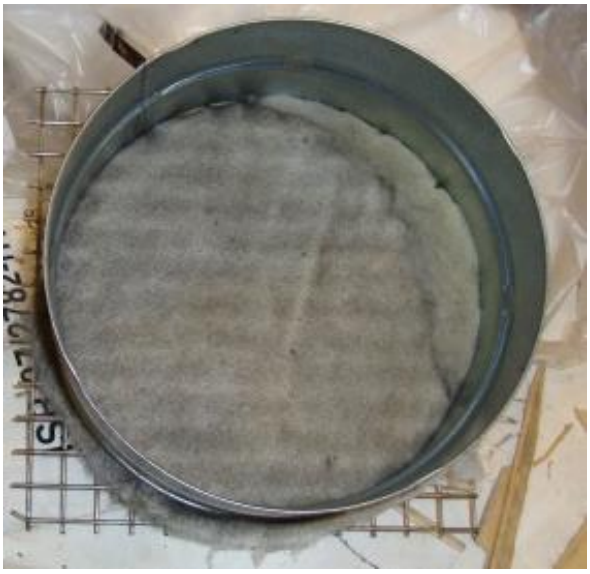


The removal of these gases can, however, also be accomplished using environmentally friendly and renewable fuels. One option is Biodiesel, for example, produced from rape seeds. The rape seed plant has been cultivated with some success in Iceland and presents the opportunity for Icelandic oil production. Biodiesel can also be produced using waste biomass, and even green algae, as raw material. Its energy potential is approximately the same as that of fossil diesel oil and it can be used as a main engine fuel without significant modifications to the system. Furthermore, methanol, DME and hydrogen are environmentally friendly energy carriers that may be suitable for ship engines. Although they possess a smaller energy potential when compared to biodiesel, a significantly smaller amount of harmful fumes are produced. Currently, research and testing of electrically powered marine propulsion systems are proving promising.

In 2006, the Icelandic Maritime Administration‘s Research and Development Department, initiated the project „Exhaust Gas Cleaning for Marine Engines“. When the institution was terminated, the project was transferred to the Icelandic Transport Authority. The objective of the project was to design and build effective exhaust gas scrubbing equipment and implement

the methodology and technology aboard Icelandic vessels. The intent was not to reinvent the wheel, so to speak, but rather to adapt this known procedure to Icelandic conditions and demonstrate the value of cleaning gas emissions from ship engines with simple equipment that pays off within a reasonable timeframe.

Our Exhaust Gas Cleaning Facilities



Filter-gauze without the cleaning system

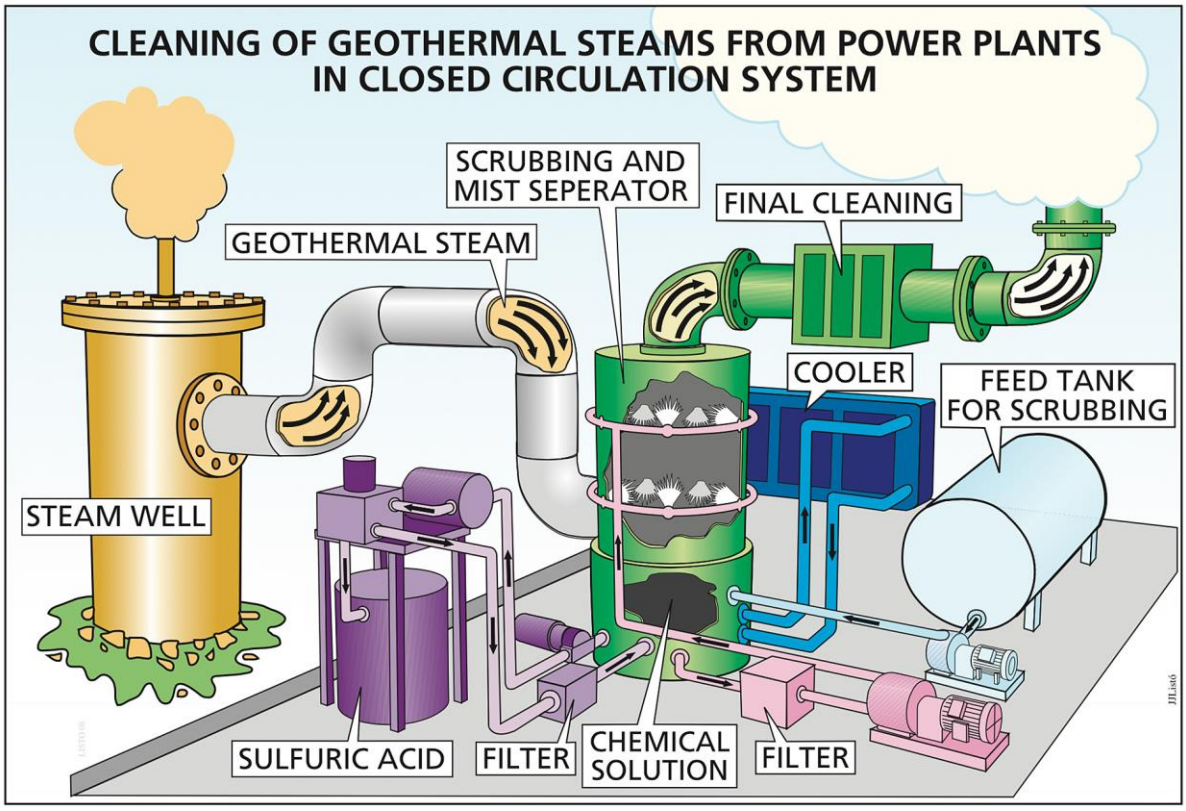
Filter-gauze with the cleaning system

Project implementation

As soon as exhaust gas equipment and testing facilities had been obtained, the project was launched. Reykjavík Energy supplied the lab location and a diesel engine at Nesjavellir geothermal power station. Véltak, a company based in Hafnarfjörður, built the scrubbing machinery and fuel distributor N1 supplied fossil diesel oil and rape-biodiesel to allow for comparison of the two fuels.

Quite early in the process a suggestion was put forward to investigate the possibility of scrubbing sulphur from steam emitted by geothermal power plants. Although there was great interest in testing the idea, it was put on hold when the facility at Reykjavík Energy was no longer available and new partners did not show as keen an interest. At this point, the project was roughly half way through and since then, locating a new facility for lab testing has been unsuccessful. However, due to the rising global need for solutions to reduce the emission of greenhouse gases, it was deemed important to publish preliminary results and illustrate the theoretical background to gas scrubbing applications for ship engines. This report discusses the relevance of scrubbing to the issue of global warming and its prospects as a contributing solution thereof. The appendix contains details on the progress of the project.

It would also be interesting to investigate the possibility of removing hydrogen sulphide from geothermal steam of power stations. Wet scrubbing alone could reduce the emissions here by over 90%.



Results

The main conclusion of the project is that utilising scrubbing as a means to clean exhaust gases from diesel engines aboard ships, even solely using water spray, has proven effective. Spraying the exhaust gas with water in the scrubbing tower, causes soot and particles to fall to the tower bottom rather than being emitted with the engine gases. This method reduced the emission of soot particles (Black Carbon) and sulphur dioxide (SO_2) by 90%, 98%, carbon dioxide (CO_2) and nitrogen oxides (NO_x) around 10% respectively using water spray scrubbing only. (Source: Abgasnachbehandlung; Bank, R. & Harndorf, H.; Universität Rostock, 2009)

The removal of CO_2 and NO_x can be increased significantly by including additional substances, such as solution of calcium and urea, with the water spray. The calcium binds to carbon dioxide and is precipitated as Sand before being removed from the scrubbing tower by filtration. The urea binds to NOx, creating harmless compounds of nitrogen. Using a solution of water, calcium and urea, the amount of sulphur compounds is reduced by 98%, soot particulates by 90%, NO_x by 35% and CO_2 by 25%. The substances removed from the exhaust gas are filtered from the solution and treated as hazardous waste and disposed of according to procedure.

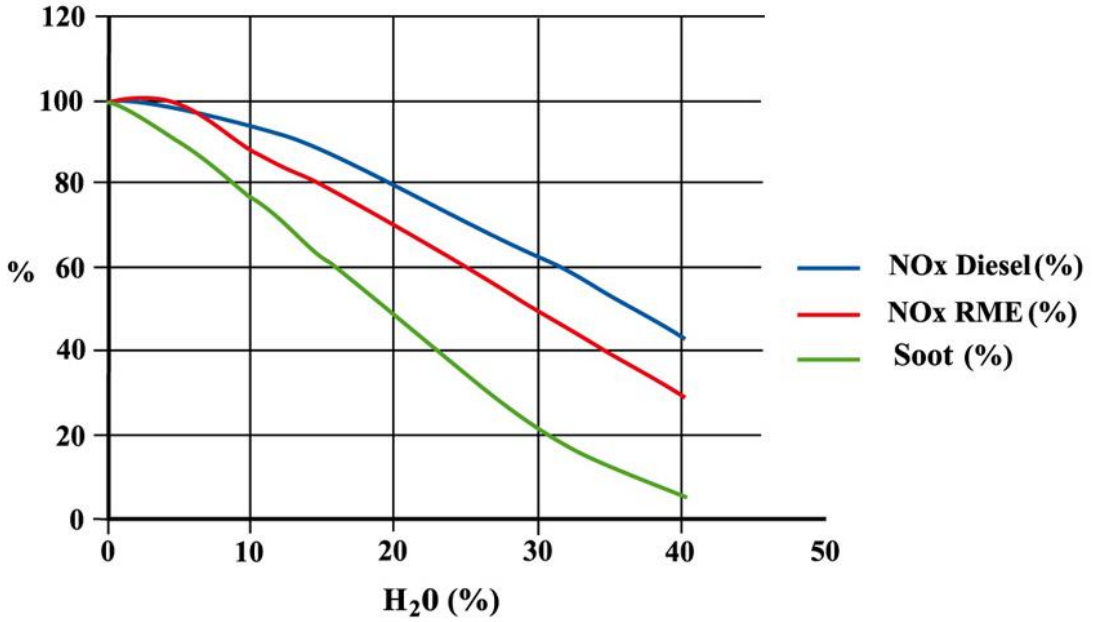
The global community has been striving to reduce the emissions of the above mentioned harmful substances. Sulphur Emission Control Areas (SECAs), regions of ocean where the allowed emission of sulphurous compounds is limited, have been created where the emission cap was set at 0.1% starting in 2015. Within the bounds of other regions, the maximum is 3.5% until 2020, after which time the maximum allowable sulphur content of fuel will be reduced to 0.5%. These measures have been set in place in order to reduce the discharge of sulphur compounds from ships. Wet scrubbing is the only existing measure which is more effective than regulating emissions, eliminating 98% of sulphur particulates from exhaust gases using water spray.

Table 1IMO SOx Emission limits. †: Alternative date is 2025, to be decided by a review in 2018.

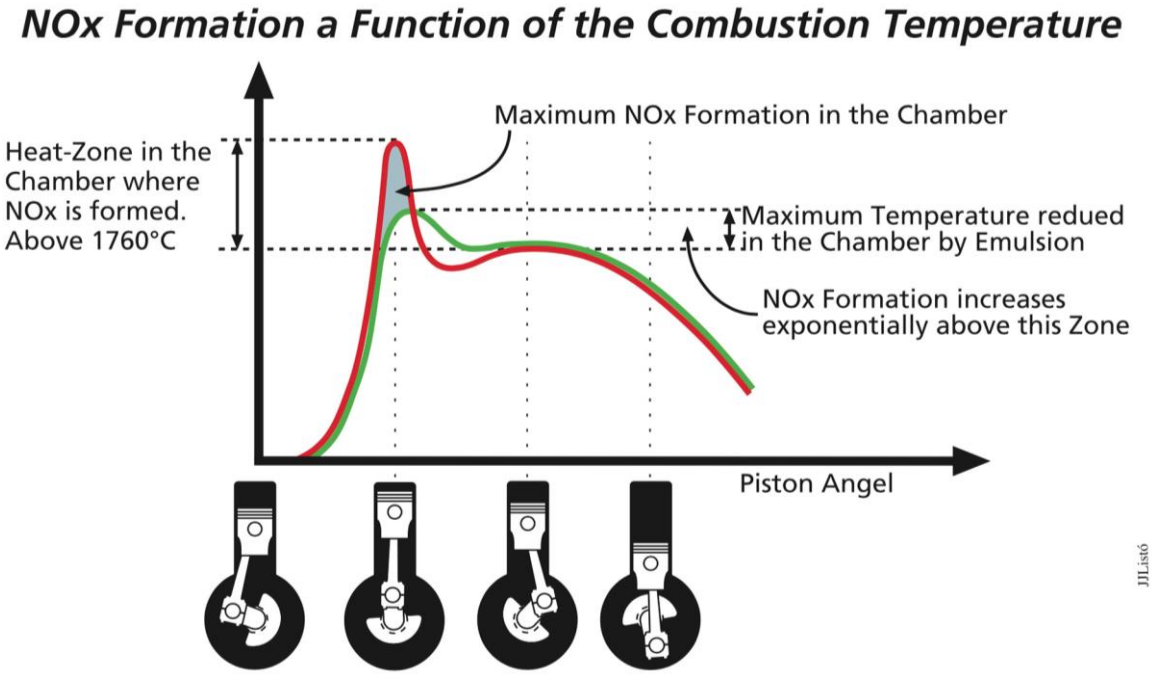
Date	Sulfur limit in fuel (% w/w)	
	SOx ECA	Global
2005	1.5	4.5
2010.07	1.0	
2012		3.5
2015	0.1	
2020†		0.5

Source: http://www2.mst.dk/udgiv/publications/2011/08/978-87-92779-30-4.pdf

Using the Water in Oil Emulsion procedure, where water and diesel are sprayed simultaneously into the engine combustion and the amount of NO_x is reduced by roughly the same ratio as that of water to fuel. That is, applying a 20% water to fuel ratio, reduces NO_x emissions by 20%. Furthermore, this method reduces the quantity of emitted soot particulates by 95%, CO_2 by 15% and sulphur compounds by less than 15%. The procedure is commonly used in main engines aboard larger vessels and does not affect the engine performance.



Result of Water in Oil Emulsion (Source: FCM Fiedler Motoren GmbH)



NOx reduction using method of Water in Oil Emulsion
(Source: http://www.exomission.de/index.php/technologien-2/kraftstoff-wasser-emulsion-kwe)

Combining the two methods described above, wet scrubbing and water in oil emulsion, into one process would enable near elimination of sulphur and soot particulates, the emission of NO_x would be reduced by over one half and the emission of CO_2 would decrease by one third.