Ultra Low Emissions Solution for gas power plants in the US market

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The Wärtsilä R&D project for ultra low air emissions with gas engines for the US market started early in 2000. As a result of this effort the first commercial project with this solution was in full operation at the beginning of 2002.

The Ultra Low Emissions (ULE) Solution is based on secondary emission reduction technologies, a selective catalytic reduction (SCR) system for control of nitrogen oxides (NO_X), and an efficient oxidation catalyst system for carbon monoxide (CO) and volatile organic compound (VOC) control. The system is specifically designed for Wärtsilä SG gas engines.

The first Wärtsilä dual-fuel (DF) engines applying a similar solution will be commissioned later this year. Feedback from the field is showing positive results, which gives us confidence in the future development of emission reduction technologies for gas engines.

Environmental impact of gas plants

All power plants have environmental impacts. The Wärtsilä lean-burn gas engine, however, is considered an environmentally sound alternative in the distributed power generation business.

The major environmental impacts of a gas power plant are the atmospheric emissions. The effective lean-burn combustion technology and the high thermal efficiency of the Wärtsilä gas engines ensure that the air emissions per kilowatt-hour of electricity produced are relatively low.

The Wärtsilä gas engine can be tuned for different NO_X emission levels to meet project-specific needs. Sulphur dioxide (SO_2) and particulate emissions are very low compared to operation on liquid fuels. The emissions of SO_2 are directly proportional to the sulphur content of the fuel being burned. In gaseous fuels sulphur can be present in the form of gas odorants and hydrogen sulphide (H_2S).

Gas suppliers usually remove H_2S from the gaseous fuels, resulting in negligible SO_2 emissions from gas engines. Abatement efficiencies up to 80% of CO can easily be achieved with a CO oxidation catalyst.

Moderate reduction of VOC, aldehyde and other hazardous air pollutant (HAP) compounds can also be achieved with this oxidation catalyst. Besides being dependent on engine optimization the VOC and aldehyde emissions from the gas engine are also strongly dependent on fuel quality, i.e. the composition of the natural gas.

Market demands

A gas engine as such or equipped with a CO oxidation catalyst can in most cases fulfil the emission limits. However, in some countries local authorities are applying stricter emission limits than the stipulated national or federal regulations, especially if the plant will be located in a sensitive area or degraded airshed.

In the USA it is common practice to restrict the emission limits for maximum allowable emitted tonnes per year, which is stipulated in the plant operation permit. In practice this means that the higher the capacity of the plant and requested annual running hours, the stricter the actual emission limits in g/kWh will be. This makes the majority of projects in the US unique. It is essential that all environmental regulations are identified early and taken into consideration at the planning and design phase of the project.

The Ultra Low Emissions Solution

The Ultra Low Emissions (ULE) Solution is based on secondary emission reduction technologies.

A conventional platinum-based oxidation catalyst for CO and moderate hydrocarbon emission control have been installed on Wärtsilä gas engines (~700 MW) worldwide since the mid-1990s. The control method uses catalyst active metals to accelerate the oxidation reactions between combustible components and flue gas residual oxygen to carbon dioxide and water.

In order to reach very low emission

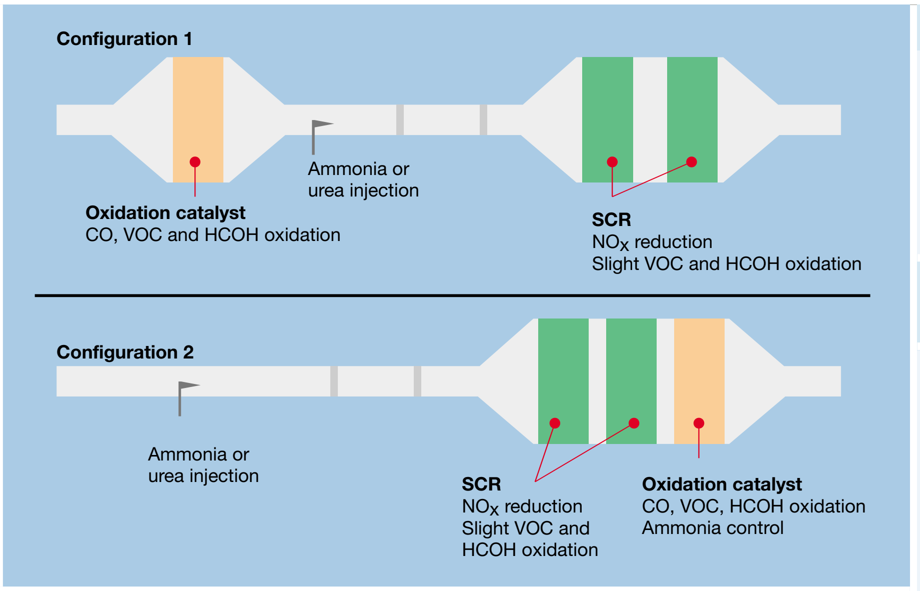

Figure 1. Alternative catalyst configurations for ULE design.

Unit	NO_X	CO	VOC	CH_2O
g/kWh *	0.082-0.125	0.10-0.30	0.125-0.25	0.018
ppm (15 %-vol O_2, dry gas)	5-9	12-35	20-40	1.5

* Calculated based on generator terminal output

Table 1. Emission limits in commercial projects in the USA.

levels (ULE) the plant has to be equipped with a more efficient oxidation catalyst. The active materials in such an oxidation catalyst are usually based on both platinum and palladium.

The use of Selective Catalytic Reduction (SCR) for removing NO_X emissions is a well known technology within Wärtsilä. SCR units have been installed on a few Wärtsilä gas engines and on many Wärtsilä diesel engines (500 MW) since early 1990.

In the SCR process, nitrogen oxides are reduced by injection of an ammonium-based compound to nitrogen (N_2, the major component of air) and water (H_2O). The system can be designed to apply either an aqueous urea (32-40%-wt) solution or aqueous ammonia (25%-wt) as the reduction agent.

The main components of the Ultra Low Emissions Solution consist of the reactor(s) with catalyst, reagent storage, injection and a control system. Figure 1 shows two different types of catalyst configurations based on the Ultra Low Emissions Solutions that are installed with Wärtsilä gas engines. The configuration is optimized for project-specific requirements and the technical solution of the catalyst vendor.

Important factors in the SCR design are the mixing stage, flue gas distribution, the amount of catalytic material and the control system. Unless there is a perfect mixing of the reagent and exhaust gas in combination with a perfect reactor design, the last ammonia (NH_3) molecules will not ‘find’ and convert the last few NO_X molecules. This will lead to excessive ammonia injection (NH_3/NO_X ratio larger than 1.0), which will eventually cause ammonia slip in the exhaust gas.

Many different compounds fall under the collective term VOC. The VOC components are oxidized at different rates. Saturated VOC, especially propane, react the slowest. Unsaturated, oxygen-containing organic compounds and polycyclic aromatics react considerably faster. The performance of the oxidation catalyst depends on exhaust gas temperature, the quantity of noble metals (tailor-made

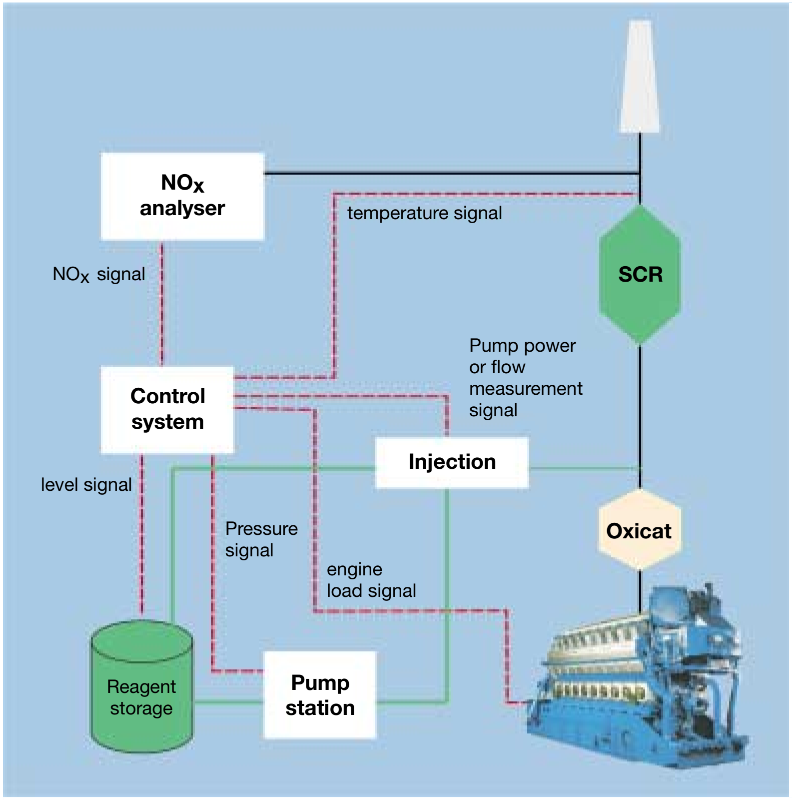

Figure 2. Schematic of control system

Investment cost (incl. installation)[Euro]	NO_X [g/kWh*]	VOC [g/kWh*]	% NO_X reduction	% VOC reduction
998,000	0.33	0.20 **	75	65
1,357,000	0.13	0.16 ***	90	78

* Based on generator terminal output
** Based on natural gas with methane number 90
*** Based on natural gas with methane number 85

Table 2. ULE system investment cost for a 23 MW gas engine plant.

Cost		74% NO_X reduction	90% NO_X reduction
Urea consumption	(4000 h/year) (8000 h/year)	69,000 138,000	83,000 165,000
Catalyst replacement *		56,000	69,000
Other O&M cost **		15,000	21,000
Total yearly cost	(8000 h/year)	209,000	255,000
Total O&M cost	(euro/MWh)	1.2	1.4

* Based on a 5-year average.
** Assuming 1.5% of investment cost

Table 3. O&M cost for a 23 MW power plant.

for ULE), the catalyst volume and the design (space velocity).

As mentioned earlier the Wärtsilä gas engine can be optimized either for optimal heat rate or for low NO_X emissions. The latter alternative has a small negative effect on heat rate and also on emissions of incomplete combustion products, such as CO and VOC emissions. Calculations show that the high efficiency engine setting is favourable for the ultra low emissions solution design.

Table 1 presents the emission guarantees in the commercial projects in the USA that were used as a design basis for the Ultra Low Emissions Solution.

The ammonia slip requirements were 0.028-0.047 g/kWh, which corresponds to 5-8 ppm (in wet gas, 15%-vol O_2)

A main limitation for the SCR technology to reach very low ppm NO_X values originates from the NH_3 slip requirement. In order to achieve very low NO_X and ammonia emissions simultaneously, the catalyst and control system must be designed with care.

The SCR control system is based on the engine load signal and a feedback signal from the NO_X analyser. The urea injection rate versus engine load curve is set during commissioning of the SCR system. The analyser is continuously (or semi-continuously if the analyser is time-shared between several engines) analysing the NO_X concentration at the reactor outlet in order to adjust the reagent injection rate. This way the system corrects for engine NO_X fluctuation due to variations in ambient conditions and consequently the guarantee values can be achieved at all times during normal stable load operation.

The exhaust temperature from the engine is optimal for SCR operation and does not require heat recovery prior or parallel to the mixing ducting of the SCR system as is the case in gas turbine installations. Both from a mechanical and operational point of view this is a simple and integrated system.

Good experience from the field

Feedback from the ULE solution installations is showing positive results. The measured emission values during commissioning have all been well below the guarantee levels (Table 1) at all installations.

Comprehensive pilot testing and successful commissioning is important in order to develop ULE further. It is also essential to follow up the long-term experience on such installations in order to optimize and develop the performance and reliability of this solution.

What does it cost?

The ULE solution has significant operation and maintenance costs in addition to the initial investment cost.

The investment, operation and maintenance costs for a catalyst system depend on the capacity of the engine, the uncontrolled emission concentration, the desired emission abatement and the annual operating hours of the engine. The prices of the catalytic materials also follow the world market prices of the catalytic active metals, such as platinum, palladium and vanadium.

Table 2 shows typical investment cost for different catalyst abatement efficiency systems. Prices are based on a 23 MW power plant operating on natural gas. Note that the VOC limit and corresponding percent reduction is heavily dependent on the natural gas specification. Values for the VOC are therefore only indicative.

Table 3 presents typical catalyst operating costs for different operation scenarios. The reagent price is dependent on specific site delivery cost, though 370 euros per ton of urea solution (40%-wt) has been used in these calculations. In the calculation it was assumed that the catalyst material has to be changed over a 5-year period. The catalyst replacement intervals are dependent on plant-specific operation conditions and will therefore vary from case to case.

It is a challenge for the regulatory

ULE:	Ultra Low Emissions	
Technology:	Secondary emission control technique Combined SCR and VOC catalyst system	
Application:	Wärtsilä gas engines	
ULE today:	NO_X	5 ppm (dry gas, 15 vol-% O_2)
	CO	12 ppm (dry gas, 15 vol-% O_2)
	VOC	20 ppm* (dry gas, 15 vol-% O_2)
	HCOH	1.5 ppm (dry gas, 15 vol-% O_2)
	Ammonia	5 ppm (wet gas, 15 vol-% O_2)

* dependent on fuel gas quality

Plains End

authority to focus on the total environmental impact. The total environmental impact includes production of the catalyst (containing heavy metals) and reagent (ammonia or urea), transportation of the catalyst and reagent to the site, disposal or recycling of the used catalyst, as well as added ammonia emissions to the atmosphere rather than the last few NO_X molecules in the exhaust gas.

The cost of secondary emission controls to achieve very low emission levels, mainly considering NO_X, might become excessive, i.e. the overall environmental impact may actually become worse. It might not be worth the price to attempt to reach zero level.

Wärtsilä offers reliable environmental solutions

Besides the ongoing development of primary emission reduction technologies for engines, i.e. increasing engine efficiency and optimizing the combustion processes, the secondary cleaning techniques for ultra low emission levels are here to stay. It is an inspiring task for Wärtsilä to develop secondary emission reduction techniques together with our sub-suppliers and to utilize these techniques in combination with our engines as successful solutions. ■

Sarayacu crude oil pump station chooses Wärtsilä 12V32LN

The Ecuadorian oil sector is divided into 32 blocks. Foreign oil companies have signed agreements with the government in order to receive the rights to explore and develop the different blocks. Perenco, with headquarters in Paris, London and the Bahamas, bought the rights to explore Blocks 7 and 21 located in the Oriente region in 2002. To get the crude oil to the market, Perenco needed to construct a pipeline about 50 km long to connect to an existing pipeline owned by AGIP. To keep the oil flowing, a new pumping station will be built at Sarayacu.

1300 m above sea level

The Sarayacu pumping station is located in the Ecuadorian jungle 1300m above sea level at the borderline of Block 21. The pumping station will start to feed the new pipeline with heavy crude oil during 2003.

The site belongs to AGIP, who have been the forerunner in using crude-oil-fired Wärtsilä engines at their AGIP Villano oil field in the neighbouring Block 10. With 3 x 16V32LN (21.5 MW) in operation at the Villano field since 1998, AGIP has proven the technical and economic reliability of this new power production concept in Ecuador. They are at this moment installing the fourth 16V32LN for the expansion of the Villano field.

Technology of choice

With this pumping station in operation, Perenco will be able to increase their production capacity in Ecuador to 20,000 bpd and fill their initial quota established for the OCP pipeline.

The Sarayacu pump station will be equipped with two Wärtsilä 12V32LN generating sets burning crude oil. This order is a follow-up to the three Wärtsilä 12V32LN units Perenco bought last year for the power plant facility at the Yuralpa field in Block 21. The gensets will be delivered four months from order.

Wärtsilä 32LN engines have become the technology of choice for oil companies needing crude-oil-burning engines to generate power efficiently. With more than 3000 MW in operation, onshore and offshore, Wärtsilä has an abundance of experience in a number of different oil and gas field applications. ■