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NSCR, SCR Systems Reduce Emissions

By Wilson Chu

MALVERN, PA.–The implementation of the federal government's new source performance standards (NSPS) and even stricter regulations in some air quality districts administered by state and local governments are significantly tightening control requirements on exhaust emissions from stationary sources.

Emissions control from stationary engines has been mandated to varying degrees over the years, depending on factors such as engine size, location, site limits, operating hours, annual emissions rates, and regional nonattainment status. Emissions of nitrogen oxides (NOx), carbon monoxide (CO) and volatile organic compounds (VOCs) specifically have been targeted. In addition to the proposed NSPS, the Environmental Protection Agency already has issued the National Emission Standards for Hazardous Air Pollutants (NESHAP) to control formaldehyde, acetaldehyde, acrolein and methanol emissions from stationary internal combustion engines.

Stationary reciprocating internal combustion engines provide the horsepower to compress natural gas in a variety of applications at every stage of the gas supply chain–from production and gathering, to processing and storage, to natural gas transmission and distribution. The spark-ignited engines packaged with gas compressors typically burn natural gas as the feedstock in both rich-burn (stoichiometric) and lean-burn configurations.

Primary measures to reduce exhaust emissions involving in-cylinder modifications can be effective, but they also can adversely impact performance. Increasingly, secondary measures such as installing catalytic conversion technologies are being specified to meet local and national emissions standards. Applying exhaust gas treatment to stationary sources can be particularly challenging because of the vast array of applications, with different duty cycles, durability demands, packaging constraints and regulatory requirements.

However, reliable solutions are available for both rich- and lean-burn stationary engines that provide high conversion efficiencies to reduce emissions of CO, hydrocarbons, VOCs, HAPs, NOx, and where applicable, particulate matter. Although lean-burn engines may offer operational advantages to the owner, such as improved fuel efficiency, compared to a rich-burn design, the cost to install emissions control can be significantly higher for lean-burn engines.

NSCR For Rich-Burn Engines

The fundamental difference between a rich-burn engine and a lean-burn engine is oxygen concentration in the exhaust. With a rich-burn engine, oxygen concentration is typically 0.5 percent, and no more than 1 percent. Nonselective catalytic reduction (NSCR) technology is the most economical and accepted emissions control method for rich-burn engines. A three-way NSCR catalyst with an air/fuel ratio controller can achieve very high conversion efficiencies (more than 98 percent) on natural gas-fired rich-burn engines.

The three-way catalysts used on stationary gas engines to reduce CO, hydrocarbon, VOC, HAPs and NOx emissions originally were developed for automotive catalytic conversion. The gasoline-fired stoichiometric engines being installed today in cars and light trucks obviously are quite sophisticated, with computer controls and multiple oxygen sensors, but they use the same basic three-way catalyst technology as a gas compressor engine: essentially, simultaneous reduction of NOx and oxidation of CO and unburned hydrocarbons with a platinum and rhodium catalyst.

In an automotive application, the engine cycles between rich- and lean-burn such that the three-way catalyst converts CO and hydrocarbons during one cycle, and converts the NOx on the other cycle. Some catalysts even contain materials that store oxygen during the lean cycle for release during the rich cycle.

Stationary gas compression engines usually are not as sophisticated as automobile engines. For instance, the air/fuel ratio controllers on stationary natural gas-fired engines typically have a single oxygen sensor. However, the basic operation of the three-way converter essentially is the same. The oxygen sensor measures the amount of O_2 in the exhaust, and the air/fuel ratio controller governs the O_2 in the fuel mixture (maintaining ±0.5 percent oxygen concentration for rich-burn engines) to ensure that the engine runs close to the stoichiometric point and that there is enough O_2 in the exhaust to allow the catalyst to eliminate unburned hydrocarbons and CO.

SCR For Lean-Burn Engines

Selective catalytic reduction (SCR) is used to reduce NOx emissions from lean-burn engines, which generally have oxygen concentrations in the 8-12 percent range. Lean-burn designs also modify the combustion process through exhaust gas recirculation (EGR) or some other method of lowering the temperature in the combustion chamber, since the higher the temperature, the greater the amount of NO_x generated.

Rather than using a three-way catalyst in a low-oxygen environment, SCR systems inject ammonia or a compound such as urea, which is decomposed into ammonia, into the lean-burn exhaust stream as a reducing agent. Pure anhydrous ammonia, aqueous ammonia or urea can be used as the reductant, but in stationary gas engine applications, urea is most common because of its ease of use. As it hydrolyzes, each mole of urea decomposes into two moles of ammonia. The ammonia then reacts with the NO_x to convert it into nitrogen and water.

An oxidation catalyst must be added to the SCR design if hydrocarbons and CO need to be controlled in addition to NOx on a lean-burn engine. The oxidation catalyst first oxidizes the exhaust stream to convert CO to CO_2 and hydrocarbons to CO_2 and water. The CO_2, water and NOx then enter the SCR catalyst, where the NOx reacts with the ammonia.

SCR systems can attain efficiencies of 95 percent or greater, but ammonia/urea requirements tend to increase with higher NOx conversion efficiencies, creating the potential to slip more ammonia. Ammonia cleanup catalysts are a relatively new technology that can be installed behind the SCR catalyst to collect any excess ammonia that slips through (converting it into nitrogen and water).

The biggest problem with SCR is that it is very expensive compared to NSCR. The cost to install SCR on a lean-burn engine can be a factor of five times higher than installing a three-way catalytic converter on a rich-burn engine. A typical SCR system plus oxidation catalyst for a 500-horsepower engine might cost $100,000 or more, compared to perhaps $20,000 for a three-way converter plus an air/fuel ratio controller for a comparably sized rich-burn engine.

Moreover, SCR systems have a fairly high cost of entry because any application will require fixed cost items such as a urea injection system, urea control system and storage tanks. In addition, urea must be stored at temperatures above 11 degrees Fahrenheit or it can solidify, adding cost and complexity in cold weather areas.

Because of the higher costs associated with SCR, the technology typically is installed only on large engines, such as those used in power generation in nonattainment areas. Three-way NSCR normally is the more economic solution for smaller horsepower applications, particularly engines under 350 horsepower. For this reason, it often makes sense for oil and gas companies to replace lean-burn engines with rich-burn models for smaller-horsepower compressor applications in nonattainment and other areas with low emissions requirements.

Obviously, an effective, low-cost NOx control system for smaller-horsepower lean-burn engines would be of significant interest to the compressor market. There are a variety of ways in which NOx could be reduced from a lean-burn engine's exhaust stream, at least theoretically. For instance, a fuel source could be injected into the exhaust to react with the NOx across a catalyst. Another approach is to use chemical technologies to absorb NOx from the exhaust and inject it into a reducing catalyst. However, neither method so far has proven capable of economically achieving high conversion efficiencies, particularly in smaller-horsepower stationary gas engines.

Horsepower Is Key

As some of the newer engine designs are demonstrating, it certainly is possible to reduce emissions from a natural gas-fired engine while optimizing its performance in gas compression applications. The key is horsepower. In the drive to reduce emissions, no operator wants to derate a compressor by sacrificing horsepower. Under some circumstances, a three-way catalytic converter could have a negative impact on horsepower by increasing system backpressure, although NSCR technology has evolved to the point where the backpressure problem pretty much has been conquered.

Installing a three-way converter on an existing engine can be accomplished fairly quickly and easily. Depending on engine size, an NSCR installation can be completed within a day in most cases. The process involves removing the silencer, installing the proper flanges, adding supports for the converter, and then reinstalling the silencer.

In some gas-producing regions, noise reduction is a growing issue, especially in metropolitan areas. A number of factors affect the noise transmitted from a compressor package, including engine size, muffler type, cooler size, etc., but the most important is the noise frequency of the engine exhaust. In general, lower frequencies are harder to abate than higher frequencies. In fact, a three-way catalyst actually reduces some of the higher frequencies, but the lower frequencies must be removed through a series of baffles in an exhaust silencer.

Integrated catalyst/silencer systems are available as self-contained units that meet critical- or hospital-grade noise requirements. Combining a three-way converter with an exhaust silencer into a single housing results in a simpler installation, smaller overall package size, less backpressure on the engine, and lower installed cost. The section of a converter/silencer unit that houses the three-way catalyst typically has a hatch to allow the catalyst to be serviced or removed. Units are commercially available today for the full range of engine sizes.

Three-way catalytic converters can be economically scaled down to meet almost any application. In fact, catalysts are even available for pumpjack engines. For very small engines, the biggest limiting factor in terms of economics tends to be the cost of the air/fuel ratio controller, as opposed to the cost of the catalytic converter itself.

Progressively More Stringent

As the NSPS standards for stationary engines are phased in over the next decade, emission control regulations will become progressively more stringent. Beginning this year, all newly manufactured stationary engines must comply with Tier 1-Tier 4 standards-49-99 horsepower engines must meet Tier 2 regulations, 100-751 horsepower engines must meet Tier 3 regulations, and engines larger than 751 horsepower must meet Tier 2 standards until 2011, when Tier 4 requirements become effective for 3,000 horsepower and larger engines.

One issue that remains unresolved at the moment relates to NSPS certification. NSPS certification is voluntary, and although engines can be certified by the manufacturer, certification also may be left up to the dealer, the packager or even the end user. The engines must be certified for a useful life of 10 years or 8,000 hours of operation. However, the engine owner will be required to perform a source test on noncertified engines. Furthermore, noncertified engines of 500 horsepower or larger will require a source test every three years or 8,760 hours of operation. That could become a very strong selling point, because if an end user buys an engine certified by the manufacturer, the end user would not have to pay for source testing.

Another issue for new lean-burn engines

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is meeting HAPs requirements under NSPS regulations. If a stationary engine emits either 10 tons a year of a single HAP (formaldehyde, acetaldehyde, acrolein or methanol) or 25 tons a year of a group of HAPs, the new standards require HAPs control. A three-way catalyst will provide some HAPs reduction on rich-burn engines because it will reduce hydrocarbons in the exhaust, but an oxidation catalyst is the only way to effectively reduce HAPs on lean-burn engines.

With heightened concerns about the emissions of gaseous air pollutants and particulate matter from stationary engine exhaust streams, emissions control technology is becoming increasingly important in the daily operation of natural gas compression equipment and facilities. The truth is that no solution can eliminate 100 percent of emissions. The internal combustion process will generate some amount of pollutants no matter what type of fuel is used or how sophisticated in-cylinder or exhaust gas treatment technologies become.

But until the day arrives when the internal combustion engine is replaced with a fuel cell or some other type of zero-emitting engine–which will not be any time soon–the natural gas compression industry, like other industries, will continue to rely on the internal combustion engine to provide the horsepower to get the job done. And that, in turn, means operators of gas compressors will need NSCR, SCR and other catalytic control technologies to reduce the emissions generated in producing, gathering, processing, storing and transporting natural gas. ❒