

WHITE PAPER

**GUIDANCE FOR
SAMPLING OF NO_x CONCENTRATIONS
FOR
SCR SYSTEM CONTROL IN GAS-FIRED
APPLICATIONS**

**PREPARED BY:
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INSTITUTE OF CLEAN AIR COMPANIES, INC.

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INSTITUTE OF CLEAN AIR COMPANIES

The Institute of Clean Air Companies, Inc. (ICAC), the nonprofit national association of companies that supply stationary source air pollution monitoring and control systems, equipment and services, was formed in 1960 to promote the industry and encourage improvements of engineering and technical standards.

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SAMPLING AND MEASUREMENT OF NO_x CONCENTRATIONS FOR SCR SYSTEM CONTROL IN GAS- FIRED APPLICATIONS

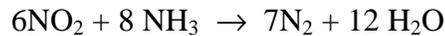
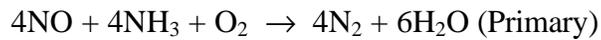
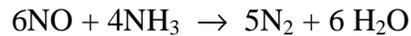
Guidelines for Accuracy and High Reliability

SUMMARY: *This document provides guidelines for the design and operation of a Continuous Emission Monitoring (CEM) systems for use with a Selective Catalytic Reduction (SCR) system in gas-fired applications. The SCR system inlet/outlet data is important to the overall control system in order to maintain system reliability in the operation and control of the SCR system and in order to determine compliance with applicable regulation.*

BACKGROUND

There are numerous selective catalytic reduction (SCR) systems in operation on gas-fired boilers and turbine engines in the U.S., and a significant number of new SCR units are also expected in the near future due to power and clean air requirements.

In the SCR process, ammonia is injected directly into the NO_x containing flue gas. The reduction occurs in a separate reactor vessel containing the catalyst at 450 – 750° F. The catalyst is usually a mixture of titanium dioxide, vanadium pentoxide, and tungsten dioxide. The known reducing reactions, depending on the amount of oxygen present, are as follows:



Continuous emissions monitoring systems (CEMS) are required to verify that the NO_x emissions are below the permitted levels established by the regulatory authority. CEM data is also used to verify NO_x reductions for use in the NO_x trading programs.

The quantity of ammonia injected into the flue gas stream must be sufficient to achieve the required reduction in NO_x. Exact stoichiometry of NH₃/NO_x is difficult to achieve at all points in the SCR reactor due, for example, to uneven flow distribution, temperature, and the response time to establish stoichiometry after adjustment of ammonia injection in response to change in flue gas NO_x inlet levels. Thus, some slip of ammonia occurs. The use of the same CEM for the measurement of unreacted ammonia is advantageous because some regulatory authorities are requiring reporting of ammonia emissions.

Efficient and cost-effective operation of the SCR depends on the ability of the control system to reliably monitor NO_x concentrations at the flue gas inlet and outlet of the SCR and NH₃ concentrations at the outlet of the SCR.

In some instances involving SCRs on gas-fired boilers and turbines, monitoring systems have experienced various problems with reliability and accuracy. As a result, SCR system performance suffered from poor control, over injection of ammonia and/or related balance of plant problems.

PURPOSE

This guideline recommends the proper design, installation and operation of NO_x and NH₃ emission monitoring systems for SCR applications on gas fired boilers and turbines.

SAMPLING ENVIRONMENT

The SCR control system must be capable of performing in a flue gas environment with a wide range of conditions. The general characteristics of flue gas from gas-fired installations that SCR systems are exposed to can range as follows:

- Gas temperatures up to 800° F for boilers
- Gas temperatures up to 1200° F for turbines
- Inlet NO_x concentrations ranging from 15 to 1000 ppmvd
- Outlet NO_x emissions as low as 0.5 ppmvd
- Outlet NH₃ emissions between 1 and 10 ppmvd
- SO₂ concentrations between 0 and 2 ppmvd
- Dust concentrations up to 0.02 gr/dscf

Gas turbines can produce 200 pounds of NO_x per one million cubic feet of gas burned, while utility boilers can generate 400 pounds of NO_x per one million cubic feet of gas burned.

The main parameters that affect NO_x formation are temperature, residence time, excess air, concentrations of the various species (N₂ and O₂), and the extent of mixing.

Gas turbines can affect these parameters by:

1. Operating with a lean primary zone (pre-mixed) in the combustion chamber – leading to lower flame temperatures.
2. Reducing the primary combustion zone volume – leading to reduced residence time.
3. Increasing liner pressure drop – leading to increased turbulence and the elimination of hot spots
4. Using water or steam injection – leading to a lower flame temperature.

Utility boilers can affect these parameters by:

1. Combustion zone cooling – leading to lower flame temperatures.
2. Special burner configurations (low NO_x burners) – leading to reduced temperatures and reduced combustion zone heat rates.
3. Flue gas recirculation – leading to reductions in combustion zone temperature and available oxygen.
4. Two-stage or off-stoichiometric combustion – leading to lower temperatures and a lack of oxygen required to form NO_x.

None of these primary combustion techniques will reduce NO_x emissions for turbines or boilers to the levels now being required by many regulatory agencies.

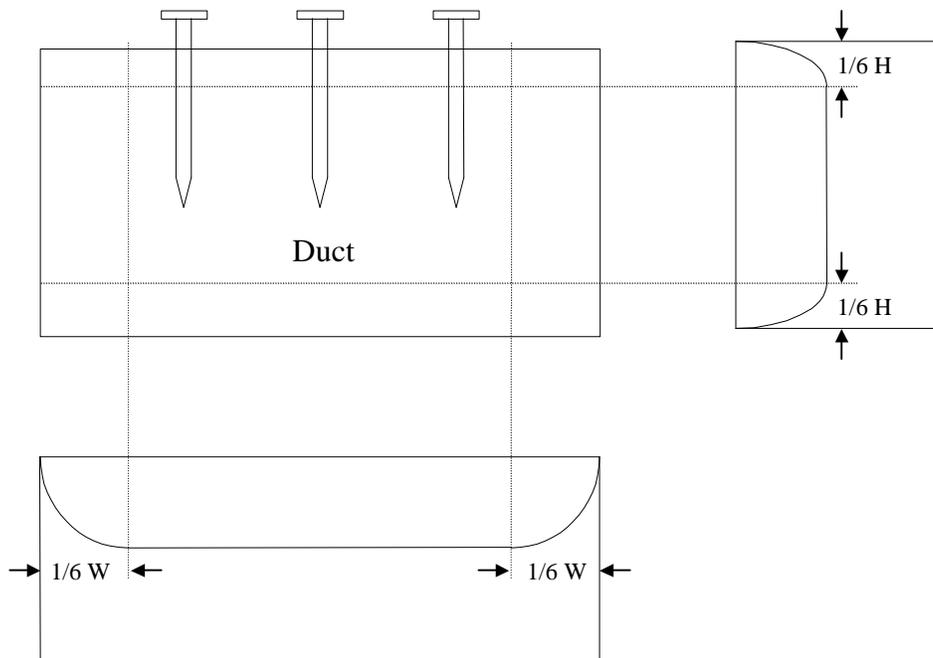
Individual system designs will require particular attention to unique operating characteristics and the flue gas composition of the specific installation.

REPRESENTATIVE SAMPLES

Large gas-fired boilers and turbines that will require SCR controls generally have large cross-sectional flue gas duct arrangements. This tends to generate unique flow profiles in the ductwork due to stratification, turbulence and other phenomenon. A situation is created whereby a single point probe will not necessarily provide a representative sample. The sampling system must be designed to provide a representative sample over the entire duct cross-sectional profile. This has to be accomplished by the use of multiple measurements in the ductwork. The best way to determine the actual duct profile is to have a testing company perform a load profile “map”. This will identify the best sampling locations, as well as the minimum number of sampling points required.

If a profile “map” cannot be developed, and the point of measurement is located in a straight run with little turbulence before or after the measurement point, a profile based on standard wind tunnel testing can be used (Fig. 1). If a profile is generated by a testing company under varied loads, then the number of probes as well as their position and length, may be different than Fig. 1.

Fig. 1. Measurement Profile Across a Rectangular Duct



SAMPLE INTEGRITY

In addition to obtaining a representative flue gas sample, the user must account for the presence of SO₂ and NH₃. If the sample temperature drops below 515° F, sulfate compounds can form and create problems for the sampling system. The minimal quantity of SO₂ formed from the mercaptans added to the gas to permit olfactory detection will not form any appreciable amounts of sulfates if the sample train is kept at an elevated temperature. Also, as the flue gas NO_x levels decrease due to the catalytic reaction across the bed, the ratio of the NO₂ to NO increases, thus making traditional NO_x monitors less accurate. An NO₂ to NO converter is required in the sample conditioning or analyzing system in order to eliminate this potential problem and maintain accuracy.

The most common method of measuring ammonia concentration consists of converting the NH₃ to NO, drying the sample and transferring it to a standard NO analyzer. The mass balance calculation for ammonia concentration is accomplished in the data acquisition and reporting system that is part of the CEM system.

A very important design consideration is the ability to maintain the quality of the sample from the probe inlet to the analyzer. Particular attention must be given to keeping the sample well above the condensation point of any of the potential sulfur compounds that may form prior to the analyzer.

At the SCR outlet, the sample gas will normally contain concentrations of ammonia of between 1 and 10 ppmvd depending on the SCR design and permitted level. The ammonia emission will gradually increase if the percent NO_x reduction remains constant, as the catalyst degrades over time.

RECOMMENDATIONS

In order to establish a NO_x/NH₃ monitoring system that provides the reliability and accuracy necessary for compliance determinations and for proper SCR control, the following guidelines are recommended:

Number of Sample Points – The optimum number and location of sample points should be established through load profile “mapping”. If this mapping is not performed, a minimum of three inlet and outlet sampling points should be specified for large ducts. Per EPA guidelines, a single sample point may be sufficient for long duct runs.

Location of Sample Inlet Points – The inlet sampling points must be located sufficiently upstream of the reaction injection grid to insure maximum NO_x reduction has occurred and to minimize possible reagent (ammonia) interference.

Type of Sample Measurement – An in-situ system can be used on the inlet side of the SCR. At either the inlet or outlet, a straight extractive or dilution extractive system can be used. For low levels of NO_x and NH₃, typically a straight extractive system has been

the preferred method of sample measurement. It is critical, however, with any system that the sample must be maintained above the condensation point of all possible compounds that may be formed. Purge air, dilution air, and all components that are in contact with the sample must be maintained above the condensation temperature. If a dilution extractive system is used, the dilution air must be totally free of all components being measured.

Temperature of Sample - Flue gas samples must be maintained above 515° F prior to conditioning in order to maintain the integrity of the sample and to prevent plugging of the sample train and analyzer systems. At the SCR outlet, ammonia slip can be expected to be present. Some ammonia will start to convert to NO at temperatures above 660° F. This will be measured as NO_x. Therefore, flue gas samples should be maintained in a range of 515° F to 660° F.

Sample Line Length – Sample line length is directly proportional to monitoring system response. The longer the sample line, the longer the system response. Furthermore, experience indicates that the longer the sample line the greater the potential for increased maintenance. The sampling system should, therefore, be designed to minimize the length of the sample lines. This is especially critical if the CEM system will also be used for process control of the SCR system. In some cases using the CEMS for outlet monitoring and control on large boilers or turbines will make it difficult to meet the system response requirements for tight control. In this situation a separate inlet/outlet NO_x monitor is recommended.

Ammonia Slip Measurement – Although there are several analytical methods available, the use of a chemiluminescent NO analyzer is currently the most common method of measuring ammonia slip. This technology provides one of the standard methods for measuring the level of NO_x in sample gas. Because this type of analyzer is already needed in a CEMS that monitors NO_x concentrations in a flue gas, it is well understood and available. The key to this best solution consists of converting the NH₃ component of the sample to NO on the stack or duct near to the probe using a thermal oxidizer, and then comparing this value to the unconverted ammonia NO measurement. This eliminates the sample transport problems associated with ammonia. In addition to chemiluminescent NO analyzers, other analyzers including laser-based direct ammonia analyzers, ion mobility spectroscopy (IMS) analyzers, and electrochemical analyzers are under development or are being tested.

SUMMARY

The measurement of very low levels of NO_x in the presence of ammonia presents unique problems. An effective CEMS for low NO_x measurement and SCR control requires total system optimization with respect to sampling, sample integrity and transport, and the measurement of both NO_x and NH₃.



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