B.16 NONSELECTIVE CATALYTIC REDUCTION[28,29,30]

B.16.1 Background

Nonselective catalytic reduction (NSCR) is an add-on NO_x control technology for exhaust streams with low O_2 content. Nonselective catalytic reduction uses a catalyst reaction to simultaneously reduce NO_x, CO, and hydrocarbon (HC) to water, carbon dioxide, and nitrogen. The catalyst is usually a noble metal. The conversion occurs in two sequential steps, as shown in the following equations:

Step 1 Reactions:
$$2CO + O_2 \rightarrow 2CO_2$$
$$2H_2 + O_2 \rightarrow 2H_2O$$
$$HC + O_2 \rightarrow CO_2 + H_2O$$

Step 2 Reactions:
$$NO_x + CO \rightarrow CO_2 + N_2$$
$$NO_x + H_2 \rightarrow H_2O + N_2$$
$$NO_x + HC \rightarrow CO_2 + H_2O + N_2$$

The step 1 reactions remove excess O_2 from the exhaust gas because CO and HC will more readily react with O_2 than with NO_x. The O_2 content of the stream must be kept below approximately 0.5 percent to ensure NO_x reduction.

One type of NSCR system injects a reducing agent into the exhaust gas stream prior to the catalyst reactor to reduce the NO_x. Another type of NSCR system has an afterburner and two catalytic reactors (one reduction catalyst and one oxidation catalyst). In this system, natural gas is injected into the afterburner to combust unburned HC (at a minimum temperature of 1700°F). The gas stream is cooled prior to entering the first catalytic reactor where CO and NO_x are reduced. A second heat exchanger cools the gas stream (to reduce any NO_x reformation) before the second catalytic reactor where remaining CO is converted to CO_2.

The control efficiency achieved for NO_x ranges from 80 to 90 percent. The NO_x reduction efficiency is controlled by similar factors as for SCR, including the catalyst material and condition, the space velocity, and the catalyst bed operating temperature. Other factors include the air-to-fuel (A/F) ratio, the exhaust gas temperature, and the presence of masking or poisoning agents. The discussions in section B.15 for SCR relating to catalyst issues and space velocity also apply to NSCR. The operating temperatures for NSCR system range from approximately 700° to 1500°F, depending on the catalyst. For NO_x reductions of 90 percent, the temperature must be between 800° to 1200°F. One source indicates that the O_2 concentration for NSCR must be less than 4 percent, and another source indicates that the O_2 concentration must be at or below approximately 0.5 percent.

B.16.2 Indicators of NSCR Performance

The key indicators for NSCR are the same performance indicators for SCR with a few exceptions (minus the NH_3/NO_x ratio, outlet NH_3 concentration, and sulfur content of the fuel). Outlet NO_x concentration, catalyst bed inlet temperature, catalyst activity, pressure differential across the catalyst bed, catalyst bed outlet temperature, inlet gas flow rate, and outlet O_2 concentration were discussed above. Table B-16 lists these indicators and illustrates potential monitoring approaches for NSCR.

B.16.3 Illustrations

The following illustration presents an example of compliance assurance monitoring for NSCR:

16a: Monitoring catalyst bed inlet temperature, catalyst bed outlet temperature, and catalyst activity.

B.16.4 Bibliography

TABLE B-16. SUMMARY OF PERFORMANCE INDICATORS FOR NSCRs

Parameters	Performance indication	Approach No.	1	2	3
		Illustration No.		16a	
		Example CAM Submittals			
		Comment			
Primary Indicators of Performance					
Outlet NO_X concentration	Direct measure of outlet concentration. Most direct single indicator of NSCR performance.		X		
Catalyst bed inlet temperature	Indicator that bed inlet is of sufficient temperature to initiate reduction. Also an indicator that bed inlet temperature is not too high for catalyst longevity.			X	X
Catalyst activity	Periodic check of catalyst activity gives an indication of catalyst fouling or masking. Must periodically clean and/or replace catalyst to ensure reduction is occurring.			X	
Other Performance Indicators					
Catalyst bed outlet temperature	Indicator of level of reduction occurring in the catalyst bed and that temperature does not exceed design limits of catalyst. Higher temperatures improve reduction of CO and VOC but encourage generation of NO_X.			X	X
Pressure differential across catalyst bed	Indicator of bed fouling or plugging. Increase in pressure differential indicates that bed is becoming fouled or plugged. Changes in pressure differential are likely to be gradual.				X
Outlet O_2 concentration	Indicator of dilution rate. Generally monitored in combination with NO_X, VOC, or CO concentration to allow for correcting concentration to a specified percent O_2.		X		
Comments: None.					

CAM ILLUSTRATION
No. 16a. NONSELECTIVE CATALYTIC REDUCTION FOR NO_X CONTROL

1. APPLICABILITY

1.1 Control Technology: Nonselective catalytic reduction [065]
1.2 Pollutants
Primary: Nitrogen oxides (NO_X)
Other: Nitric acid (HNO_3), ammonia (NH_3)
1.3 Process/Emission units: Internal combustion engines (ICE)

2. MONITORING APPROACH DESCRIPTION

2.1 Indicators Monitored: Catalyst bed inlet temperature, catalyst bed outlet temperature, and catalyst activity.
2.2 Rationale for Monitoring Approach
- Catalyst bed inlet temperature: Indication that the gas stream is at sufficiency temperature to initiate reduction on the catalyst bed; too high a bed temperature may generate NO_X rather than reduce NO_X.
- Catalyst bed outlet temperature: Indication that the reaction is occurring in the catalyst bed; too high a bed temperature may generate NO_X rather than reduce NO_X.
- Catalyst activity: Indication of the catalyst's ability to promote the reduction of NO_X.

2.3 Monitoring Location
- Catalyst bed inlet temperature: Inlet to the catalyst bed.
- Catalyst bed outlet temperature: Outlet to the catalyst bed.
- Catalyst activity: Removal of a small portion of catalyst for testing.

2.4 Analytical Devices Required: Thermocouples or other temperature instrumentation.
2.5 Data Acquisition and Measurement System Operation
- Frequency of measurement:
  - Catalyst bed inlet temperature: Measure continuously.
  - Catalyst bed outlet temperature: Measure continuously.
  - Catalyst activity: Measure periodically.
- Reporting units:
  - Catalyst bed inlet temperature: Degrees Celsius or Fahrenheit (C or F).
  - Catalyst bed outlet temperature: Degrees Celsius or Fahrenheit (C or F).
  - Catalyst activity: Percent active compared with new catalyst (or other as appropriate).
- Recording process:
  - Catalyst bed inlet temperature: Recorded automatically on strip chart or data acquisition system.
  - Catalyst bed outlet temperature: Recorded automatically on strip chart or data acquisition system.
  - Catalyst activity: Manually recorded in NSCR maintenance log.

2.6 Data Requirements
- Baseline catalyst bed inlet temperature, catalyst bed outlet temperature, and catalyst activity measurements concurrent with emission test.
- Historical plant records of catalyst bed inlet temperature, catalyst bed outlet temperature, and catalyst activity measurements.

2.7 Specific QA/QC Procedures
- Calibrate, maintain, and operate instrumentation using procedures that take into account manufacturer's recommendations.

2.8 References: _____

3. COMMENTS

None.