B.17 WATER OR STEAM INJECTION[28,29,30]

B.17.1 Background

Water or steam injection provides control of NO_x in the combustion zone. The formation of NO_x results from one of three mechanisms: thermal NO_x, fuel NO_x, and prompt NO_x. Because thermal NO_x formation increases exponentially with temperature, small reductions in temperature will result in significant reductions of NO_x. Water or steam injection into the flame area provides a heat sink that lowers the flame temperature and reduces thermal NO_x formation. Water injection provides greater NO_x reduction than steam injection. Injection rates are defined by water-to-fuel ratios (WFR). Water or steam injection only control thermal NO_x formation due to the lower flame temperature; injection may actually increase the rate of fuel NO_x formation. The most important factors in the injection system performance are the WFR, the combustor geometry, injection nozzle design, and the fuel-bound nitrogen (FBN) content. Water injection corresponds to an approximate 60 to 70 percent reduction from uncontrolled levels for small turbines and approximately 70 to 80 percent reduction for utility and large turbines. For natural gas, typical WFR range from 0.33 to 2.48 on a weight basis. For oil fuel, typical WFR range from 0.46 to 2.28. A WFR of 1.0 (weight basis) on a natural gas-fired turbine will reduce NO_x by 70 to 80 percent (depending on initial NO_x levels). The reduction efficiency of NO_x increases as the WFR increases, up to an optimum level, beyond which water injection interferes with combustion. Combustor geometry and injection nozzle design affect the performance. The water must be atomized to give a homogeneous spray of water droplets to avoid localized hot spots in the combustor that may produce increased NO_x emissions. Fuel types such as natural gas and distillate oils have low-nitrogen contents and provide lower NO_x emissions levels when water injection is used. The FBN contents of coal-derived liquid fuel, shale oil, and residual oils result in higher fuel NO_x formation.

In some applications, CO emissions increase as the WFR increases; steam injection does not cause as much increase in CO emissions as water injection. Increasing WFR also results in an increase in HC emissions but to a lesser extent than for CO emissions.

A combustor using water or steam injection has increased maintenance requirements due to erosion and wear. The interval of time between inspections should be decreased due to injection use. Water and steam injection is not applicable to internal combustion engines but the technology has been applied to many turbines. High purity water is used to minimize wear on turbine components (nozzles, combustor cans, turbine blades). The water quality, amount of water injected, combustor can design and materials, and load cycle are factors affecting the failure rate of turbine units.

B.17.2 Indicators of Water/Steam Injection Performance

The key indicators for water or steam injection are outlet NO_x concentration, WFR, and fuel-bound N_2 content.

Outlet NO_x concentration. The most direct single indicator of the performance of water or steam injection is the NO_x concentration at the outlet of the unit.

Water-to-fuel ratio. The water or steam injection rate to the burner reduces the combustion temperature and reduces the formation of thermal NO_x. Increases in the injection rate reduce formation of NO_x up to a critical rate beyond which the water or steam interfere with combustion in the turbine.

Fuel-bound N_2 concentration. The fuel-bound N_2 content is a factor in the amount of NO_x formed from the combustion of fuel. Increases in the N_2 content will result in increases in the outlet NO_x concentration.

B.17.3 Illustrations

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

17a: Monitoring water-to-fuel ratio.

B.17.4 Bibliography

TABLE B-17. SUMMARY OF PERFORMANCE INDICATORS FOR WATER INJECTION

		Approach No.	**1**	**2**
		Illustration No.		**17a**
		Example CAM Submittals		
Parameters	**Performance indication**	**Comment**		
Primary Indicators of Performance				
Outlet NO_X concentration	Direct measure of outlet concentration. Most direct indicator of water or steam injection performance.		X	
Water-to-fuel ratio	Affects the combustion temperature and lowers thermal NO_X formation. Increase in the water rate results in a decrease in NO_X emissions up to a critical rate, after which the combustion flame may be doused.			X
Other Performance Indicators				
Fuel-bound N_2 content	Affects the fuel NO_X formation. Increase in N_2 content of the fuel or increase in the amount of fuel used will increase NO_X emissions.			
Comments: None.				

CAM ILLUSTRATION
No. 17a. WATER INJECTION FOR NO_X CONTROL

1. APPLICABILITY

1.1 Control Technology: Water injection [028]
1.2 Pollutants
Primary: Nitrogen oxides (NO_X); (NO, NO_2, NO_3)
1.3 Process/Emissions Units: Stationary gas turbines

2. MONITORING APPROACH DESCRIPTION

2.1 Indicators Monitored: Water-to-fuel ratio.
2.2 Rationale for Monitoring Approach: Water injection reduces the combustion temperature and reduces thermal NO_X formation.
2.3 Monitoring Location
- Water injection rate: Inlet water feed line.
- Fuel use: Inlet fuel line.

2.4 Analytical Devices Required
- Water injection rate: Liquid flow meter or other device for liquid flow.
- Fuel use: Natural gas flow meter or other device for gas flow.

2.5 Data Acquisition and Measurement System Operation
- Frequency of measurement: Continuously on strip chart or data acquisition system.
- Reporting units: Pound of water per pound of fuel combusted.
- Recording process: Recorded automatically on strip chart or data acquisition system.

2.6 Data Requirements
- Baseline water injection rate and fuel flow rate measurements and WFR calculations concurrent with emission test.
- Historical plant records of fuel feed rate and water injection rate measurements and WFR calculations.

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

2.8 References: ______

3. COMMENTS

None.