**NEW MEXICO AIR QUALITY BUREAU**

**NSR & TV: TURBINE MONITORING PROTOCOL –**

**PERMIT TEMPLATE LANGUAGE**

**Version: May 23, 2016**

Purpose. These guidelines are intended to help permit specialists include adequate monitoring conditions into construction or operating permits in accordance with 20.2.72.210 NMAC or 20.2.70.302 NMAC. These guidelines also help ensure consistency in monitoring conditions for all permits regardless of which permit specialist is assigned the permit.

All turbines are combustion devices subject to 20.2.61 NMAC and opacity monitoring, unless they qualify for the exemption under 20.2.61.109 NMAC (see permit template for opacity language).

[NOTE: Each permit writer shall review and adjust the requirements below according to the specific facility circumstances.]

## Turbines

1. Maintenance and Repair Monitoring (Units A-1 and A-2)

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| **Requirement:** Compliance with the allowable emission limits in Table 106.A shall be demonstrated by properly maintaining and repairing the units. |
| **Monitoring:** Maintenance and repair shall meet the minimum manufacturer's or permittee's recommended maintenance schedule. Activities that involve maintenance, adjustment, replacement, or repair of functional components with the potential to affect the operation of an emission unit shall be documented as they occur for the following events:  (1) Routine maintenance that takes a unit out of service for more than two hours during any twenty-four hour period.  (2) Unscheduled repairs that require a unit to be taken out of service for more than two hours in any twenty-four hour period. |
| **Recordkeeping:** The permittee shall maintain records, including dates, and maintenance activities conducted in accordance with Section B109. The permittee shall also maintain a copy of the manufacturer’s or permittee’s recommended maintenance schedule. |
| **Reporting:** The permittee shall report in accordance with Section B110. |

1. Periodic Emissions Tests (Unit(s) X, Y, and Z)

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| **Requirement:** Compliance with the allowable emission limits in Table 106.A shall be demonstrated by conducting periodic emission tests during the monitoring period. |
| **Monitoring:** The permittee shall test using a portable analyzer or EPA Reference Methods subject to the requirements and limitations of Section B108, General Monitoring Requirements. Emission testing is required for NOx and CO, [change reference to pollutants as necessary] and shall be carried out as described below.  [If the unit has VOC emission limits, include the following.] Test results that demonstrate compliance with the CO emission limits shall also be considered to demonstrate compliance with the VOC emission limits.   1. The testing shall be conducted as follows: 2. Testing frequency shall be once per [month, quarter, or year]**.** 3. The monitoring period is defined as [a calendar month, a calendar quarter, a calendar year], or [a custom schedule requested by the permittee].   (2) The first test shall occur within the first monitoring period occurring after permit issuance. **[or if testing already required]** The tests shall continue based on the existing testing schedule.  (3) All subsequent testing shall occur in each succeeding monitoring period. No two monitoring events shall occur closer together in time than 25% of a monitoring period.  (4) The permittee shall follow the General Testing Procedures of Section B111.  [add #5 if subject to testing in NSPS GG or KKKK] (5) Performance testing required by 40 CFR 60, Subpart GG or 40 CFR 60, Subpart KKKK may be used to satisfy these periodic testing requirements if they meet the requirements of this condition and are completed during the specified monitoring period. |
| **Recordkeeping:** The permittee shall maintain records in accordance with Section B109, B110 and B111. The permittee shall also record the results of the periodic emissions tests, including the turbine's fuel flow rate and horsepower at the time of the test, and the type of fuel fired (natural gas, field gas, etc.).  The permittee shall also keep records of all raw data used to determine exhaust gas flow and of all calculations used to determine flow rates and mass emissions rates. |
| **Reporting:** The permittee shall report in accordance with Section B109, B110, and B111. |

**[Installation of a PEMS on turbines is optional. If the facility intends to install a PEMS, use the following sections. See Background section of this document for a discussion.]**

1. Continuous / Predictive Emissions (Unit(s) X, Y, and Z)

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| **Requirement:** The unit(s) shall be equipped with a properly operating continuous predictive emissions monitoring system PEMS). |
| **Monitoring:** The permittee shall use the PEMS to determine the NOx and CO maximum pound per hour emission rate for each turbine.  Within six months of the issue date of this permit, the PEMS shall undergo a relative accuracy test assessment (RATA) according to NSPS Appendix B, Performance Specification 2. The reference method shall be Method 20 of NSPS Appendix A. |
| **Recordkeeping:** The permittee shall record the pound per hour NOx and CO emission rates. |
| **Reporting:** The permittee shall report according to Section B110. |

1. Initial Compliance Test (Unit(s) X, Y, and Z)

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| **Requirement:** Compliance with the allowable emission limits in Table 106.A shall be demonstrated by performing initial compliance testing. |
| **Monitoring:** The permittee shall perform an initial compliance test in accordance with the General Testing Requirements of Section B111. Emission testing is required for NOx and CO. [change reference to pollutants as necessary].  [If the unit has VOC emission limits, include the following.] Test results that demonstrate compliance with the CO emission limits shall also be considered to demonstrate compliance with the VOC emission limits.  The monitoring exemptions of Section B108 do not apply to this requirement. [TV: Add additional requirements from NSR Permit such as timeframe] |
| **Recordkeeping:** The permittee shall maintain records in accordance with applicable Sections in B109, B110, and B110. |
| **Reporting:** The permittee shall report in accordance with the applicable Sections in B109, B110, and B111. |

1. 40 CFR 60, Subpart GG (Unit(s) X, Y, and Z)

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| **Requirement:** The unit(s) is/are subject to 40 CFR 60, Subpart GG and the permittee shall comply with the applicable requirements of 40 CFR 60, Subpart A and Subpart GG. |
| **Monitoring:** The permittee shall comply with the monitoring and testing requirements of 40 CFR 60.334 and 60.335. |
| **Recordkeeping:** The permittee shall comply with the recordkeeping requirements of 40 CFR 60.334 and 40 CFR 60.7. |
| **Reporting:** The permittee shall comply with the reporting requirements of 40 CFR 60.7. |

Add to the Emission Section A106 the following limits, ppmv should be calculated by applicant and verified by permit writer using the NSPS GG spreadsheet.

1. NOx emissions from any of the [Solar Mars] turbines (Unit(s) XX, YY, and ZZ) shall not exceed [xxx] ppmv at 15 percent oxygen on a dry basis. (40 CFR 60.332)
2. NOx emissions from the [Solar Taurus] turbine (Unit(s) XX, YY and ZZ) shall not exceed [xxx] ppmv at 15 percent oxygen on a dry basis. (40 CFR 60.332)
3. SO2 emissions from each turbine, Units XX, YY, and ZZ, shall not exceed 0.015 percent by volume at 15 percent oxygen on a dry basis, or shall not burn fuel which contains sulfur in excess of 0.8 percent by weight (8000 ppmw). (40 CFR 60.333)
4. 40 CFR 60, Subpart KKKK (Unit(s) X, Y, and Z)

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| **Requirement** The unit(s) is/are is subject to 40 CFR 60, Subpart KKKK and the permittee shall comply with the applicable requirements of 40 CFR 60, Subpart A and Subpart KKKK. |
| **Monitoring:** The permittee shall comply with all applicable monitoring and testing requirements, including but not limited to 40 CFR 60.4333. |
| **Recordkeeping:** The permittee shall comply with all applicable recordkeeping requirements, including but not limited to 40 CFR 60.7. |
| **Reporting:** The permittee shall comply with all applicable reporting requirements, including but not limited to 40 CFR 60.4375, 60.4395, and 60.7. |

**[Case by Case: If the emission unit is operating below its full capacity, additional requirements may be necessary. The permit writer should review the calculations and/or manufacturer’s specifications provided to determine emissions for the facility’s specific operating scenario(s). ]**

1. Fuel Consumption (Unit(s) X, Y, and Z)

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| **Requirement:** Compliance with the allowable emission limits in Table 106.A shall be demonstrated by[insert operational requirement]. |
| **Monitoring:** The permittee shall measure the fuel usage of each unit with a dedicated fuel meter. |
| **Recordkeeping**: The permittee shall record the average amount of fuel consumed by each affected turbine for every calendar [month/quarter], expressed in MMBTU/hour, including the make and model of the fuel flowmeter, all charts generated by the flowmeter, the type of fuel fired (natural gas, field gas, etc.), a contemporaneous fuel analysis if the fuel is other than natural gas, and all instrument calibrations. The record shall include a flow diagram showing the configuration of the flow meter relative to the turbine. |
| **Reporting:** The permittee shall report in accordance with Section B110. |

1. Load Requirement (Unit(s) X, Y, and Z)

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| **Requirement** Compliance with the allowable emission limits in Table 106.A shall be demonstrated by not operate below a minimum of XX percent ISO load conditions. |
| **Monitoring:** The permittee shall monitor the operational load conditions. |
| **Recordkeeping:** The permittee shall record the time, duration, and date of turbine operation below XX percent of ISO load. |
| **Reporting:** The permittee shall report in accordance with Section B110. |

## BACKGROUND INFORMATION

(Not for inclusion in permit)

In New Mexico, turbines are found almost exclusively at mainline compressor stations, oil refineries, and natural gas processing plants. Turbines are also located at power generation plants but these are generally external combustion units. Most medium sized turbines (about 1000 HP through about 15,000 HP) in New Mexico were built by Solar Inc. of San Diego, CA, a division of Caterpillar Engines. General Electric built mostly larger turbines. This document will only discuss gas-powered turbines.

**Regulatory Requirements:** There are no state regulations that apply specifically to turbines.

NSPS Subpart GG (40 CFR 60.330 et seq.) applies to turbines whose heat input >10 MMBTU/hour and for which construction or modification commenced after October 3, 1977. The regulation limits the NOx and SO2 concentrations for affected turbines. Unfortunately, Subpart GG is seriously out of date and fails to account for the enormous changes in turbine design made since the regulation's original promulgation in 1979.

NSPS Subpart KKKK applies to turbines whose input >10 MMBTU/hour and for which construction, modification, or reconstruction commenced after February 18, 2005.

**Operating Principles of Natural Gas Turbines:** Most turbines at New Mexico oil and gas plants are of the simple cycle type and the majority of these are two-shaft units. Figure 1 shows a simplified schematic of a simple-cycle, two-shaft turbine. In a simple cycle turbine, the turbine’s front-end compressor first compresses inlet air. The compressed air enters a combustor where natural gas is injected and ignited. The heat of combustion raises the temperature and pressure of the compressed air. The newly acquired thermal energy is converted to kinetic energy (i.e. work) by expanding the heated air through a set of aerodynamically designed turbine blades arranged around a shaft. Part of the shaft's energy is used to drive the front-end air compressor and the remaining energy is available for external work, usually to drive a natural gas compressor.

In a two-shaft simple cycle turbine, the turbine that drives the front-end air compressor is decoupled from the turbine that provides the useful work, thereby allowing for variable speed applications.

A combined-cycle turbine uses the turbine's exhaust heat to generate steam to drive a secondary steam turbine, thereby improving the thermal efficiency of the turbine. A recuperative-cycle turbine uses the turbine's hot exhaust to preheat the incoming air, thereby also improving the turbine's overall thermal efficiency.

**Character of Emissions:** The principal pollutants from a turbine are NOx and SO2. The latter pollutant occurs only from turbines using fuels other than natural gas. CO and unburned hydrocarbons (UHC) can be found in the turbine exhaust, but these are rarely the subject of regulatory concern.

NOx from turbines is exclusively thermal NOx. The high combustion temperatures found in a turbine ensure the copious production of NOx. In simple cycle turbines at least, NOx increases with increasing load while CO and UHC decrease. Figure 2 shows the pollutant concentration trend, normalized to 15% exhaust gas oxygen, for a so-called typical turbine. According to Mr. Wilfred Hung, an engineer with Solar Turbines, Inc. and the author of numerous papers on NOx emissions from turbines, the linear NOx trend shown in Figure 2 is the exception, not the rule.

Note 1: Periodic Emissions Testing: “Test results that demonstrate compliance with the CO emission limits shall also be considered to demonstrate compliance with the VOC emission limits.” The rationale for this statement is that the portable analyzers do not speciate VOC compounds and the cost of a separate EPA method test is significant; therefore, AQB relies on CO monitoring to demonstrate compliance with VOC limits. Taking into account that the manufacturer tests the equipment and specifies the expected NOx, CO, and VOC emissions for a unit operating properly, as well as basic principles of combustion chemistry, if an engine test demonstrates that CO concentration fall within the emission limits, then VOC also falls within the emission limits, and the engine is performing as represented in the application.

**Predictive Emissions Monitoring Systems (PEMS/CEMS):** PEMS/CEMS for turbines falls into two broad categories. The first, statistical PEMS/CEMS, relies on statistical data obtained from many similar turbines to predict NOx emissions. These emissions are predicted as a function of turbine load. This type of PEMS/CEMS lacks the flexibility to adjust NOx predictions as the turbine's operating parameters change, for example barometric pressure or humidity. The general availability of statistical PEMS/CEMS packages is unknown at this time.

The second form of PEMS/CEMS, first principles PEMS/CEMS, relies on a fundamental thermodynamic model of the combustion process to predict NOx emissions. First principle PEMS/CEMS relies on sensors located throughout the turbine as input to the thermodynamic model. This form of PEMS/CEMS is capable of adjusting its prediction of NOX emissions as the turbine's operating parameters change. First principles PEMS/CEMS is at a sufficiently advanced state of development that many have passed the RATA of NSPS Appendix B.

A third form of PEMS/CEMS is a hybrid of the first two. Emissions data from a particular turbine are used to "calibrate" the thermodynamic model in order to obtain a more precise prediction of NOx emissions.

A fundamental problem with any PEMS/CEMS is that it cannot easily take into account the effects of turbine wear and tear. As turbines age, blades wear down and internal deposits occur that decrease the turbine efficiency. The additional fuel required to overcome these defects changes the NOx emissions and may not be fully accounted for by the PEMS/CEMS. Fortunately, changes to NOx emissions from these defects are not expected to be very large.

**Solar Turbines:** Mr. Hung of Solar Turbines in San Diego, CA, stated that Solar provides PEMS/CEMS programs for every turbine that the company manufactures, regardless of the turbine's date of construction. Michelle Long, a Solar permitting engineer (619-694-1602), said that the cost of providing the PEMS/CEMS software for a new or recent vintage Solar turbine was $35K to $40K per turbine. Whether or not the PEMS/CEMS software is installed, all new and recent vintage Solar turbines come equipped with the sensors that provide the data used as PEMS/CEMS input. Solar turbines older than about 8 years would need the sensors installed.

Solar's PEMS/CEMS is of the first-principles type that relies on only two variables to completely characterize the emission profile of a turbine. For Solar's simple-cycle, two-shaft turbines, these two variables are T1, the ambient air temperature, and T5, the power turbine inlet air temperature. Figure 1 shows the location of these temperatures. These temperatures are easily and accurately measured, and when fed into a computer program, give reliable NOx and CO emission rates.

**General Electric Turbines:** General Electric offers its trademarked GTPEMS/CEMS system to predict NOx emissions from GE turbines. GTPEMS/CEMS is a hybrid model that uses "real" data to calibrate the first-principles model. According to a GE brochure, GTPEMS/CEMS is available for all GE turbines. Mr. Chris Forland of GE Reuter-Stokes in Cleveland, OH, stated that the company charges about $150,000 to outfit an existing turbine with GTPEMS/CEMS. The cost of outfitting additional turbines at the same site is about $100,000 each.

**JUSTIFICATION**

(Not for inclusion in permit)

**Periodic Emission Test:** Exhaust gas NOx and CO emission rate measurements using a portable analyzer: All turbines without a PEMS/CEMS will be required to have periodic emissions tests and measure the fuel flow annually. As explained in the background section of this document, with PEMS/CEMS as the primary compliance tool, very little information is to be gained from the use of a portable analyzer to measure species mass emissions from a turbine.

**Requirement for RATA on PEMS/CEMS:** A PEMS/CEMS, like a CEMS, should be certified before accepting its results. The RATA may be waived for PEMS/CEMS with a proven track record for the particular type of turbine in question.

**Requirement for a PEMS/CEMS:** Due to its high cost, the Bureau will not require a PEMS/CEMS for turbines.

**REFERENCES**

1. Predictive Emission Monitoring System (PEMS/CEMS): The Established NOx Monitoring System for Industrial Gas Turbines, Wilfred S.Y. Hung, Solar Turbines Inc., San Diego, CA, paper presented at 88th Annual AWMA Meeting, San Antonio, TX, June 1995;

2. Code of Federal Regulations, Title 40, Part 60, Subpart GG (Standards of Performance for Stationary Gas Turbines), 60.330 et seq;

3. NOx Emission Control For Gas Turbines: A 1995 Update on Regulations and Technology, Marvin M. Schorr, GE Power Systems, Schenectady, NY, paper presented at the CIBO NOx Control VIII Conference, Philadelphia, PA, March 1995;

4. GE Gas Turbine Performance Characteristics, F.J. Brooks, GE Industrial Power Systems, Schenectady, NY, document no. GER-3567E, September 1994.