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SUBJECT: Consideration of Collateral Environmental Impacts Associated with the Use of SCR at Dry Low NO_x Combined Cycle Natural Gas Turbines

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TO: Air Division Directors

The purpose of this memorandum is to provide guidance concerning consideration of collateral environmental impacts associated with the use of selected catalytic reduction in determinating best available control technology for NO_x at dry low NO_x natural gas combined cycle turbines. In most cases best available control technology (BACT) for controlling NO_x emissions from combined cycle natural gas turbines used to generate electricity is a concentration that is achieved by selective catalytic reduction (SCR). This is true at all combined cycle natural gas plants including those that use a variant of the technology called dry low NO_x (DLN) turbines that can achieve less than 10 parts per million NO_x emissions without add on controls. In some situations, however, the collateral environmental impacts associated with the use of ammonia with SCR may justify not requiring SCR on DLN turbines. This guidance discusses those collateral environmental impacts that are appropriate to consider as part of a BACT determination of SCR use on a combined cycle turbine when they are presented to the permitting authority by a permit applicant. It is the permit applicant's obligation to present information on any impacts, specific to the installation of SCR on the unit being permitted, that he wishes to be considered in the BACT determination.

Background on NO_x Control

In most instances, BACT for NO_x control at combined cycle natural gas turbines is found to be SCR. Combined cycle natural gas turbines that are widely available today produce less NO_x than other types of fossil fuel electricity generating plants. These turbines typically emit up to 25 parts per million (ppm) NO_x and are usually permitted at between 2.5 ppm and 4.5 ppm with SCR. Dry low NO_x (DLN) turbines, a technology that was developed to achieve single digit NO_x emissions without add-on controls, can be operated so that they emit no more than 9 ppm of NO_x. When SCR is applied to DLN turbines they also emit NO_x in the 2.5 ppm to 4.5 ppm range.

SCR is a widely used technology for controlling NO_x emissions from a wide variety of

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stationary combustion sources. SCR selectively reduces NO_x emissions by injecting ammonia into the exhaust gas upstream of a catalyst where the NO_x reacts with the ammonia and oxygen to form N_2 and water. SCR is most effective within a certain temperature range and higher or lower temperatures and other operating conditions can cause some of the NO_x and ammonia to pass through the catalyst without reacting. Catalysts degrade eventually, and that also can cause ammonia to pass through the catalyst unreacted. The ammonia that is emitted is called ammonia slip. Plant operators can minimize ammonia slip by using a larger catalyst bed and by replacing it as it degrades. Some states specify a limit for the ammonia slip, usually between 5 ppm and 10 ppm, in permits for combined cycle natural gas turbines. Units operate well below the limit for most of time they are operating so as not to exceed the permitted limit. However EPA does not limit emissions of ammonia.

Permit applicants have raised a variety of collateral issues concerning the use of SCR. The most frequently cited concern is the potential danger of handling ammonia. Other concerns include the environmental impacts associated with the small amount of ammonia that is emitted as ammonia slip. Finally, because the catalyst does have to be replaced from time to time, concerns are sometimes raised about spent catalyst as waste. This guidance is intended to help permitting authorities address these issues.

Applicability

This guidance is intended to assist permit authorities when a permit applicant raises issues concerning the collateral environmental impacts of ammonia use with SCR at DLN combined cycle natural gas turbines used to generate electricity. This guidance does not apply to the use of SCR on combined cycle natural gas turbines other than DLN turbines. At DLN turbines the reduction in NO_X emissions that can be achieved with the use of SCR is small (approximately 5.5 ppm of NO_X) in comparison to NO_X emissions reduction that can be achieved with SCR at other types of turbines and roughly equivalent to the small amount of ammonia slip that may be emitted (often less than 5ppm to 10ppm of ammonia). When uncontrolled NOx emissions are that close to what can be achieved with SCR, the impacts of using SCR become an appropriate subject of analysis as part of determining BACT.

This guidance also does not apply to other types of facilities or other types of electric power generating plants. The NO_x reductions that can be achieved when SCR is used at other types of combustion power plants are many times what can be achieved at a DLN combined cycle power plant. Furthermore, the ammonia slip from coal-fired power plants, the most common type of combustion power plant, is much smaller relative to the amount of NO_x reduction achieved by SCR than is the ammonia slip at natural gas combined cycle power plants. Finally, the modest benefits in terms of NO_x reductions that can be achieved by putting SCR on a DLN natural gas combined cycle power plant are further limited by the dynamics of the

electricity market. If SCR is required on a new DLN turbine, the added capital and operating costs of SCR may mean that more electricity will be produced by dirtier plants. This could occur because fewer of these new plants will be built and because less electricity will be generated from those that are built. Therefore, total NO_x emissions, could increase, not decrease, as a result of requiring SCR on these plants, as would emissions of SO_2, CO_2, and mercury on a national or regional basis.[1] This is not the case when SCR is applied to other kinds of power plants where large NOx emissions reductions can be achieved with SCR or in other industries which can not respond to small price changes as fluidly and quickly as the electric power generating industry.

BACT in the Clean Air Act: the Legal Background

Best available control technology, or BACT, is required for new or modified major sources in order to prevent significant deterioration of air quality in attainment areas.[2] The Clean Air Act allows permitting authorities to weigh environmental, energy and economic concerns against the proven environmental benefits of technologies such as SCR in making BACT determinations in order to determine whether a less effective technology for NO_x control is warranted in specific cases. See In re Kawaihae Cogeneration Project, 7 E.A.D. 107 at 115-119 (EAB 1997).

The Clean Air Act defines "best available control technology," or BACT, as

> [A]n emission limitation based on the maximum degree of reduction of each pollutant subject to regulation under this chapter emitted from or which results from any major emitting facility, which the permitting authority, on a case-by-case basis, taking into account energy, environmental, and economic impacts and other costs, determines is achievable for such facility. 42 U.S.C. § 7479(3).

Taking these "collateral" impacts into account, the permitting authority may reject the most effective control technology as BACT, but only in limited circumstances. In re Columbia Gulf Transmission Co., 2 E.A.D. 824, 827 (Adm'r 1989)("[T]he collateral impacts clause operates primarily as a safety valve

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[1] For a discussion of an EPA analysis of this effect see: USEPA, NO_x Control on Combined Cycle Turbines : Issues Regarding the Use of Selective Catalytic Reduction as Best Available Control Technology for Low NO_x Turbines, August 4, 2000.

[2] In non- attainment areas new and modified sources have to meet a different standard, Lowest Achievable Emissions Rate, or LAER, which is not discussed in this paper.

whenever unusual circumstances specific to the facility make it appropriate to use less than the most effective technology."); In re World Color Press, Inc., 3 E.A.D. 474, 478 (Adm'r 1990) ("[T]he collateral impacts clause focuses upon specific local impacts which constrain a particular source from using the most effective control technology."). More specifically, with respect to the consideration of collateral environmental impacts, the Environmental Appeals Board has explained that the definition of BACT has been interpreted to mean that "if application of a control system results directly in the release (or removal) of pollutants that are not currently regulated under the Act, the net environmental impact of such emissions is eligible for consideration in making the BACT determination." Kawaihae, 7 E.A.D. at 116, citing In re North County Resource Recovery Associates, 2 E.A.D. 229, 230 (Adm'r 1986).

A decision by a permitting authority to reject the most effective control technology, due to environmental concerns, must be based on sound evidence that the environmental concerns associated with the use of this technology outweigh the benefits. Thus for, example, in Kawaihae, the EAB rejected a claim "that purely hypothetical catastrophic failure of the SCR ammonia system...warrants further consideration as a 'collateral environmental impact' in [the State's] BACT analysis." 7 E.A.D. at 117. The State had considered the risks associated with the use of ammonia and found them to be minimal. The EAB, also found that the source must use the most effective technology unless it is demonstrated to the permitting authority's satisfaction that unique circumstances specific to the facility would make the use of that technology inappropriate. Similarly, the New Source Review Workshop Manual (Draft 1990) makes clear that if a control technology has been applied to similar facilities elsewhere, it may still be rejected as BACT if the permit applicant can show that unusual circumstances at the proposed facility create greater problems than experienced elsewhere.[3] In the same way, if the permit applicant can convincingly show evidence that the environmental impacts associated with a control technology outweigh the benefits, that can be taken into account in the BACT determination. Thus, a permitting authority could appropriately conclude that BACT in a specific case was DLN turbines without additional controls for a combined cycle gas turbine if a case-by-case assessment of the environmental, energy, and economic impacts demonstrates that the collateral impacts associated with a control technology such as SCR outweighed the benefits of additional NOx reduction.

Collateral Environmental Impacts

In making a case-by-case BACT determination, the permitting authority must weigh the

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[3] USEPA, NSR Draft Manual at B.47.

environmental impacts of the various control options.[4] In the case of DLN turbines with and

without SCR, the change in NO_X emissions (approximately 5.5 ppm of NO_X) is small in comparison to NO_X emissions from other types of combustion power plants, and therefore, it is appropriate to compare the impacts from this increment of NO_X emissions to the small amount of ammonia slip emissions that result from the use of SCR (often less than 5 to 10 ppm of ammonia). Where the ratio between reductions in NO_x emissions and potential reductions in ammonia emissions is large, the environmental impacts of ammonia emissions are unlikely to be a reason to reject SCR as BACT.

The tradeoffs between NO_X and ammonia emissions, however, are not simple. Both NO_X and ammonia are acutely toxic; both contribute to fine particle formation, acidifying deposition, eutrophication, and enrichment of terrestrial soils; and both may be converted to nitrous oxide (N_2O), a powerful greenhouse gas. In addition, NO_X (as NO_2) is a chronic toxin and an essential precursor for the formation of tropospheric ozone. The contribution of NO_X or ammonia emissions from a single facility to any of these environmental problems is primarily determined by existing levels of NO_X and ammonia in the area of a source, the availability of other pollutants in the atmosphere that react with and transform the emitted oxidized or reduced nitrogen, and the characteristics of the aquatic and terrestrial ecosystems into which the nitrogen eventually is deposited.

The various environmental impacts associated with NO_x and ammonia emissions, ammonia handling in SCR systems, and the management of SCR catalyst waste are discussed in a separate supporting document that accompanies this guidance.[5] The relative significance of each of these potential impacts and some important factors to consider when weighing each of those impacts is summarized below.

Tropospheric Ozone

NO_X is an essential precursor to the formation of ozone, which is formed through a series of reactions of NO_X and volatile organic compounds (VOCs) in the presence of sunlight. Ammonia does

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[4]The environmental impacts analysis is not to be confused with the air quality impact analysis (i.e., ambient concentrations), which is an independent statutory and regulatory requirement and is conducted separately from the BACT analysis. The negligible air quality impact of a given level of emissions should not be considered in choosing BACT. See USEPA, NSR Draft Manual at B.47, Columbia Gulf Transmission, World Color Press.

[5] USEPA, NO_x Control on Combined Cycle Turbines : Issues Regarding the Use of Selective Catalytic Reduction as Best Available Control Technology for Low NO_x Turbines, August 4, 2000.

not contribute to ozone formation. NOx may lead to ozone accumulation near its emissions sources or may be transported long distances downwind and contribute to ozone accumulation hundreds of kilometers from its source. In area that are immediately upwind of nonattainment or Class I areas, the impact of NO_X emissions on regional ozone concentrations

should be an important consideration in any permitting decision and weighs in favor of requiring SCR.

Some important factors to consider in weighing the potential ozone impacts are:

- the proximity of an ozone nonattainment or sensitive Class 1 area;
- the sensitivity of high ozone concentrations downwind to changes in NO_x or VOCs (I.e., is the ozone formation NO_x or VOC sensitive?);
- the size of the incremental contribution of the source to the availability of NO_x downwind; and
- the presence of any meteorological phenomena that would mitigate or exacerbate the contribution of the source to ozone formation downwind.

<u>Fine Particles</u>

Both NO_X and ammonia emissions contribute to the formation of fine particles. Once converted to fine particles, the nitrogen from NO_x and the ammonia may be transported much farther downwind and contribute to visibility impairment, as well as human health risks.

The sensitivity of particle formation to changes in ammonia or NO_x is dependent on the ambient concentrations of ammonia, nitric acid, and sulfate, as well as relative humidity and temperature. In areas where the ambient concentrations of sulfuric acid, from SO_2 emissions, or nitric acid, from NO_X emissions, are high, and ammonia emissions are relatively low, ammonia emissions are likely to increase fine particle formation. In areas where sulfuric and nitric acid concentrations are relatively low and ammonia emissions are high, an incremental increase in ammonia emissions may have little impact on fine particle formation.

Some important factors to consider when weighing the impacts on fine particles in comparison to other impacts are:

- the presence of other sources of ammonia and SO2 near the source and downwind; and
- the relative contribution of nitrate from ammonia and ammonium from ammonia to fine particle composition near the source and downwind, taking into account changes

composition by season.

Acidifying Deposition

In the atmosphere, NO_X contributes to the formation of acid aerosols, while ammonia neutralizes atmospheric acidity. Once deposited, however, both NO_X and ammonia can contribute to the acidification of terrestrial soils and surface waters, depending on a variety of site specific characteristics.

Nitric acid or nitrate deposition, derived from NOX emissions, contributes to episodic acidification and, if the ecosystem has reached nitrogen saturation, chronic acidification. Ammonium ion deposition, derived from ammonia emissions, on the other hand can contribute to both chronic and episodic acidification regardless of the state of nitrogen saturation. In the case of episodic events, ammonium deposition can be twice as acidifying as nitric acid if the ammonium has undergone microbial nitrification. Therefore, acidification impacts tend to weigh more in favor of limiting ammonia emissions and not requiring SCR.

Some important factors to consider when weighing the impacts on acidification in comparison to other impacts are:

- the proximity to areas downwind of the source that are vulnerable to acidification;
- the extent of nitrogen saturation in downwind areas; and
- the relative importance of episodic acidification events as compared to chronic acidification.

Nitrogen Deposition and Eutrophication

When oxidized or reduced nitrogen is deposited on soils or surface waters, the nitrogen serves as a biological fertilizer, regardless of whether the nitrogen came from NO_X or ammonia emissions, respectively. While the speed and mechanisms by which aquatic or terrestrial biological systems make use of the nitrogen may differ depending on whether the nitrogen is in oxidized or reduced form, the overall fertilization effect is the same. Thus, on the basis of these impacts, the tradeoff between NO_X and ammonia emissions should be made in favor of the option that decreases the total amount of oxidized and reduced nitrogen being emitted.[6]

[6] In terms of nitrogen emitted, 1 ton of ammonia is equal to 1.7 tons of NO and 2.7 tons of NO_2.

Some important factors to consider in weighing the relative importance of nutrient impacts in comparison to other impacts:

- the proximity to downwind areas that are sensitive to nutrient inputs, including Class 1 areas, freshwater lakes and rivers, and coastal estuaries
- the availability of nitrogen sources as inputs to these sensitive ecosystems relative to the incremental nitrogen emissions from the turbine or SCR system

Global Warming and Stratospheric Ozone Depletion

A small fraction of ammonia emissions, once deposited on soils, is converted by soil microbes to nitrous oxide (N_2O), a powerful greenhouse gas and a stratospheric ozone depleter. Soil microbes oxidize ammonium to nitrates in a process known as nitrification. Microbes further convert nitrates to molecular nitrogen, NO_X, and nitrous oxide in a process known as denitrification. While some nitrous oxide is produced as a by-product during nitrification, denitrification is a larger source and acts equally on nitrates regardless of whether the nitrogen originated as NO_X or ammonia. On the basis of impacts associated with nitrous oxide, therefore, the tradeoff between NO_X and ammonia emissions should be made in favor of the option that decreases the total amount of oxidized and reduced nitrogen being emitted.

In addition to the nitrous oxide impacts, the use of SCR has implications for global warming. To the extent that use of an SCR on a DLN turbine reduces construction and operation of natural gas turbines, and associated displacement of coal, oil and gas steam generation, the addition of SCR on new natural gas combined cycle generating capacity may reduce the CO_2 benefit of this type of plant. There is also a negligible power penalty associated with SCR of between 0.2 percent to 0.25 percent.

Ammonia Safety

Some permit applicants and turbine manufacturers have cited ammonia safety concerns as an issue that mitigates the benefit of using SCR to control NO_x. Ammonia is identified by EPA as an extremely hazardous substance.[7] It is toxic if swallowed or inhaled and can irritate or burn

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[7] NO_2 is also toxic if inhaled in high enough concentrations. The EPA has set a primary and secondary National Ambient Air Quality Standard (NAAQS) for NO_2 equal to an annual arithmetic average concentration not to exceed 100 ug/m3. While potential violations of the ambient standards for NO_X should be taken into consideration in any permitting decision, these levels are high enough that it is unlikely that the types of emissions being considered here will violate the NO_2 standards.

the skin, eyes, nose or throat. Vapors may form an explosive mixture with air. None-the-less, ammonia is a commonly used material. OSHA regulations require that employees of facilities where ammonia is used be trained in safe use of ammonia, and it is typically handled safely and without incident.[8]

As discussed earlier, the Environmental Appeals Board, in reviewing a challenge to a BACT determination requiring the use of SCR, In Re Kawaihae Cogeneration Project, 7 E.A.D. 107, 116 (EAB 1997), addressed the issue of possible catastrophic releases of ammonia. In upholding the permitting authority's decision to require SCR, the Board held that the permit applicant had failed to show that "any facility anywhere utilizing SCR technology had experienced such a catastrophic failure" nor, that there were unusual circumstances specific to the facility that would make ammonia safety concerns a compelling reason not to use SCR.

Therefore, safety issues, when taken into consideration with other concerns, add weight to the decision to not require SCR, but by themselves these issues should have very little influence on a decision.

Waste Issues

The use of SCR systems results in spent catalyst waste. The amount of spent catalyst waste generated is dependent on the amount of catalyst used,[9] the life of the catalyst, and the amount of recycling of spent catalyst that occurs. This waste usually not hazardous waste and with proper management, should not create significant environmental impacts. Therefore, waste issues, when taken into consideration with other concerns, add weight to the decision to not require SCR, but by themselves these issues should have very little influence on a decision.

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[8] *Chemical Emergency Preparadness and Prevention Advisory,* USEPA, September, 1991, (OSWER 91-008.2).

[9] Note that using more catalyst results in lower NO_X and ammonia slip emissions, but higher costs and more spent catalyst waste.