Arizona Electric Power Cooperative, Inc.

P.O. Box 670 • Benson, Arizona 85602-0670 • Phone 520-586-3631

CTS: 214939

Via FedEx (7967 5724 2164)

July 8, 2009

Mr. Trevor Baggiore, Manager
Air Quality Permits Section
Arizona Department of Environmental Quality
1110 W. Washington Street
Phoenix, AZ 85007

RE: Apache Generating Station Best Available Retrofit Technology Analysis

Dear Mr. Baggiore:

Arizona Electric Power Cooperative, Inc. (AEPCO) is in receipt of your letter dated May 5, 2009 requesting additional information in order for the Arizona Department of Environmental Quality to complete a review of the Best Available Retrofit Technology Analysis (BART) completed for Apache Generating Station in December 2007.

In support of AEPCO's original BART analysis we have provided the attached Technical Memorandum prepared with the assistance of our consultant, CH2M HILL.

If you have any questions regarding this submittal, please feel free to contact me at (520) 586-5122 or Jim Andrew at (520) 384-6517.

Sincerely,

Michelle Freeark

Michelle R. Freeark
Manager of Environmental

Enc.

c/ J. Andrew, w/ enc.
G. Grim, w/o enc.
M. Vakili, w/ enc.
P. Ledger, w/o enc.
File: ADEQ/Regional Haze – BART, w/ enc.

CTS: 214939

AEPCO BART ANALYSIS
Response to Arizona Department of Environmental Quality

PREPARED FOR:	Ms. Michelle Freeark, Arizona Electric Power Cooperative, Inc. Mr. Jim Andrew, Arizona Electric Power Cooperative, Inc.
PREPARED BY:	CH2M HILL
DATE:	July 8, 2009
PROJECT NUMBER:	391527

This Technical Memorandum is prepared in response to a request for additional information presented to Arizona Electric Power Cooperator, Inc. (AEPCO) by the Arizona Department of Environmental Quality (ADEQ) in correspondence dated May 5, 2009. The requested information pertains to the Best Available Retrofit Technology (BART) Analysis for the Apache Generating Station Units 1, 2, and 3.

ADEQ Request # 1:

"Appendix A of the submittal presents the economic analysis that was performed to support the final recommendations for BART technologies and associated emission limits. There are numerous assumptions that are made to perform the cost computations. It appears that some of these are engineering and business assumptions and some other information may have been obtained as quotes from vendors. ADEQ hereby requests that AEPCO provide all supporting information relating to the economic analysis. This supporting information should include an explanation of all assumptions made in the economic analysis, including the choice of the interest rate used in the analysis."

Response # 1:

The economic analysis was completed for various BART technology alternatives based on a combination of AEPCO and CH2M HILL information and assumptions. While some vendor information was obtained for the Apache BART analyses, it is considered conceptual and preliminary consistent with the BART rules. More detailed engineering and vendor proposals are envisioned to be completed only after the technology selection has been made.

All data were compiled into a CH2M HILL proprietary spreadsheet, which was originally developed from the EPA QUECOST model and is refined on a project-by-project basis. This economic analysis was included in the BART report, and an example calculation is provided in Appendix A, along with a summary of the primary assumptions made for the study.

Interest Rate Discussion

As noted within the economic analysis provided as Appendix A of the final BART report, 7.1 percent was listed as both the interest rate and discount rate for the analysis. This rate was an assumption, based upon an estimate of a reasonable economic evaluation factor for AEPCO at the time the BART report was completed. Although several economic considerations entered into the 7.1 percent rate assumption, two primary factors were instrumental in the development of this interest rate:

Prime Rate

The BART report and economic analysis was completed in December 2007. The prime rate in December 2007 was 7.50 percent, which is significantly higher than the current prime rate. As a utility cooperative entity, the interest and discount rates are similar to the prime rate when completing any economic analyses.

AEPCO Corporate Structure

As a rural electric cooperative, the cost of capital and required rate of return would generally be lower for AEPCO than for utility companies with different corporate structures.

While the 7.1 percent is higher than current rates, it is a reasonable representation of the economic conditions in late 2007 for AEPCO. It should also be noted that the BART technology analysis utilizes the economic analyses as a relative comparison between alternatives, as well as evaluating the overall cost per ton of pollutant removed. If a lower interest rate had been utilized for the economic analysis, this lower rate would not have altered the relative comparison and selection of technologies.

ADEQ Request # 2:

"The BART analysis submitted for SO_2 for Units 2 and 3 is insufficient. The analysis identifies upgrades to the existing scrubbers as BART for SO_2. The analysis further states that AEPCO will "define cost-effective options for obtaining additional reductions" from the units. The Department requests that AEPCO identify the proposed upgrades and propose a post-upgrade emissions limit."

Response # 2:

The BART reports for Apache Units 2 and 3 listed six alternatives which were considered for additional SO_2 emissions control. They are as follows:

- Elimination of bypass reheat
- Installation of liquid distribution rings
- Installation of perforated trays
- Use of organic acid additives
- Improve or upgrade scrubber auxiliary system equipment
- Redesign spray headers or nozzles

Over the past several years AEPCO has completed several scrubber upgrades to improve performance, including the following:

- Elimination of flue gas bypass
- Splitting the limestone feed to both the absorber feed tank and tower sump

- Upgrade of the mist eliminator system (installation of two-stage chevron mist eliminators)
- Installation of suction screens at pump intakes
- Automation of pump drain valves
- Replacement of scrubber packing with perforated stainless steel trays
- Installation of Lechler spray nozzles in the tray loop of each absorber module.

Dibasic acid additive was tested; however results did not show significantly higher SO_2 removal. Additional improvements to the existing limestone scrubber system may be feasible, which could improve overall performance. At this time, it is not known what those additional improvements may be, so costs for this option are not included in this report.

Additional upgrades have been identified for this response; they include:

1. Upgrade limestone grinding system
2. Improve operation of the scrubber bypass damper system

Technology Discussion

All of the FGD upgrade alternatives were evaluated for their potential to further reduce SO_2 emissions.

Upgrade Limestone Grinding System

The original FGD system was designed with one 5 ton/hr limestone ball mill grinding system to produce 70 percent less than 325 mesh limestone reagent feed slurry for both units. This grind size is significantly coarser than desired and limits limestone utilization in the scrubbers. In addition, the 5 ton/hr capacity of the current grinding system is insufficient to meet periods of high demand with no flue gas bypass and coal sulfur levels above average.

AEPCO is in process of upgrading the limestone grinding system by adding a second limestone ball mill with 10 ton/hr capacity and grinding system to produce 90 percent less than 325 mesh limestone reagent feed slurry for both units at design coal sulfur conditions. An additional 122,000 gallon slurry tank will be installed that feeds reagent slurry to both units. The original grinding system can then be used as a backup should the new ball mill system experience an outage.

Improve Operation of Scrubber Bypass Damper System

Currently there are two scrubber bypass dampers, one each at the discharge of each induced draft fan on each Apache unit, and consist of double louver dampers with pressurized seal air. Presently the seal air fans are non-functional and depending on damper condition, a closed bypass damper could leak unscrubbed flue gas directly to the stack which might result in an increase of SO_2 and particulate emissions. AEPCO is planning to investigate reactivation of the seal air system and upgrading the louver dampers to determine the impact on overall FGD operations.

Upgrade Mist Eliminator Wash System

The existing two-stage mist eliminators experience scaling and pluggage, resulting in excess liquid carryover into the downstream ductwork. This affects wet FGD system reliability and performance. Mist eliminator effectiveness is a function of clean component surfaces which are maintained by effective washing. The current wash system could be improved to provide better flushing of mist eliminator components.

Additional Tray

The original FGD system design included a packed bed section in each absorber to provide the required gas/liquid contact area for SO_2 removal. These packed beds experienced a significant amount of scaling and had to be replaced on a periodic basis due to pluggage. The packed bed section in each absorber was eventually replaced with a sieve tray to mitigate the pluggage problems while still providing the needed gas/liquid contact area.

The spacing will be evaluated to determine if there is enough room available to add a second tray and spray level to each tower. This would provide additional gas/liquid contact area and increased SO_2 removal capability. However, if this option requires a significant capital cost to upgrade or replace the existing ID fans due to the increased pressure drop from the additional tray, and increased operating cost due to the additional power requirement for the ID fans, it might not be economically feasible.

Modification of Flue Gas Inlet

The lower loop of the scrubber towers experiences physical scaling caused by an inadequate wet/dry interface zone design. This is caused by the inlet duct design and insufficient spray coverage.

The absorber inlet and quench headers can be modified to prevent scaling and increase FGD system performance. AEPCO will investigate to determine if the inlet duct can be repositioned to prevent cyclonic flow and the spray headers can be redesigned to provide better spray coverage.

SO_2 Emissions Discussion

As noted in the BART reports, average SO_2 emissions from 2005 to 2007 were 0.184 lb/MMBtu for Unit 2 and 0.151 lb/MMBtu for Unit 3, which has demonstrated consistent compliance with the current SO_2 emission limit of 0.8 lb/MMBtu. However, SO_2 emission rates vary based on the coal supply.

SO_2 emissions after the completion of the wet FGD upgrades are anticipated to be 0.15 lb/MMBtu or less based on selection of coal burned in the units. The SO_2 post-upgrade emissions limit is recommended to be 1,192 tons/year per unit, which is based on an average emissions rate of 0.15 lb/MMBtu for 8,760 hours per year.

Conclusions

After considering the multiple wet FGD upgrade options discussed above for Apache Units 2 and 3, the implementation plan below is recommended. The remaining wet FGD options were not selected on the basis of low probability of successfully making a significant difference in scrubber performance, and/or high cost.

Wet FGD Upgrade Implementation Plan

- **New Limestone Grinding System** – A second ball mill grinding system will be installed to produce a finer limestone grind to increase limestone utilization for both units. The original ball mill grinding system will be used as a spare.
- **Improve Operation of Scrubber Bypass Damper System** – The bypass damper and seal air system operation will be investigated and modified or replaced in order to ensure a more consistent sealing capability and minimize flue gas bypass to the stack.
- **Upgrade Mist Eliminator Wash System** – The mist eliminator wash system will be upgraded by repositioning the wash headers at a more optimum distance from each stage and by installing new nozzles to achieve better wash coverage. The wash header between the first and second stage of the mist eliminator will also be modified to provide wash coverage to the trailing edge of the first stage and leading edge of the second stage.

ADEQ Request # 3:

"The BART analysis submitted for PM_{10} for Units 2 and 3 is insufficient. The analysis identifies unknown future upgrades to the existing ESPs as BART for PM_{10}. The analysis further states that AEPCO has "yet to conduct an evaluation of the performance upgrades that could be applied to the existing ESPs". The Department requests that AEPCO identify the proposed upgrades and propose a post-upgrade emissions limit."

Response # 3:

The BART reports for Apache Units 2 and 3 listed three alternatives which were considered for additional PM_{10} emissions control. They are as follows:

- Performance upgrades to existing hot-side ESP
- Replace current ESP with fabric filter unit
- Polishing fabric filter after ESP

From the above list, implementation of performance upgrades to the existing hot-side ESP was chosen as BART. The fabric filter options were eliminated in the BART analysis due to high control costs. While AEPCO had not completed an evaluation of potential ESP upgrades, there were several possibilities listed in the BART report.

- Improve rappers
- Improve ESP controllers
- Conversion to cold-side operation
- Flue gas conditioning
- Implement wide plate spacing
- Install pre-charging system

Additional potential upgrades that could be evaluated have been identified during the preparation of this technical memorandum; they include 1) conversion of the wire electrodes to ridged frame electrodes, 2) impact of improved operation of the scrubber bypass damper system on ESP, 3) replace opacity monitors in ESP outlet ductwork with state-of-the-art opacity monitors, and 4) evaluation of upgrading of the ESP controls including automatic voltage regulators, transformer rectifiers, and rapper controls.

Technology Discussion

All of the identified ESP upgrade alternatives were evaluated for their potential to improve PM_{10} emissions. Typical to operation of all the hot-side ESPs, the performance of an ESP degrades over time and usually requires a unit outage to water wash the ESP internals.

Improve Rappers

Several ESP rapper modifications and improvements have been implemented and investigations are continuing in order to provide better rapping to the wire electrodes and plates. New rappers have been tested in the ESPs, along with new rapper controllers. In addition, increasing the rapper lift distance in order to impart a greater force on the electrodes and plates has been tried. Rapping times have been varied, and sequencing the rappers between inlet and outlet ESP fields has been completed.

While improvements in rapping has shown some improvement in ESP operation, there has not been any rapping modification identified which has successfully lengthened the time between the required forced outages for precipitator cleaning. The current rapper controllers represent the state-of-the art technology.

Optimize Programming for ESP Controls

The currently installed ESP Automatic Voltage Controls (AVC), represent the state-of-the-art ESP control package. AEPCO will work with the vendor to optimize programming of the controls to maximize ESP performance and train operations and maintenance staff. The rapper control optimization is ongoing.

Conversion to Cold-side Operation

The goal of an ESP cold-side conversion is to lower the resistivity of the fly ash through operation at a lower flue gas temperature, which is typically approximately 280 to 300 degrees F. Another advantage of such a modification is that since the hot-side ESP was sized for the flue gas volume at a higher operating temperature, cold-side operation would result in a much lower flue gas velocity through the ESP thus enhancing the possibility of charging and collecting the particulate matter.

While cold-side conversions have been successful on hot-side ESPs, there is no guarantee of the extent of improvement. The cold-side conversion is also very expensive, requires significant modification to the ductwork, and a unit outage would be required to complete the conversion. Depending on the coal being burned, cold-side operation can also result in high resistivity fly ash which is difficult to charge and collect. However, fly ash resistivity issues with a cold-side precipitator may be more easily addressed than in a hot-side configuration. Due to the significant cost of this upgrade it is not economically feasible for AEPCO.

Flue Gas Conditioning

In order to address fly ash resistivity and the sodium depletion problem with hot-side precipitator operation, flue gas conditioning chemicals may be utilized. The two alternatives investigated for Apache Units 2 and 3 were the dry injection of either sodium carbonate or sodium sulfate, and a liquid injection of an additive.

The dry injection of either sodium carbonate or sodium sulfate can be achieved by adding the chemical to the coal prior to the combustion process, or may be injected into the flue gas just ahead of the precipitator. While adding the chemical to the coal is the preferred means of application, there exists the potential for increased boiler slagging. Predictive calculations can be performed to help assess the risk for this alternative. The sodium compounds have also been successfully added ahead of the ESP, and specific Apache coal and operating conditions must be evaluated prior to determining the quantity and injection point of the sodium compound application.

AEPCO will evaluate the coal and /or flyash conditioning systems to determine their impact on ESP PM_{10} removal impact and their effect on ESP performance degradation in time.

Implement Wide Plate Spacing

The normal separation between precipitator collector plates is nine inches, with the discharge electrode suspended in location equidistant between the plates. Theoretically, if the plate spacing is increased, to a typically-used dimension of 12 inches, a higher voltage can be imparted on the discharge electrode before sparking occurs between the electrode and the plate. While the potential for increased precipitator power is enhanced, there is also a reduction of collection area in the sections where the plate spacing is increased. This modification is not practical for the Apache units.

Install Pre-charging System

Insuring that the fly ash particles are adequately charged is an important consideration in achieving high efficiency collection in an ESP. The installation of a high energy pre-charging system ahead of the precipitator theoretically provides a better opportunity for imparting an electrical charge on the fly ash. With a pre-charging system, the downstream precipitator discharge electrode and wire configuration remains unchanged.

However, results from utilization of a pre-charging system have not demonstrated consistent and significant improvement in precipitator performance. There is not a good pre-charging system currently available, and a pre-charger does not address the sodium depletion problem.

Conversion of Wire Electrodes to Ridged Frame Electrodes

The current Apache ESPs have weighted wire discharge electrodes. An upgrade option for the wire electrode is a replacement with a rigid frame electrode. The rigid frame electrode consists of an electrode generally made from tubular or channel members, which is structurally more durable than a wire. Since wire failure is a concern with ESP operation, the primary advantage of the rigid electrode is improved electrode reliability and reduced maintenance.

Improve Operation of Scrubber Bypass Damper System

Currently there are two scrubber bypass dampers, one each at the discharge of each induced draft fan on each Apache unit, and consist of double louver dampers with pressurized seal air. When the seal air fans are non-functional, the bypass damper can leak unscrubbed flue gas directly to the stack. The bypassed flue gas will result in an increase of SO_2 and PM_{10} emissions.

Replace Opacity Monitors in ESP Outlet Ductwork

Opacity monitors were originally installed in the outlet ductwork for each unit's ESPs, however these monitors are currently not in operation. There are two monitors installed on each unit. While the duct opacity monitors do not directly improve ESP performance, they will be used to troubleshoot the ESP and tune rapper and transformer/rectifier controls.

Upgrade of the ESP controls

AEPCO will investigate upgrade and optimization opportunities of the ESP controls. These controls will include the automatic voltage controls, the plate and wire rappers controller and transformer-rectifiers. Periodically vendors introduce more advanced controls that can enhance the ESP performance. AEPCO will evaluate and test these controllers to determine their effect.

PM_{10} Emissions Discussion

As noted in the BART reports, historical stack particulate tests from 1997 to 2006 have resulted in particulate emissions of 0.007 lb/MMBtu to 0.045 lb/MMBtu, which has demonstrated consistent compliance with the current PM_{10} emission limit of 0.1 lb/MMBtu. While particulate emissions from a fabric filter installation are expected to be 0.015 lb/MMBtu, this PM_{10} emission level cannot consistently be expected from hot-side ESP technology. Hot side ESP's are sensitive to changes in coal supply and inlet flue gas temperature which can cause variability in PM_{10} emissions.

PM_{10} emissions after the completion of the ESP upgrades are anticipated to be in the range of 0.015 lb/MMBtu to 0.045lb/MMBtu, which can be correlated to fuel and boiler operating parameter variability. Therefore, the PM_{10} post-upgrade emissions limit is recommended to be 239 tons/year, which is based on an average emissions rate of 0.03 lb/MMBtu for 8,760 hours per year.

Compliance would continue to be demonstrated through an annual stack test, with annual emissions being calculated from an emission factor derived from the annual test.

Conclusions

After considering the multiple ESP upgrade options discussed above for the Apache Unit 2 and 3 ESPs, the implementation plan below is recommended. The remaining ESP options were not selected on the basis of low probability of successful making a significant difference in precipitator performance, and/or high cost. During a recent Unit 3 outage, AEPCO conducted a detailed condition assessment of the internals of the ESP. During this inspection the internal of the ESP was realigned and all the broken wires were replaced. The spacing of the wires and plates were within the design tolerance. Based on this inspection no major upgrade to the box and ESP internal could be identified that would have improved the ESP performance significantly.

ESP Upgrade Implementation Plan

- **Flue Gas Conditioning** -- Perform a test of flue gas conditioning agents, including sodium carbonate/sulfate and/or flyash conditioning. An evaluation will be made after testing to determine if the installation of a permanent flue gas conditioning system is warranted.

- **Improve Operation of Scrubber Bypass Damper System** – The bypass damper and seal air system operation will be investigated and modified or replaced in order to ensure a more consistent sealing capability and minimize flue gas bypass to the stack.
- **Replace Opacity Monitors in ESP Outlet Ductwork** – Opacity monitors in the ESP outlet ductwork will be replaced with the state-of-the-art opacity monitors.
- **Implement Programming Optimization Measures for ESP Automatic Voltage Controls** – Optimize programming of the controls to maximize ESP performance and update training for operations and maintenance staff.

ADEQ Request # 4:

"The BART analysis submitted for SO_2 and PM_{10} for Unit 1 is based on the unit firing 100% Fuel Oil No. 6. The Department requests that AEPCO provide documentation as to actual fuel usage in Unit 1, so that actual SO_2 and PM_{10} reductions can be quantified."

Response # 4:

While Steam unit 1 is permitted to burn Fuel Oil No. 6, AEPCO has never burned Fuel oil No. 6 in this generating Unit. The option to burn Fuel Oil No. 6 was included in Apache Generating Station's Class I Air Permit as a contingency against long-term natural gas delivery failure.

APPENDIX A
Example Calculation

Example Calculation

Apache Unit 2 (ST2)
LNB w/OFA & SCR

Total First Year Cost = Total Fixed Cost + Total Variable Cost + Debt Service

$6,102,739 = $330,000 + $1,136,181 + $4,636,559

Total Fixed Cost = **Total Fixed O&M Cost** * (1 + *escalation rate*)^year

$330,000 = $330,000 * (1 + 2.0%)^0

- **Total Fixed O&M Cost** = Operating Labor + Maintenance Material + Maintenance Labor + Administrative Labor

    $330,000 = $0 + $132,000 + $198,000 + $0

Total Variable Cost = **Reagent Cost** + **SCR Catalyst Cost** + **Electric Power Cost**

$1,136,181 = **$441,597** + **$292,500** + **$402,084**

- **Reagent Cost** = First Year Reagent Cost * (1 + *escalation rate*)^year

    $441,597 = $441,597 * (1 + 2.0%)^0

    - First Year Reagent Cost = (Reagent Usage/2000) * *Annual Operation* * *Unit Cost*

        $441,597 = 275 lb/hr * 1 ton/2000 lb * 8042 hr * $400/1 ton

    - Reagent Usage = *Molar Stoichiometry* * (NOx Removal Rate LNB w/OFA & SCR – NOx Removal Rate LNB w/OFA) * 17.034/*Reagent Purity*

        275 lb/hr = 1.0 * (26.93 – 10.81) lb moles/hr * 17.034 lbs/lb moles * 1/100

- **SCR Catalyst Cost** = First Year Catalyst Cost * (1 + *escalation rate*)^year

    $292,500 = $292,500 * (1 + 2.0%)^0

    - First Year Catalyst Cost = *Annual SCR Catalyst* * *SCR Catalyst Cost*

        $292,500 = 98 m^3 * $3000/$m^3$

- **Electric Power Cost** = First Year Auxiliary Power Cost * (1 + *escalation rate*)^year

    $402,084 = $402,084 * (1 + 2.0%)^0

    - First Year Auxiliary Power Cost = *Auxiliary Power Requirement* * *Unit Cost* * *Annual Operation*

        $402,084 = 1.0 MW * $50/MW-hr * 8042 hr

Debt Service = PMT(*Interest Rate, Plant Life,* Installed Capital Cost)

- Definition: PMT calculates the payment for a loan based on constant payments and a constant interest rate.

- **PMT(rate,nper,pv)**
  - Rate - is the interest rate for the loan.
  - Nper - is the total number of payments for the loan.
  - Pv - is the present value, or the total amount that a series of future payments is worth now; also known as the principal.

$4,636,559 = PMT(7.10%, 20 yrs, $48,740,300)

- Installed Capital Cost – A build up of the design cost usually provided by a vendor. Built up using the following categories, then a contingency is added:
  - Construction
  - Balance of Plant
  - Electrical (Allowance)
  - Owner's Costs
  - Surcharge
  - AFUDC – Allowance for Funding During Construction

Economic Analysis Assumptions:

Unit Design	Provided by AEPCO
Coal Characteristics	Provided by AEPCO
Economic Factors	AEPCO provided information and CH2M HILL assumptions
Installed Capital Cost	Combination of CH2M HILL database and vendor information
Fixed O&M Costs	CH2M HILL database
Variable O&M	CH2M HILL database