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SUBJECT: Beyond-the-floor analysis for existing and new coal- and oil-fired electric utility steam generating units national emission standards for hazardous air pollutants

This memorandum describes the development of the beyond-the-floor analysis for existing and new coal- and oil-fired electric utility steam-generating units National Emission Standard for Hazardous Air Pollutants (NESHAP). In this memorandum, we considered available regulatory options (i.e., technologies or work practices) that were more stringent than the MACT floor level of control for each of the different subcategories that make up the Electric Utility source category.

OUTLINE

- 1.0 Introduction
- 2.0 Beyond-the-floor Options for Existing Coal- and Oil-fired Electric Utility Steam Generating Units
 - 2.1 Coal-fired Units
 - 2.2 Integrated-coal Gasification Combined Cycle Units
 - 2.3 Coal Refuse-fired Units
 - 2.4 Oil-fired Units
- 3.0 Beyond-the-floor Options for New Coal- and Oil-fired Electric Utility Steam Generating Units
 - 3.1 Coal-fired Units
 - 3.2 Integrated-coal Gasification Combined Cycle Units
 - 3.3 Coal Refuse-fired Units
 - 3.4 Oil-fired Units

1.0 INTRODUCTION

As discussed in the memorandum entitled “MACT Floor Analysis for Coal- and Oil-Fired Electric Utility Steam-Generating Units National Emission Standards for Hazardous Air Pollutants,” the EPA chose to set MACT for mercury (Hg) from existing and new coal-fired electric utility steam-generating units and nickel (Ni) from existing and new oil-fired electric utility steam-generating units. Therefore, this discussion addresses beyond-the-floor control options for existing or new units.

2.0 BEYOND-THE-FLOOR OPTIONS FOR EXISTING COAL- AND OIL-FIRED ELECTRIC UTILITY STEAM GENERATING UNITS

In order to determine possible beyond-the-floor control options for existing units, we analyzed all available emissions data on air pollution control devices (APCD) that are currently utilized or experimental (both full-size and pilot-scale). The following are the possible beyond-the-floor control options for existing units.

2.1 Coal-fired Units

Conventional PM controls (electrostatic precipitators [ESP] and fabric filters) generally do not remove the vapor-phase HAP (i.e., elemental Hg, hydrochloric acid [HCl], and hydrogen fluoride [HF]) from coal-fired unit emissions. This is because these controls do not effectively capture gaseous pollutants. Two technologies that possibly could be used to further reduce the amount of vapor-phase HAP emitted from utilities are sorbent injection and selective catalytic reduction (SCR).¹

2.1.1 Sorbent injection. Due to their multiple internal pores and high specific surface area, sorbents have the potential to improve the removal of Hg (mostly through the capture of elemental mercury (Hg^0 ; sorbents will also remove Hg^{++}) as well as other gaseous pollutants that are carried with combustion fine particulates in all coal-fired subcategories (except for integrated gasification combined cycle [IGCC] units because of their lack of external PM control device).

The extent of the potential Hg removal is dependent on: (1) efficient distribution of the sorbent (e.g., activated carbon) in the flue gas; (2) the amount of sorbent needed to achieve a specific level of Hg removal, which will vary depending on the fuel being burned; (3) the amount of chlorine (Cl) present in the fuel; and (4) the type of PM control device (e.g., at a given sorbent feed rate, a fabric filter provides more Hg control than an ESP because of the additional adsorption that occurs on the bags of the fabric filter because of the increased gas contact time).

Sorbents can be introduced by two basic methods: by channeling flue gas through a bed of sorbent or by direct sorbent injection. Sorbent bed designs consist of fixed-sorbent filter beds, moving beds, or fluidized sorbent filter beds. With direct sorbent injection, after sorbent is introduced into the flue gas, it adsorbs Hg and other contaminants and is captured downstream in an existing or sorbent-specific PM control device. The types of sorbent that may be viable in sorbent injection include two basic types of activated carbon (AC; regular and impregnated) as well as other carbon (mixed with other sorbents) and noncarbon sorbents.

Activated carbon is a specialized form of carbon produced by pyrolyzing coal or various hard, vegetative materials (e.g., wood) to remove volatile material. The resulting carbon-based material (char) then undergoes a steam or chemical activation process to produce an AC that contains multiple internal pores and has a very high specific surface area. With this internal pore structure, the AC can adsorb a broad range of contaminants. Various studies, shown in Table 1, have shown good to excellent Hg removal with the injection of AC (particularly on bituminous-fired units); however, other studies (also shown in Table 1) have not shown good Hg removal (particularly on subbituminous- and lignite-fired units). The Hg removal performance of AC injection seems to be highly dependent on coal rank and composition (i.e., Hg and Cl content of the coal) and specific utility plant configuration (e.g., sequencing of APCD equipment). Further, little long-term data are available.

Chemically impregnated AC is AC that has been supplemented with chemicals to improve its Hg removal. The Hg in the flue gas reacts with the chemical that is bound to the AC, and the resulting compound is removed by the PM control device. Typical impregnants for AC are chlorine, sulfur, and iodide. Chemically impregnated AC has shown enhanced Hg removal over regular AC. Chemically impregnated AC requires smaller rates of carbon injection than does regular AC for equivalent Hg removals. The required carbon-to-mercury mass ratio may be

reduced by a factor of from 3 to 10 with the chemically impregnated AC.² The cost per mass unit of impregnated AC may, however, be significantly greater than that of unmodified AC.

Other commercially available sorbent materials are Sorbalit™ (a mixture of lime with additives and 3 to 5 percent AC) and Darco FGD (an AC derived from lignite).² Zeolites constitute another category of sorbent. There are naturally occurring mineral zeolites, in addition to commercially available synthetic zeolites. Both types contain large surface areas and have a good potential for Hg removal.

The AC test data available to EPA, representing full-scale electric utility units, consists of tests taken at four sites. The sites had initial baseline tests conducted without AC injection in 2001, and parametric tests and long-term test programs conducted in 2002 and 2003 after installation of AC injection. The test sites' sampling description, coal type, control device configuration, and total Hg removal (both the maximum Hg removal during each test and average Hg removal during the entire test period) are listed in Table 1. Even though these tests were taken over an extended period of time, the summary data available show that there appears to be variability in Hg removal results between the maximum Hg removal during each test and the average Hg removal during the entire test period at a given site.

Although AC, chemically impregnated AC, and other sorbents show potential for improving Hg removal over what is achieved with conventional PM and SO₂ controls, this technology is not currently available on a commercial basis and has not been installed, except on a demonstration basis, on any electric utility unit in the United States to date. Further, limited long-term data (e.g., longer than a few days) are available to indicate the performance of this technology on all representative coal ranks or on a significant number of different power plant configurations. Therefore, these technologies do not provide a viable basis for either establishing or going beyond the floor.

2.1.2 Selective catalytic reduction (SCR). The SCR test data available to EPA, representing full-scale electric utility units, consists of tests taken at four sites in 2001, two of the original four sites were then retested in 2002, and finally two additional sites were tested in 2002, for a total of eight sets of data. The test sites' coal type, control device configuration, and total Hg removal (with SCR turned off and SCR operating) are listed in Table 2. The data suggests

that, although designed as a nitrogen oxides (NO_x) control technology, the SCR has ability to transform certain species of Hg into other speciated forms that are easier for conventional PM and SO₂ controls to capture. The transformation of Hg species can be seen most prominently when an SCR is operating at a site with a PM control device and a wet FGD control device or a site with only a single particulate (venturi) scrubber. The Hg emitted during combustion, which would (in the absence of the SCR) tend to remain as Hg⁰, is oxidized to Hg⁺⁺. The highly soluble oxidized Hg is then removed by the wet FGD or particulate (venturi) scrubber. However, this Hg reduction effect has been observed in limited stack testing on bituminous coal-fired sites (S2 and S4), and results on a subbituminous coal-fired site have not been uniformly successful.³ Sites S1 and S3 showed only minimal Hg oxidation across the SCR. To EPA's knowledge, no commercial-scale, lignite-fired, SCR-equipped unit has been tested to date, though it is entirely possible that greater Hg removal would result when applied to a lignite-fired unit. Similarly, SCR has not yet been tested on all types of coal sources as well as on blends of coal. It should be noted that these tests were of short-term nature and the maximum Hg removal seen may not represent the long-term average observed even at a given site. Also, the data show that SCR does not lead to increased Hg oxidation and removal in all cases on all coal ranks.

In summary, sorbent injection has not been sufficiently demonstrated in practice, nor have long-term economic considerations (e.g., carbon availability, waste disposal issues, and required permitting for new waste landfill and sludge ponds) been evaluated to allow sorbent injection to be considered viable as a beyond-the-floor option. With regard to the use of SCR, there is inadequate effectiveness information on which to base a beyond-the-floor standard.

Table 1. Full-scale Activated Carbon Injection Emission Tests at Coal-fired Electric Utility Sites

Test site, Location	Description of test plan	Coal type	Control device	Maximum Hg removal during each test	Average Hg removal during the entire test period
Alabama Power, Gaston ⁴	Long-term tests over 10 days, constant conditions, are scheduled for 2002-2003.	Bituminous	Hot-side ESP; COHPAC FF	S-CEM: <ul style="list-style-type: none"> 90% 	S-CEM: <ul style="list-style-type: none"> 78% Ontario-Hydro: <ul style="list-style-type: none"> 90% total 86% oxidized >98% elemental
WE Energies, Pleasant Prairie ⁵	Long-term tests over 10 days, constant conditions. <i>Note: The S-CEM removal efficiencies shown here averages and maximums taken over (1) three days with an average injection rate of 1.6 lbs/MMacf, (2) four days with an average injection rate of 3.7 lbs/MMacf and (3), five days with an average injection rate of 11.3 lbs/MMacf.</i>	Powder River Basin Subbituminous	Cold-side ESP, SCA	S-CEM: <ul style="list-style-type: none"> 49%, 61%, and 70% 	S-CEM: <ul style="list-style-type: none"> 47%, 57%, and 66% Ontario-Hydro: <ul style="list-style-type: none"> 72.9% total 74.5% oxidized 70.7% elemental
PG&E NEG Salem Harbor Station ³	Parametric tests and long-term tests in Spring 2002.	Bituminous	Cold-side ESP; SNCR	280-290F: 68%, 70% 298-306F: 67%, 75%, 78% 322-327F: 65%, 85%, 85% 343-347F: 25%, 45%	280-290F: 69% 298-306F: 73% 322-327F: 78% 343-347F: 35%
PG&E NEG Brayton Point Station ⁶	Parametric tests and long-term tests in Fall 2002.	Bituminous	2 Cold-side ESP, in series with combined SCA	Hg capture varied based on sorbent and operating conditions.	S-CEM: <ul style="list-style-type: none"> 62%

COHPAC - combination of an upstream electrostatic precipitator followed by a high air-to cloth ratio fabric filter

SCA - Specific Collection Area

S-CEM - Semi-Continuous Emissions Monitor

Ontario Hydro - Ontario Hydro speciated mercury analysis method

SNCR - Selective Non-Catalytic Reduction

Table 2. Full-scale SCR Emission Tests at Coal-fired Electric Utility Sites⁷

Site	Coal	Year sampled	PM Control	SO2 Control	Total Hg removal, % (w/SCR off: w/SCR on)
S1	Powder River Basin Subbituminous	2001	ESP	None	60 / 78
S2	Ohio Bituminous	2001	ESP	Wet FGD	51 / 88
S2*	Ohio Bituminous	2002	ESP	Wet FGD	NA / 84
S3	Pennsylvania Bituminous	2001	ESP	None	16 / 13
S4	Kentucky Bituminous	2001	Particulate (Venturi) Scrubber	None	46 / 90
S4*	Kentucky Bituminous	2002	Particulate (Venturi) Scrubber	None	44 / 91
S5	West Virginia Bituminous	2002	ESP	Wet FGD	51 / 91
S6	Kentucky & West Virginia Bituminous	2002	ESP	None	No data currently available

* Retest

NA - Not analyzed with SCR off.

2.2 IGCC Units

Integrated gasification combined cycle units are specialized units in which coal is first converted into synthetic coal gas. In this conversion process, the carbon in the coal reacts with water to produce hydrogen gas and carbon monoxide (CO). The synthetic coal gas (syngas) is then combusted in a combustion turbine, which drives an electric generator. Hot gases from the combustion turbine then pass through a waste heat boiler to produce steam. This steam is fed to a steam turbine connected to a second electric generator. Because of their design, IGCC units have no external APCD. Therefore, we believe the best potential way of reducing Hg emissions from existing IGCC units is to remove Hg from the syngas before combustion. An existing industrial IGCC unit has demonstrated a process, using sulfur-impregnated AC carbon beds, that has proven to yield 90 to 95 percent Hg removal from the coal syngas.⁸ This technology could potentially be adapted to the electric utility IGCC units.

To our knowledge, neither of the two existing IGCC units have run tests of this type of carbon bed, fuel cleaning, device. Because of concerns about the costs involved and because existing IGCC units utilize older technology, it is not clear if using sulfur-impregnated AC carbon beds would be effective on the particular syngas burned in these units.

2.3 Coal Refuse-fired Units

Coal refuse units (i.e., 99 percent of their heat input supplied by burning coal refuse) are located adjacent to old coal mine refuse piles. The units are specially designed to burn this high-ash silt. All of the 13 coal refuse-fired units existing in 1999 are equipped with fluidized bed combustors (FBC); 10 of these 13 units inject limestone as a sorbent for SO₂ control, and 4 of these 13 units are equipped with SCR for NO_x control. The only two coal refuse-fired units on which performance tests were conducted in response to the ICR are the MACT floor facilities for the coal-refuse fired subcategory.

To our knowledge, there are no currently available technologies that could be used as beyond-the-floor options for coal refuse units.

2.4 Oil-fired Units

The only emission control technology that we are aware of to consider as a beyond-the-floor option for existing oil-fired units is fabric filtration. Fabric filters have been shown in pilot-scale testing to be more effective at reducing Ni emissions than an ESP. However, the use of fabric filters on oil-fired units is also known to be problematic due to the prevalence of the “sticky” PM emitted from such units, which sticks to the fabric and creates a fire safety hazard. No existing oil-fired units are known to employ fabric filters as their PM control. Because of this, fabric filters are not considered to be a viable beyond-the-floor option for oil-fired units.

3.0 BEYOND-THE-FLOOR OPTIONS FOR NEW COAL- AND OIL-FIRED ELECTRIC UTILITY STEAM GENERATING UNITS

Once the MACT floor determinations were done for new units in each subcategory (by fuel type), EPA considered various regulatory options more stringent than the MACT floor level of control (i.e., additional technologies or other work practices that could result in lower emissions) for the different subcategories. Due to the technical complexities of controlling Hg and Ni emissions from the sources affected by this rule, we have not been able to determine whether (identified) potential beyond-the-floor options are available. The following describes the possible beyond-the-floor options of which we are aware for new units.

3.1 Coal-fired Units

As discussed in Section 2 of this memorandum, two technologies that possibly could be used to further reduce the amount of vapor phase Hg emitted from utilities are sorbent injection and SCR. However, as explained in Section 2, sorbent injection is not available on a commercial basis and has not been demonstrated on a utility unit operating at full capacity over an extended period of time. Similarly, SCR has not shown the same change-in-speciation effect on Hg emissions on all types of coal sources (and among different seams within a coal rank).

3.2 IGCC Units

Because of their design, IGCC units have no external APCD controls. Therefore, as is explained in Section 2 of this memorandum, the best potential way of improving Hg removal from IGCC units is to remove the Hg from the syngas before combustion. Based on published information regarding the industrial IGCC unit noted in Section 2, EPA believes that a 90 percent reduction in Hg emissions is possible from new IGCC units based on the use of carbon bed technology. Therefore, we believe that proposing a 90 percent Hg reduction based on the use of carbon bed technology as a beyond-the-floor level for new IGCC units is reasonable.

3.3 Coal Refuse-fired Units

Existing coal refuse-fired units utilizing 100 percent coal refuse, all of which utilize FBC technology, have demonstrated the best Hg control of any emissions-tested electric utility unit in the industry based on the electric utilities information collection request (ICR).

3.4 Oil-fired Units

There has not been a new oil-fired unit constructed in the United States since 1981. As discussed in Section 2 of this memorandum, if a new oil-fired unit is constructed, the only technology that would offer emissions control better than the proposed new MACT limits for emission control is the use of fabric filtration; however, fabric filtration is not presently considered to be a viable control option for oil-fired units because of the prevalence of the “sticky” PM emitted from these units, which sticks to the fabric and creates a fire safety hazard.

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