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Quarter 8 – Commercialization Aspects of Sorbent Injection Technologies in Canada

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Canadian Electricity Association
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EERC
Energy & Environmental Research Center

Center for Air Toxic Metals

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QUARTER 8 – COMMERCIALIZATION ASPECTS OF SORBENT INJECTION TECHNOLOGIES IN CANADA

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REPORT AVAILABILITY

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EXECUTIVE SUMMARY

The primary objective of this quarterly report is to provide information on the state of commercialization of sorbent injection technologies. The quarterly includes the following topics:

- Policy and regulatory issues that impact commercialization of mercury sorbent technologies.
- Sorbents most likely to be used based on coal type and plant configurations.
- Capital investment requirements and the availability of necessary equipment and labor.
- Availability of sorbents and/or additives.
- Status of mercury measurement technology for compliance purposes.
- Balance-of-plant impacts.

The Clean Air Mercury Rule in the United States and the acceptance in principle of a draft of the Canada-Wide Standards for mercury illustrate the need for cost-effective mercury control strategies for coal-fired electric utilities. Recent demonstration activities have shown effective mercury capture with sorbent injection at full-scale systems. Out of this effort, concerns have been raised regarding the availability of carbon, sorbents, additives, and the related capital equipment if there was widespread adoption of activated carbon injection (ACI) technology. Projections by the activated carbon industry do not suggest that either the availability of activated carbon or equipment will be an issue. However, the strong labor market in Canada as well as high demand for construction-related materials, such as steel, will likely continue as utilities look to make any capital improvements. There are several areas of concern that still need to be addressed in the long term as well. These include the following:

- Environmental and economic impacts of lost fly ash utilization
- The impact of ACI on fabric filter (FF) and electrostatic precipitator (ESP) performance
- Longer-term leaching potential of disposed ash

Clearly, the salability of fly ash is a major concern as it does not take much carbon in the ash to render it unacceptable to the concrete industry. This would result in a substantial financial penalty for those plants currently selling ash as well as an increase in ash in landfills and an increase in demand for portland cement and associated energy and emissions from its manufacture. To maintain fly ash sales, plants may have to consider the installation of a FF specifically for mercury capture, downstream of an existing ESP.

If the fly ash is to be disposed of, a concern has been that ACI is only converting one environmental problem into another. Short-term leaching tests indicated that once mercury is captured by the ash or carbon, it is very stable and does not leach to any significant degree. However, long-term leaching testing has not been widely conducted and will be necessary to verify the stability of mercury on carbon.

The impact of ACI on particulate control devices has not yet been determined. The short duration—less than 2 months—of most of the large-scale test activities has not shown significant detriment to either ESP performance or FF pressure drop. However, there are data for specific plants that indicate problems could arise if ACI were conducted for longer periods. In the coming year, longer-term tests of 3- to 12-month duration will be conducted which should provide more conclusive information regarding the impact of ACI on ESP performance and help determine if long-term carbon use will increase pressure drop across FFs. These long-term data will be critical to support vendors' ability to provide performance guarantees on systems designed to maintain mercury emission compliance. Other possible concerns, which will need to be investigated over long-term operation include the fate of halogens from treated carbons across the unit and their environmental impact on air emissions and by-products.

MERCURY INFORMATION CLEARINGHOUSE

QUARTER 8 – COMMERCIALIZATION ASPECTS OF SORBENT INJECTION TECHNOLOGIES IN CANADA

INTRODUCTION

The Canadian Electricity Association (CEA) identified a need and contracted the Energy & Environmental Research Center (EERC) to create and maintain an information clearinghouse on global research and development activities related to mercury emissions from coal-fired electric utilities. With the support of CEA, the Center for Air Toxic Metals® (CATM®) Affiliates, and the U.S. Department of Energy (DOE), the EERC is developing comprehensive quarterly information updates to provide a detailed assessment of developments in mercury monitoring, control, policy, and research.

In order to adequately address the many topics and provide the detail necessary for the various stakeholders to make informed decisions, selected topics are discussed in detail in each quarterly report. Issues related to mercury from coal-fired utilities include the general areas of measurement, control, policy, and transformations. Specific topics that have been addressed in previous quarterly reports include the following:

- Quarterly 1 – Sorbent Control Technologies for Mercury Control
- Quarterly 2 – Mercury Measurement
- Quarterly 3 – Advanced and Developmental Mercury Control Technologies
- Quarterly 4 – Rerelease of Mercury from Coal Combustion By-Products
- Quarterly 5 – Mercury Fundamentals
- Quarterly 6 – Mercury Control Field Demonstrations
- Quarterly 7 – Mercury Regulations in the United States: Federal and State

Recent promulgation of mercury regulations from coal-fired power plants in the United States, the Clean Air Mercury Rule (CAMR), and the acceptance in principle of a draft of the Canada-Wide Standards (CWS) illustrate the need for cost-effective mercury control strategies for coal-fired electric utilities. Full-scale tests conducted across North America have demonstrated very good mercury capture using sorbent injection or activated carbon injection (ACI), and it appears that this technology will receive widespread implementation as coal-fired utilities work to meet the new regulations. A review of commercialization aspects of widespread sorbent injection technologies for mercury control is provided in this quarterly report and includes the following:

- Policy and regulatory issues that impact commercialization of mercury sorbent technologies.

- Sorbents most likely to be used based on coal type and plant configurations.

- Capital investment requirements and the availability of necessary equipment and labor.
- Availability of sorbents and/or additives.
- Status of mercury measurement technology for compliance purposes.
- Balance-of-plant impacts.

MERCURY POLICY

In March 2005, the U.S. Environmental Protection Agency (EPA) issued the first-ever mercury regulation entitled the CAMR. At Air Quality V, Robert Weyland of EPA said the rationale for the rule was EPA's desire to allow electric generating utilities as much flexibility as possible and still protect public health. As a result, EPA issued the rule under Section 111 rather than Section 112 of the Clean Air Act Amendments (CAAA), thereby providing a cap-and-trade mechanism. The rule is designed to be implemented in two phases. The first phase would cap mercury emissions from coal-fired power plants at 38 ton/year by 2010. Using a baseline mercury emission rate of 48 ton/year, the Phase 1 cap represents a reduction of 21%. The second phase would permanently cap mercury emissions at 15 ton/year by 2018, corresponding to a reduction of nearly 69%. It is EPA's position that the first phase will be accomplished as a cobenefit of the February 2005 Clean Air Interstate Rule (CAIR), which requires that a number of utilities in the eastern states install wet flue gas desulfurization (FGD) systems for SO_2 control and selective catalytic reduction (SCR) for NO_x control. Mitchell Baer of DOE added that, although the second phase of the rule will require additional mercury controls, it is expected that a number of mature economical technologies will be available to meet CAMR requirements.

The CAMR provides individual states the right to establish their own rules, provided that they meet the state-specific caps established under the CAMR. As outlined by Joyce Epps of the Pennsylvania Department of Environmental Protection, several northeastern states are evaluating options as a response to the CAMR, which may include lawsuits against EPA (10 states and several environmental groups have currently filed) or instituting more restrictive legislation. Of particular concern to many states and organizations is the delisting of mercury from Section 112 of the CAAA which provides for maximum achievable control technology and the decision to regulate mercury under Section 111, providing for a cap-and-trade structure. As a result of these suits and petitions from states, tribes, and environmental groups, EPA opened a reconsideration process on June 24, 2005, for parts of Section 112 to ensure sufficient public comment. However, the reconsideration process will not stay the rule. Although, several states are developing more stringent rules and most likely there will be several early adapters, the United States will not directly compete with Canadian utilities for mercury sorbents and/or additives until 2012 or later.

The government of Canada, working closely with provincial and territorial partners, has accepted in principle a draft of the CWS for mercury emissions from coal-fired power plants (www.ccme.ca/initiatives/standards.html). Later this year, the draft will be reviewed by the Air Management Committee, Environmental Planning and Protection Committee, and Deputy

Ministers Committee and a finalized version developed. In November, the final CWS is expected to be endorsed by the Canadian Council of Ministers of the Environment (CCME). Based on the provincial caps provided for under the CWS, mercury emissions would be reduced from the current 2695 kg/yr to 1130 kg/yr (58% reduction) by 2010 based on best achievable control technology economically available (BATEA). Therefore, the coal-fired utilities will need to install mercury technologies that can provide 50%–60% control. In addition, as part of the CWS, a review process will be implemented to evaluate requiring much higher levels of control, up to 80% by 2018. For new facilities, use of best available control technologies (BACT) for mercury will be required upon start-up. Based on current estimates, BACT levels would be 85% control for bituminous coals and blends (emission rates of 3 kg/TWh) and 75% control for lignites (15 kg/TWh) and subbituminous fuel (8 kg/TWh).

QUARTER 8 FOCUS: COMMERCIALIZATION ASPECTS OF SORBENT INJECTION TECHNOLOGIES IN CANADA

SORBENTS MOST LIKELY TO BE USED BASED ON COAL TYPE AND PLANT CONFIGURATIONS

In March 2005, the EERC issued a report to the CCME entitled "Technical Review of Mercury Technology Options for Canadian Utilities" (1). It was determined the most likely near-term candidate to obtain 50% to 60% mercury control for all Canadian utilities would be ACI. The estimated ACI rates based on U.S. full-scale test data (shown in Figure 1) are provided in Table 1.

Results are now being reported (2) from large-scale test activities conducted under the DOE Phase II mercury control program. Data have shown that using halogenated carbons, manufactured by Sorbent Technologies (B-PAC) and NORIT Americas Inc. (DARCO Hg-LH), may be a cost-effective mercury control option particularly for low-rank fuels (lignites and subbituminous coals). It may be possible to achieve 50% to 60% mercury control at ACI rates of <2 lb/Macf, even for facilities with only a cold-side electrostatic precipitator (ESP). Results have also shown that with a fabric filter (FF) only 1 lb/Macf or less of the halogenated carbon may be needed. Data also indicate that putting in low-cost proprietary additives, such as the EERC sorbent enhancement additive (SEA)2 or Alstom's KNX, ACI rates may even be lower (3, 4). These tests are ongoing, and additional data are needed before final conclusions can be drawn. DOE recently issued a request for proposals for its Phase III program, and announcements of awards should be made in February 2006. It is expected that these projects will provide much more definitive results along with balance-of-plant impact information over longer operating periods and data related to how halogenated injection may impact plant operation, emissions, and by-products.

Although research is being conducted, it is not expected that noncarbon sorbents will be commercially available for mercury control prior to implementation of the CWS.

CAPITAL INVESTMENT

There are essentially three scenarios for mercury control that would require capital investment by the power industry. The first scenario is that only activated carbon (treated or untreated) is used. The second includes an additive along with activated carbon. The final and most costly scenario, from a capital investment point of view, is the installation of a FF downstream of an existing ESP with ACI between the ESP and FF.

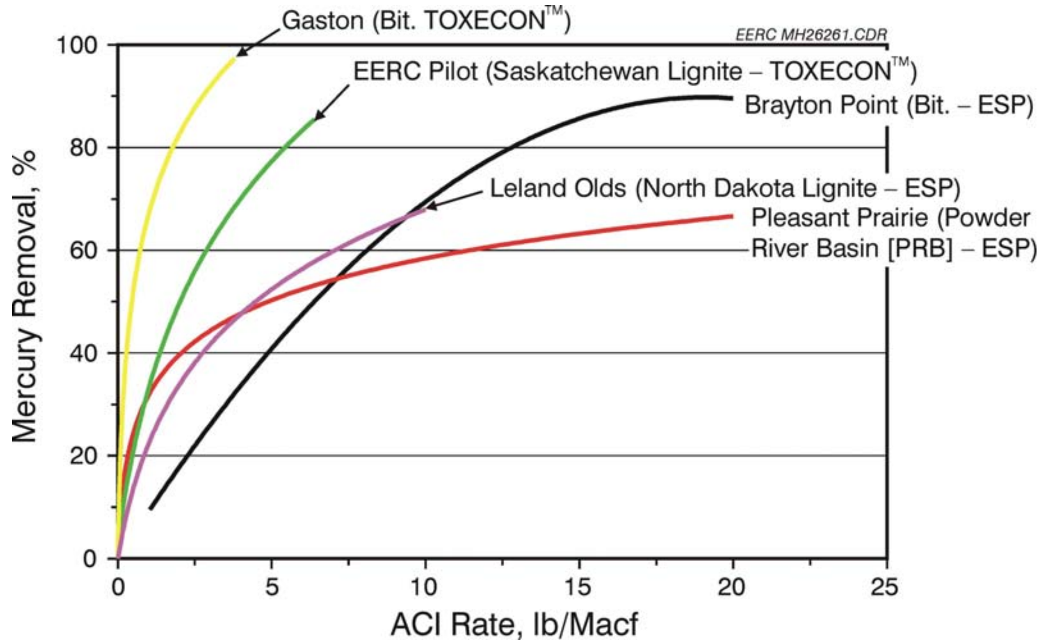

Figure 1. U.S. field test experience with ACI.

Table 1. Estimated ACI Rates Based on U.S. Full-Scale Testing Experience and Select Pilot-Scale Test Results

Coal Type	ACI–ESP[1], lb/Macf	ESP–ACI–FF, lb/Macf
Blend (bit.–sub.–petcoke)	4–8	2–4
Bituminous	4–8	2–4
Subbituminous	5–10	3–5
Lignite	5–20	3–6

[1]Cold-side ESP.

Capital Cost of ACI and/or Additives

Based on an economic study done by Hoffman and Ratafia-Brown for DOE (5), it was estimated that the capital cost for ACI equipment for a 500-MW plant would be US$3–US$4/kW. For smaller systems, the cost can be as high as US$8/kW. Typically, capital costs for an ACI system include the following:

- Equipment transportation costs
- Equipment installation costs including concrete pads and injection ports
- Activated carbon storage silo
- A feeder skid that includes blowers, variable-screw feeders, and control system
- Injection lances including piping and distribution manifolds

With the exception of the injection lances and piping, the equipment is off-the-shelf and has been used for a number of years in the waste-to-energy industry to control mercury. The injection lances will need to be sized based on the duct dimension and, most likely, a modeling effort will be needed to ensure adequate sorbent distribution. The injection skids can be purchased directly from vendors such as NORIT Americas, or a contractor can be hired to assemble the skid on-site. Figure 2 is a photograph of an ACI skid. Based on discussion with NORIT Americas, the availability of injection skids will not be a factor limiting the adoption of ACI.

When additives are used to enhance activated carbon activity, they are either added to the raw coal as spray onto the coal as it exits the mill or as solid near the top of the boiler. Somewhat similar injection equipment is needed for the additives as for activated carbon, but the system will be considerably smaller and, therefore, less costly. Based on field tests, it is expected that the total capital cost for the additive injection equipment will be less than US$100,000. Figure 3 is a photograph of the additive injection equipment.

The third and most expensive option is to install a FF downstream of the ESP, with ACI occurring between the ESP and FF. This has three primary advantages. The first is to provide a better contactor for the activated carbon, resulting in higher mercury removal. The second benefit is that the majority of the fly ash is not contaminated with the activated carbon and can be sold to the concrete industry. This issue will be discussed more fully later in this report. Finally, installation of a FF has the potential to improve overall particulate control. The capital cost for installing a FF is estimated to be US$55–US$70/kW, depending on the size of the plant and the air-to-cloth ratio needed to maintain a reasonable pressure drop and cleaning cycle. The cost items are as follows:

- Major equipment (35%)
- Auxiliary or accessory equipment (15%)
- Field installation (20%)
- Project management and engineering (13%)
- Freight, taxes, subcontractor, etc. (17%)
- Start-up cost, working capital, and other capitalized costs (15%–20%)

It should be noted that these costs represent vendor prices and do not necessarily include additional costs incurred by the facility. Additional time and expense can be borne by the utility to install foundations, modify ductwork and controls, and install additional fan capacity. Under some scenarios the added cost to the utility can be as much as 2 times greater than the quoted vendor costs.

Availability of Equipment

A typical FF installation will require 3 to 4 months, with an additional 4 to 7 weeks to hook up the baghouse to the boiler unit. The amount of time depends on the size of the plant, overall configuration, size of the baghouse, and general complexity of the design. Taking into account design, lead times, project planning, and system shakedown, project completion could require up

EERC MH26262.CDR

Figure 2. Photograph of an ACI skid.

EERC MH26263.CDR

Figure 3. Photograph of a skid used to spray additives onto the coal.

to 2 years. There are 32 units in Canada that have cold-side ESPs and would potentially benefit from adding a FF as part of their overall mercury control strategy (excluding those that are scheduled for shutdown, which includes all of those in Ontario). If 10 units were to install FFs prior to 2010, the primary concerns include availability of steel, labor, and heavy-lifting cranes. In the United States, it has been estimated that the additional wet FGD and SCR units that would be installed as a result of the Clear Skies Initiative or CAIR would only increase the demand for steel by 0.1% (6). The addition of 10 baghouse in Canada over 3 years would have little impact on an already high steel demand. However, the high demand for raw materials and construction materials has resulted in delays and price increases as suppliers work to meet increased demand globally. Of more concern would be the availability of cranes. Although EPA does not consider it an issue, utilities have stated that the unavailability of cranes in the United States could delay installation of SCRs.

Labor requirements for the installation of the air pollution control technologies are split between two categories, general construction labor and high-skilled labor (boilermakers, pipe fitters, electricians, etc.). The following statements are based on the report "Labour Requirements for Canada and Provinces from 2005 to 2013" (7):

- In general, labor markets will be somewhat tight with potential shortages of skilled labor.
- There will be pressure for specialty trades serving the industrial sector and also on construction engineering.
- Specialty labor that would impact the utility industry, including crane operators, pipe and gas fitters, electricians, and boilermakers, are expected to have very strong markets in the next 5–10 years.

Although skilled labor may be at a premium during the next decade, it is unknown how much of an impact the installation of 10–15 FFs and 20–25 ACI skids over the next 5 years would have on the overall labor market. Currently, a shortage of labor has been experienced, especially in western Canada where increased oil and gas work has led to very low unemployment. As Canadian utilities begin to bring mercury control technologies online beginning in 2008, a strong labor market is expected to exist. The continued demand for labor to support the energy industry in Canada is likely to continue well into the projected implementation period for mercury control technology.

AVAILABILITY OF SORBENTS AND ADDITIVES

Adoption of the CWS for mercury will have more stringent mercury control requirements than the U.S. CAMR, at least until CAMR Phase II occurs in 2018. Although several states are adopting more stringent controls and there will be some early adopters, it is not expected that there will be much pressure on the availability of activated carbon or chemical additives by U.S. utilities until at least 2012–2015.

Availability of Activated Carbon

There are a number of major producers of powdered activated carbon (PAC) in the United States, Canada, Europe, and China. Several of the more important ones are the following:

- NORIT Americas
- Calgon Carbon Corporation
- Nucon International, Inc.
- Luscar Ltd.
- Barneby & Sutcliffe Corp.
- RWE Rheinbraun
- Ningxia Huahui

NORIT Americas has stated (8) it currently has the capacity to provide 20–30 power plants with all the carbon they would need and not impact their current business. In addition, within several years, NORIT said, it could greatly increase its capacity if needed. Table 2 presents the PAC requirements needed to achieve 50%–60% mercury removal for each power plant in Canada (1). The table does not list those plants that are scheduled to be decommissioned in the next decade or coal-fired power plants in Ontario that are expected to be shut down by 2009. It can be seen from Table 2 that the maximum PAC requirement for Canadian plants would be 35,000–90,000 metric tons (tonne)/yr. The current worldwide installed capacity for PAC is approximately 726,000 tonne/yr of which 50% is produced in the United States and China. Therefore, the maximum Canadian utility demand would be less than 13% of the overall capacity. This level of usage is not expected to put pressure on the overall market.

The availability of treated carbons is also not expected to be a concern. Both NORIT (DARCO Hg-LH) and Sorbent Technologies (B-PAC) have indicated that today they could provide brominated carbons to treat 8–10 300-MW boilers, and this capacity could easily be expanded to treat 30–50 plants within 2 years (8, 9). As was stated earlier, these treated carbons and/or halogenated additives may be the low-cost option for plants burning low-chloride lignites and subbituminous coals. Halogenated additives are often chloride or bromide salts and are readily available from bulk chemical suppliers in the quantities required by power plants.

OPERATION AND MAINTENANCE (O&M) COSTS ASSOCIATED WITH MERCURY CONTROL

Using the report generated by Hoffman and Ratafia-Brown for DOE (5), the following are variable O&M costs associated with ACI:

- Sorbent
- Activated carbon disposal
- Power
- Operating labor
- ACI equipment maintenance

Table 2. Potential Activated Carbon Usage in Canada Based on a Requirement of 50%–60% Mercury Removal (1)

Power Station	Net Capacity, MW	Capacity Factor[3]	Units	ACI, lb/Macf	ACI Rate, kg/hr	Total PAC, tonne/yr
Alberta						
Battle River	675	88.30%	3	5–10	400–800	3100–6200
Sheerness	766	88.60%	2	5–10	440–880	3420–6840
Genesee	1212	92.30%	3	5–10	700–1400	5600–11,200
Keephills	720	89.10%	2	5–10	480–960	3750–7500
Sundance	2020	83.20%	6	5–10	1250–2480	9110–18,220
Manitoba						
Brandon	95	48.90%	1	5–10	65–130	280–560
New Brunswick						
Belldune[1]	450	92.70%	1	0	0	0
Nova Scotia						
Lingan	600	84.60%	4	4–8	260–520	1930–3860
Point Aconi[2]	165	84.00%	1	0	0	0
Point Tupper	150	91.20%	1	4–8	65–130	520–1040
Trenton	310	76.60%	2	4–8	130–260	870–1750
Saskatchewan						
Boundary Dam	814	78.60%	6	5–20	540–2220	3720–14,880
Poplar River	562	81.50%	2	5–20	360–1460	2570–10,280
Shand	279	82.80%	1	5–20	190–740	1380–5520
Total	***8834***		***35***			***36,190–87,850***

[1] Belldune is already achieving 70% mercury removal.
[2] Point Aconi is already achieving 90% mercury removal.
[3] Capacity factors are based on CEA 2001 data.

- Water (for spraying additives if used)
- Cost of money (inflation and interest)

In addition to these items, another potential cost would be the loss of revenue from selling fly ash and the resultant increased disposal costs. If a FF were installed to prevent this loss, there would be costs associated with pressure drop (increased power requirements), general maintenance of the baghouse, and bag replacement.

Table 3 presents the total O&M cost for each plant in Canada based on the carbon usage presented in Table 2. Table 3 assumes that there is no loss of income as a result of selling the fly ash; however, the table includes the added cost of disposal. The cost of the sorbent is 93%–94% of the total O&M cost. Therefore, any technology that reduces PAC usage will have a substantial impact on O&M costs.

Table 3. Additional O&M Costs for Canadian Power Plants as a Result of Adding ACI

Power Station	Net Capacity, MW	Units	Total O&M[1] for all Units, Million US$/yr
Alberta			
Battle River	675	3	8.95–12.41
Sheerness	766	2	6.44–8.00
Genesee	1182	3	6.46–12.61
Keephills	766	2	4.44–8.66
Sundance	2020	6	11.50–22.40
Manitoba			
Brandon	95	1	0.30–0.59
New Brunswick			
Belldune	450	1	0[2]
Nova Scotia			
Lingan	600	4	1.32–4.92
Point Aconi	165	1	0[3]
Point Tupper	150	1	0.60–1.16
Trenton	310	2	1.23–2.37
Saskatchewan			
Boundary Dam	814	6	5.11–19.86
Poplar River	562	2	3.38–13.08
Shand	279	1	1.71–6.60

[1] O&M Costs are based on a report to DOE (5).
[2] Belldune is already achieving 70% mercury control (w-FGD).
[3] Point Aconi is already achieving 60%–90% mercury control (circulating fluid bed).

MERCURY MEASUREMENT

The U.S. CAMR will require continuous mercury monitoring at each stack of coal-fired units by January 1, 2009. There are two allowable mercury measurement methods in the CAMR. The first is to install continuous mercury monitors (CMMs), and the second is to use mercury sorbent traps. Protocols for measurement and reporting under the CWS for mercury have not yet been established, but based on conversations with Environment Canada, these protocols will be available to the public by early spring 2006. Although there has been some discussion that coal and hopper ash mercury concentrations can be used instead of actual stack measurements, it is possible that some form of direct mercury measurement will be required at the stack. There are essentially three direct mercury measurements methods:

- Wet chemistry methods such as the Ontario Hydro (OH) mercury speciation method (ASTM International [ASTM] D6784-02)
- Sorbent trap method (40 CFR, Part 75, Appendix K)

- CMMs (Tekran, PS Analytical, Horiba/NIC, etc.)

All three of these methods were discussed in detail in CEA Quarterly 2 – Mercury Measurement and updated in CEA Quarterly 6. Each of these methods has advantages and disadvantages.

OH Method

There are many groups in both the United States and Canada that can conduct OH method testing. However, depending on the number of samples required and the duration, testing can be expensive, and a high level of quality assurance/quality control (QA/QC) is needed. The OH method is not a continuous method and, therefore, not allowed under CAMR. However, it is the only acceptable reference method for conducting relative accuracy test assessments (RATAs).

Sorbent Trap Method

Although the sorbent trap methods are relatively easy to use, there have been some problems. EPA requires that the traps be configured with three distinct, but identical, sections connected in series (the sections must be connected such that they can be analyzed separately). The first section is the primary trap for capturing the gas-phase mercury. The second section is a backup in case of mercury breakthrough. The third section is designated for QA/QC purposes and is, therefore, spiked with a known amount of elemental mercury (Hg^0). Paired traps must be used, with the mercury results averaged. It is the spiked third section that has been a source of problems. To date, the spiking of this section has not been consistent enough to ensure good recoveries (10).

The cost of the sorbent trap method is currently quite high. This is a result of limited competition in making the traps and doing the analysis. The cost for obtaining two spiked traps and doing the analyses is approximately US$1800, or about US$60,000–US$80,000/yr (assuming weekly trap replacement). This cost does not include the equipment (current equipment cost is US$25,000–US$30,000) shown in Figure 4, which is a schematic of the method, or the labor required to replace the traps, about 4 hours a week. It is expected that during the next 1–2 years, costs will be reduced considerably with increased competition and the development of more cost-effective spiking and analytical methods.

Included in the CAMR protocols for the sorbent trap method is the requirement that a RATA be done each year. This requires a minimum of nine valid (as discussed in Appendices A and K of 40 CFR, Part 75) dual OH trains be completed. The U.S. utility industry is strongly urging EPA to produce a protocol that would lead to the development of an instrumental reference method to replace the OH method.

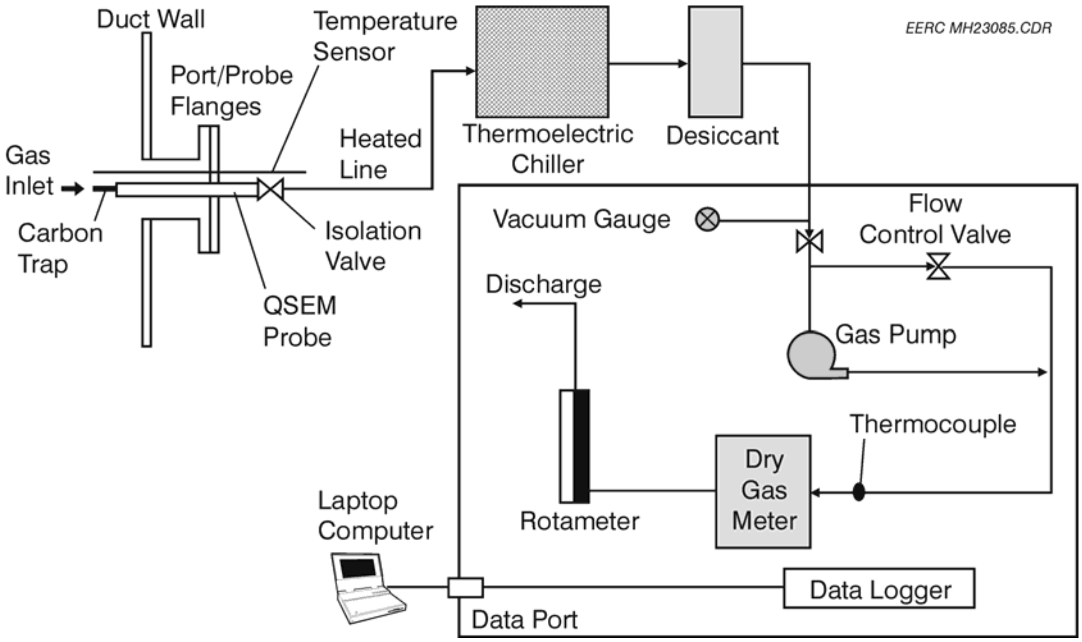

Figure 4. Schematic of the sorbent trap method.

Continuous Mercury Monitors

It is expected that most facilities in the United States will opt to install CMMs. Over the past 3 years, there has been significant improvement in CMM technology. The most important improvements have been 1) the development of dry pretreatment/conversion systems, 2) the use of inertial filtration, and 3) the development of automated calibration methods. As a result of performance specifications (PS 12A) being established by EPA over the next several years, the technology will continue to improve (9). EPA has been conducting RATAs at two sites. To date, only three CMMs have finished the RATA, the Tekran Model 3310, the Thermo Electron Mercury Freedom system, and the Horiba/NIC DM-6B. The Tekran has passed at both sites, the Thermo Electron passed at the first site (it did not finish the testing at the second site), and the Horiba/NIC failed at both sites. However, in the next 2–3 years it is expected that all three of these instruments as well as a PS Analytical system will be able to meet the PS 12A specifications. The capital cost for the complete Tekran or PS Analytical systems is about US$200,000 and for the Thermo-Electron or Horiba/NIC, about US$180,000. Also, there are operating costs that include supplies, training, and maintenance. These cost have not yet been established as there are few long-term operating data. The Tekran analyzer has been located at Ontario Power Generation's Nanticoke Station for 18 months and has been operating quite well. This CMM is being monitored and maintained by Tekran personnel. Also, two Tekrans have been operated at the slipstream test facility at SaskPower's Poplar River Station for several months with good success, however, improvements in reliability are necessary before widespread unmanned operation can occur.

It is anticipated that in the United States during the next 3 years, 500–800 of these monitors will be ordered. With the exception of Thermo Electron and Horiba, the companies that manufacture these analyzers are small; although many have now associated themselves with larger companies, there may be challenges in large-volume production in the near term.

BALANCE-OF-PLANT IMPACTS AS A RESULT OF MERCURY CONTROL TECHNOLOGY

If ACI is to be the primary method for reducing emissions in Canada, there are four potential impacts on plant operation, which include the following:

- Inability to sell ash to the concrete industry
- Decrease in ESP effectiveness
- Increased pressure drop in FFs
- Leaching of mercury from the ash after disposal

There are a large number of utilities in Canada and the United States that sell at least a portion of the ash collected to the concrete industry. In Canada, almost all of the utilities burning lignite or subbituminous coal (SaskPower, TransAlta, EPCOR, and ATCO) have facilities selling their ash for use as an admixture in place of portland cement at varying concentrations up to as high as 50%. A review of the impacts of mercury on by-product utilization was addressed in Quarter 4, Rerelease of Mercury from Coal Combustion By-Products, which is available on CEA's Web site: www.ceamercuryprogram.ca. Therefore, any mercury control technology that prevents the sale of ash would have financial as well as environmental penalties. Increased ash to the landfill, forgone revenue from by-product sales, and increased energy consumption to manufacture portland cement not replaced with fly ash all directly result from activated carbon in fly ash. Typically, a power plant can receive US$4–US$7/tonne of ash. Ash disposal costs are US$14–US$16/tonne; a difference of US$18–US$23/tonne.

Very low levels of PAC addition to the flue gas have the potential to prevent ash use in the concrete industry. ASTM C618 puts a limit on carbon content in the concrete of 6%. However, the foam index test has failed at carbon concentrations as low as 1% when that carbon is from the injection of activated carbon. For reference, a prediction of the additional carbon that could be present in the ash for a 500-MW plant at several ACI rates is presented in Table 4. In the foam index test, set amounts of cement, fly ash, and water are placed in a jar and shaken. Drops of a concrete air-entraining admixture are added in small increments and shaken after each addition. The number of drops necessary to produce a stable foam on the surface of the cement–ash mixture is the foam index. The salable limit is 25 drops. Foam index results with ash collected from a slipstream pilot baghouse during ACI tests at We Energy's Pleasant Prairie Station are shown in Table 5. As can be seen, even 1% carbon in the ash may not meet requirements. PAC, more than unburned carbon generated during combustion, appears to have a more detrimental impact on the foam index test. This may be a result of the higher surface area and the more extensive pore structure of PAC.

Table 4. Additional Carbon from ACI in the Ash for a 500-MW Plant

Injection Concentration, lb/Macf	Injection Rate, lb/hr	Additional Carbon in the Ash, %
10	340	4.3
5	170	2.2
2	70	0.9
1.1	40	0.5

Table 5. Carbon in Ash Foam Index Results

Injection Concentration, lb/Macf	Unburned Carbon in Ash, %	Foam Index, drops	Comments
0	0.55	15	Acceptable
1	1.1	>72	Maxed out
3	1.6	>72	Maxed out
10	3.6	>72	Maxed out

An option for mercury control, while maintaining a marketable fly ash product, is to add a FF after the ESP. The PAC is then added between the ESP and baghouse. The bulk of the fly ash is captured in the ESP and can be used for concrete, without problematic ACI; the FF provides mercury capture and overall particulate capture improvements for the plant. Initially, it was thought that a very small-footprint baghouse (air-to-cloth ratios of 8–12 ft/sec) could be used; however, because of bag blinding and pressure drop, more moderately sized baghouses (air-to-cloth ratios of 4–6 ft/sec) are now favored for these configurations.

Other potential solutions include the use of noncarbon-type sorbents, such as the amended silicates being developed by ADA Technologies or the cement-friendly carbon materials being developed by Sorbent Technologies. However, these materials are less commercially available than PAC.

For those plants that dispose of their ash in landfills, some concern exists that captured mercury will leach from the ash and enter the environment. Bench-scale tests conducted to date show that the captured mercury is very stable and does not leach from the solids (11, 12). Following standard leaching tests, the mercury concentrations in the solution are measured in the parts-per-trillion range. As ACI is still a relatively new technology, long-term landfill leaching tests have not been done.

A long-term concern is the impact of ACI on ESP performance. Carbon is an insulator and has the potential to degrade ESP performance by limiting the power that can be applied to the electrodes without arcing. The results to date have been mixed. In short-term tests (5–10 days), there has not been any apparent impact on ESP performance as a result of carbon injection (13). However, in other short-term tests when PAC was injected prior to a small ESP (surface collection area of about 200) there was increased arcing but no detrimental effects on particulate emissions or opacity (14). The only longer-term data (1 month) reported were for the tests being conducted at the Yates Plant (15). From this test, it was concluded that carbon injection caused an increase in the arc rate of the ESP at low-load conditions, compared to arcing that occurs without ACI. There was no observed physical damage to the ESP after 1 month, but it is unclear as to the effect that the increased arcing will have on the mechanical integrity of the ESP over longer time periods. Over the next several years, a number of longer-term tests, up to 12 months, will have been conducted, and the results should clarify whether ACI will affect ESP performance. Those long-term data will be critical to support vendors' ability to provide performance guarantees on systems designed to maintain mercury emission compliance.

CONCLUSIONS

The U.S. CAMR and the acceptance in principle of a draft of the CWS for mercury illustrate the need for cost-effective mercury control strategies for coal-fired electric utilities. Recent demonstrations have shown effective mercury capture with sorbent injection at full-scale systems. Out of this effort, concerns have been raised regarding the availability of carbon, sorbents, additives, and the related capital equipment if there were widespread adoption of ACI technology. Projections by the activated carbon industry do not suggest that either the availability of activated carbon or equipment will be an issue. However, there are several areas of concern that still need to be addressed in the long term. These include the following:

- Salability of the fly ash
- The impact of ACI on ESP performance
- Longer-term leaching potential of disposed ash

Clearly, the salability of fly ash is a major concern as it does not take much carbon in the ash to render it unacceptable to the concrete industry. This would result in a substantial financial penalty for those plants currently selling ash. Further, to maintain fly ash sales, those plants may have to consider the installation of a FF specifically for mercury capture downstream of an existing ESP.

If the fly ash is to be disposed of, a concern has been that ACI is only converting one environmental problem into another. Short-term leaching tests indicated that once mercury is captured by the ash or carbon, it is very stable and does not leach to any significant degree. However, long-term leaching testing has not been widely conducted and will be necessary to verify the stability of mercury on carbon.

The impact of ACI on ESP performance has not yet been determined. The short duration—less than 2 months—of most of the large-scale testing activities has shown no significant detriment. However, there are data for specific plants that indicate problems could arise if ACI were conducted for longer periods. In the coming year, longer-term tests of 3–12-month duration will be conducted, which should provide more conclusive information regarding the impact of ACI on ESP performance.

Currently, the following conclusions can be drawn with the respect to the adoption of ACI by Canadian utilities to meet the provincial caps as stated in the draft CWS for mercury:

- Because of the differences between the U.S. CAMR and CWS for mercury, it is not expected that U.S. utilities will be in direct competition with Canadian utilities for PAC or ACI equipment until 2012 or later.

- There will not be a shortage of PAC or treated carbons or ACI equipment if Canadian utilities adopt ACI to reduce mercury emissions by 50%–60%.

- It is possible that there could be a shortage of skilled labor in Canada in the next decade, especially in western Canada.

- It is clear that the adoption of ACI will negatively impact the salability of the fly ash and may result in the installation of FFs.

- There is a potential for ACI to have a negative impact on ESP performance, but longer-term tests must be completed before any conclusions can be drawn.

- CMMs may be in short supply and long delivery times may occur as U.S. utilities will be required to continuously monitor mercury by January 1, 2009.

- Short-term leaching data show that the potential for mercury leaching from combustion by-products is very low; however, longer-term leaching measurements from landfills need to done.

UPCOMING EVENTS

Power-Gen International 2005 Conference & Exhibition
December 6–8, 2005, Sands Expo & Convention Center, Las Vegas, NV
http://pgi05.events.pennnet.com

Pittcon 2006
March 12–17, 2006, Orlando, FL
www.pittcon.org

231st ACS National Meeting & Exposition
March 26–30, 2006, Atlanta, GA
www.chemistry.org

Coal Ash Professionals Training Course
April 19–21, 2006, Memphis, TN
www.undeerc.org

Air & Waste Management Association Annual Conference & Exhibition
June 20–23, 2006, New Orleans, LA
www.awma.org

Eighth International Conference on Mercury as a Global Pollutant
August 6–11, 2006, Madison, WI
www.mercury2006.org/Default.aspx?tabid+1393

The Mega Meeting: Power Plant Air Pollutant Control Symposium (formerly The Mega-Symposium)
August 28–31, 2006, Baltimore, MD
www.megasymposium.org

Pittcon 2007
March 11–16, 2007, New Orleans, LA
www.pittcon.org

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