Lignite Research Council Project Files

Project Title: EVALUATION OF POTENTIAL SCR CATALYST BLINDING DURING COAL COMBUSTION

NDIC File No: FY00-XXXVI-100

LEC File No: 24.S.30.A

Confidential: ☐ **Yes** ☒ **No** ☐ **Partial**

File Reviewed By:

Date: 11-08-09, 2009

	IN FILE	
*** Six-Part Files**	**YES**	**NO**
1 – Project Summary – 1 or 2 pages	☒	☐
2 – Contract & all amendments to contract	☐	☒
2 – Technical Reviews of the application	☒	☐
2 – Technical Advisor's Recommendation on the application	☒	☐
3 – Incoming Correspondence	☒	☐
4 – Outgoing Correspondence	☒	☐
4 – Recommendations for payment	☒	☐
5 – Status Reports	☒	☐
5 – Draft Final Reports if they have one	☒	☐
5 – Final Report or if large, may be separate	☒	☐
6 – Proposals – original application	☒	☐

*Number indicates which section of the file these items appear in.

COMMENTS:
Note:

It was moved by ____________________ and seconded by ____________________ that the Industrial Commission accept the recommendation of the Lignite Research Council and fund the "Evaluation of Potential SCR Catalyst Blinding During a Coal Combustion" application as amended submitted by the Energy & Environmental Research Center with the conditions that the industry matching funding letters of commitment be obtained by September 1, 2000 and that the project include testing with North Dakota lignite and to authorize Karlene Fine, Executive Director of the Industrial Commission, to execute a contract for an amount not to exceed $200,000.

Attachment 2

LIGNITE RESEARCH COUNCIL MEETING
February 22, 2000

IV. Grant Round XXXVI - A Application

TECHNICAL ADVISOR'S RECOMMENDATION
LRC XXXVI-A
"Evaluation of Potential SCR Catalyst Blinding During Coal Combustion"
Submitted by Energy & Environmental Research Center;
Co-Project Managers –Steven A Benson, Ph.D.; Jay R. Gunderson; Chris J. Zygarlicke;
Request for: $200,000; Total Project Cost: $733,333
Time Frame: 24 months

Description of the Project

This overall objectives of this study are to determine the potential of lignite to cause blinding of Selective Catalytic Reduction (SCR) catalysis and to determine the degree of elemental mercury (Hg^{o}) conversion across the catalysis. The proposed study includes the following six key tasks: 1) identify coals and coal blends, 2) conduct bench-scale screening tests, 3) design and construct SCR slipstream test chambers, 4) slipstream testing at commercial-scale facilities, 5) identify mechanisms, rates and cleaning methods, and 6) data interpretation, reporting and recommendations.

The U.S. Environmental Protection Agency existing and proposed rules and recommendation may require the construction of SCR facilities at existing or new lignite fired facilities. However, data does not exist on the use of SCR with U.S. or North Dakota lignite. Utilities in Germany when operating with high sodium coals, brown coal and lignite have experienced severe SCR problems with catalysis deactivation, catalysis degradation, blinding and failure[7].

Recommendation – Fund - with contingencies

I recommend FUND with the following contingencies:
1. Industry matching funding letters of commitment obtained by September 1, 2000.
2. Program includes testing with North Dakota lignite.

Prepared by Clifford R. Porter, February 11, 2000.

Conflict of Interest

Energy & Environmental Research Center

[7] Licata, Anthony, Hans-Ulrich Hartenstein, and Heinz Gutberlet, Ph.D., "Utility Experience with SCR in Germany" Sixteenth Annual International Pittsburgh Coal Conference, Pittsburgh, PA. Oct. 11-15, 1999

15 Recommend Funding
0 Do Not Fund

TECHNICAL REVIEWER RATING SUMMARY

LRC-XXXVI-A: "Evaluation of Potential SCR Catalyst Blinding During Coal Combustion"
Submitted by EERC
Request for $200,000; Total Project Costs $733.333

Rating Category	Weighting Factor	Technical Reviewer Rating 00-3	00-1	00-2	Average Weighted Score
Objective	9	4	4	3	33.0
Availability	9	3	3	2	24.0
Methodology	7	4	3	3	23.3
Contribution	7	5	4	4	30.3
Awareness	5	4	4	4	20.0
Background	5	4	4	4	20.0
Project Management	2	3	3	3	6.0
Equipment Purchase	2	5	3	2	6.7
Facilities	2	5	4	3	8.0
Budget	2	4	5	3	8.0
Average Weighted Score		200	182	156	**179.3**
Maximum Weighted Score					**250**

OVERALL RECOMMENDATION

	00-3	00-1	00-2
FUND	X	X	
FUNDING TO BE CONSIDERED			X
DO NOT FUND			

TECHNICAL REVIEWERS' COMMENTS
LRC-XXXVI-A

"Evaluation of Potential Catalyst Blinding During Coal Conversion"
Submitted by: Energy & Environmental Research Center;
Principal Investigators: Donald Toman, Jay Gunderson, Donald McCollor, Ph.D.;
Project Managers: Chris J. Zygarlicke, Stephen A. Benson, Ph.D.;
Request for: $200,000 over two years; Total Project Cost: $733,333

1. OBJECTIVES

The objectives or goals of the proposed project with respect to clarity and consistency with Industrial Commission/Lignite Research Council goals are: 1 - very unclear; 2 - unclear; 3 - clear; 4 - very clear; or 5 - exceptionally clear.

Reviewer 00-01 (Rating: 4)

This project will help determine if SCR is the Best Available Control Technology for NO_x reduction in power plants that burn low rank coals. Some questions have arisen about the relative potential for SCR catalyst blinding in those power plants fueled with low rank coals that are rich in alkaline metals, sulfur and arsenic. A good understanding of the mechanisms that cause blinding or fouling of SCR catalyst surfaces is necessary to communicate potential risks or lack of risks to fuel users.

A successful project should help preserve markets for North Dakota lignite and could avoid an unnecessary expense for the installation of SCR systems that could prove either ineffective or inexpensive to operate. The knowledge gained could also result in the development of more effective systems for these circumstances by vendors.

Reviewer 00-02 (Rating: 3)

The proposal is clear in its linkage to the goals of the NDIC/LRC. That is, the need to investigate the impacts (potential) of low-rank coals on the performance of SCR systems in order that (1) low-rank coal production/usage is not negatively impacted by NO_x regulations, and (2) the regional electric utilities do not invest in NO_x control technologies (i.e., SCR) that does not meet performance specifications.

Issues: The offeror is silent as to how many catalysts will be screened and, more importantly, the relationship between themselves and the unidentified German catalysts vendor who will participate in the project. Will there be proprietary data issue with the vendor? If it is shown that LRC do mask blind the catalyst, will this information be made public, that is, will it be shared with the lignite coal industry and utility industry?

Reviewer 00-03 (Rating: 4)

The authors have a good understanding of the overall potential problem and impacts on the environment, plant operations and the economy.

The emission limits proposed for lignite boilers by USEPA is more restrictive than the limits currently in place in Germany.

2. ACHIEVABILITY

With the approach suggested and time and budget available, the objectives are: 1 - not achievable; 2 - possibly achievable; 3 - likely achievable; 4 - most likely achievable; or 5 - certainly achievable.

Reviewer 00-01 (Rating: 3)

The most important experimental parts of the project are the boiler field tests. It is important to be sure that the time-temperature history of the slip-stream of boiler effluent is the same as would be experienced in a full scale SCR installation. It is important that volatile species are not condensed out in the piping system between the boiler and test bed and that no atypical solid particulates are formed in the gas stream and carried through the catalyst surfaces.

Simulating the proper time-temperature history in the lab apparatus and the field test and its importance is not discussed in the proposal.

Reviewer 00-02 (Rating: 2)

The project schedule and budget are very ambitious in terms of the work scope. The offeror proposes to select test coals (and catalysts?), screen coals/catalysts at the bench scale—including evaluation of blinding/deactivation and the effect of catalyst on Hg oxidation, design and construct a slip-screen catalyst bed, install and test the bed on two host utilities, and evaluate results—all in a 24-month period. Of some concern is the budget required to do the work. The offeror may be underestimating the cost associated with the installation of the test bed on a slipstream of two utilities. There is a significant effort (i.e., costs) involved in the ducting, piping, instrumenting, wiring, safety and health, etc. associated with installing the test bed on an operating, full-scale commercial power plant. And to do this on one plant, and then remove the bed and do it on another compounds the cost, time, and complexity of the task. It is not clear that the proposed budget of $733,333 (including $200,000 from the NDIC) is sufficient to complete the proposed effort.

Reviewer 00-03 (Rating: 3)

Insufficient data on budgets for complete evaluation

3. METHODOLOGY

The quality of the methodology displayed in the proposal is: 1 - well below average; 2 - below average; 3 - average; 4 - above average; or 5 - well above average.

Reviewer 00-01 (Rating: 3)

The approach suggested to investigate the problem seems appropriate. Adequate laboratory sample testing is proposed to help define which utility boilers would be most appropriate. Assessment by the vendor of decline in catalyst activity may or may not produce a meaningful result because of the relatively short duration, 1 to 4 months, of the two field tests.

Reviewer 00-02 (Rating: 3)

The offeror has put together a fairly solid proposal. However, there are some details lacking that result in a questioning of the overall value of the project. For example, as noted under #1 above, it is not clear what the relationship between EERC and the "German" vendor will be in terms of the availability of the catalyst data. On page 6 (Task 5), EERC states that it will send the catalyst from the field testing to a laboratory, possibly in Germany. The concern here is one of perception. If the company supplying the catalysts runs the laboratory, and it turns out that the catalyst is negatively impacted by LRCs, will the vendor make the data publicly available for fear of its implication on the company's competitiveness? If it is made publicly available, will there be a perception that the data is somehow skewed because the vendor supplier did the analyses—sort of like the fox guarding the hen house?

It is also unclear as to how many catalysts will be evaluated--One, two, or half a dozen? Will they be supplied by the same vendor? What criterion will be used to screen the catalysts so a decision can be made as to which will be evaluated in the field?

Reviewer 00-03 (Rating: 4)

There is limited published data available. Most data to date is unpublished. It appears that the authors did a good job in obtaining unpublished data.

4. CONTRIBUTION

The scientific and/or technical contribution of the proposed work to specifically address Industrial Commission/LRC goals will likely be: 1 - extremely small; 2 - small; 3 - significant; 4 - very significant; or 5 - extremely significant

Reviewer 00-01 (Rating: 4)

If the project is successful, the information on SCR catalyst blinding and mercury conversion in SCR systems for North Dakota lignite fired boiler effluents will provide unique information about potential issues involved in the use of North Dakota lignite. This will help maintain markets for the fuel.

Reviewer 00-02 (Rating: 4)

The concern about the impact of LRC on SCR catalyst is a real issue. There is no significant track record in this country for SCR technology on utility coal-fired boilers, particularly those burning low-rank coals, PRB coals. This should be a real concern for both the producers and consumers of LRCs. Of particular concern would be a utility that will invest in SCR to deal with NO_x, and who may be currently burning LRC or may be planning to switch to LRCs. The proposed work would also be of value in regulatory debates at the local, State, and Federal level as to the availability of technology to control NO_x to levels currently mandated. The proposed work will also look at the effect of catalyst on the oxidation of elemental mercury. This is an important research topic, in that EPA is looking at various regulatory options to address mercury emissions, and one of those is co-pollutant control. The benefit of HgO oxidation across a SCR catalyst bed would be of particular interest to those utilities that already employ wet scrubbers. All of these benefits would be accrued to electric utilities and their customers in the North Dakota region, as well as LRC producers.

Reviewer 00-03 (Rating: 5)

It is cost beneficial to have the mercury research done at the same time. However, the authors must not lose focus on the main goal of finding if there are SCR deactivation factors associated with lignite combustion. The main focus should not be mercury. The mercury work is important in regards to future EPA regulations. There is very limited data available on the impact that SCRs have on mercury emissions.

5. AWARENESS

The principal investigator's awareness of current research activity and published literature as evidenced by literature referenced and its interpretation and by the reference to unpublished research related to the proposal is: 1 - very limited; 2 - limited; 3 - adequate; 4 - better than average; or 5 - exceptional.

Reviewer 00-01 (Rating: 4)

The investigators understand the problem and are knowledgeable about recent experiences with SCR systems in overseas locations.

Reviewer 00-02 (Rating: 4)

The EERC project team appears to be very aware of ongoing research and published literature based on the background portion of the proposal. They are correct in identifying the blinding/de-activation of catalyst as a potential problem associated with the use of SCR on units that fire LRCs.

Reviewer 00-03 (Rating: 4)

(Reviewer provided no comments.)

6. BACKGROUND

The background of the investigator(s) as related to the proposed work is: 1 - very limited; 2 - limited; 3 - adequate; 4 - better than average; or 5 - exceptional.

Reviewer 00-01 (Rating: 4)

The team that is proposed for the project is very well qualified. They have experience with investigating combustion of low rank fuels and studies of mercury reaction pathways and analytical nuances in dealing with mercury.

Reviewer 00-02 (Rating: 4)

The proposed team possesses excellent credentials relative to the work to be performed. However, it is not apparent that this expertise transcends the research and development of catalyst-based NO_x control. That is, it is clear that the team has had direct hands-on work on the development, formulation, manufacture, and/or application of the types of catalysts used in today's SCR systems. Although this is not a showstopper, it is an issue in terms of being able to interpret the results from the German vendor that will analyze the catalysts.

Reviewer 00-03 (Rating: 4)

(Reviewer provided no comments.)

7. PROJECT MANAGEMENT

The project management plan, including a well-defined milestone chart, schedule, financial plan, and plan for communications among the investigators and subcontractors, if any is: 1 - very inadequate; 2 - inadequate; 3 - adequate; 4 very good; or 5 - exceptionally good.

Reviewer 00-01 (Rating: 3)

The general management plan appears adequate. There was no milestone chart in the proposal. The involvement of the co-sponsors in the project will result in appropriate communication between the investigators, power plant operators and the catalyst vendor that will analyze the used SCR system.

Reviewer 00-02 (Rating: 3)

The offeror has not provided a milestone schedule for the project, although the total duration of the project and individual tasks is presented. EERC also identifies the total cost and anticipated cost sharing requirements of the project. The question again arises about the relationship between EERC and the unknown German vendor that is identified as providing

$20,000/year to the project. The issue is whether or not there will be a limitation placed on the availability of the data that comes from testing the vendor's catalyst. This needs to be addressed by EERC.

Reviewer 00-03 (Rating: 3)

Insufficient data in proposal.

8. EQUIPMENT PURCHASE

The proposed purchase of equipment is: 1 - extremely poorly justified; 2 - poorly justified; 3 - justified; 4 - well justified; or 5 - extremely well justified. (Circle 5 if no equipment is to be purchased.)

Reviewer 00-01 (Rating: 3)

It is difficult to determine, from the proposal, the cost two slipstream units will cost to fabricate and install at the power plants. A total of $21,500 is identified for equipment purchases out of a total of $733,333. The balance of the funding is to pay for the man-hour related activities, some of which may be associated with fabrication of the slipstream units. If in fact, the two units can be fabricated for a total of $21,500; that appears to be a bargain. However, the information presented does not justify the equipment cost very well.

Reviewer 00-02 (Rating: 2)

The offeror does not provide adequate information on equipment requirements to evaluate the rational/justification of its purchase. EERC does state that it will design and build the catalyst test bed that will be tested in the field, but there are no details as to the materials required to do so.

It may be assumed that all of the necessary equipment is already in the possession of EERC, but this is only an assumption. The offeror talks about using an on-line mercury analyzer, but it is not clear whether this piece of instrumentation already exists or would need to be purchased.

Reviewer 00-03 (Rating: 5)

(Reviewer provided no comments.)

9. FACILITIES

The facilities and equipment available and to be purchased for the proposed research are: 1 - very inadequate; 2 - inadequate; 3 - adequate; 4 - notably good; or 5 - exceptionally good.

Reviewer 00-01 (Rating: 4)

The equipment available to do the analytical and bench scale work is world-class.

Reviewer 00-02 (Rating: 3)

See comment #8. In terms of mercury measurements, EERC certainly has in its possession such equipment. However, with as many mercury projects that EERC is involved in, will they need to purchase a separate analyzer, or sampling train, for the proposed project? What about SCR catalysts? How many different catalysts will be tested? Who will supply the catalyst? What will they cost?

Reviewer 00-03 (Rating: 5)

(Reviewer provided no comments.)

10. <u>BUDGET</u>

The proposed budget "value"[8] relative to the outlined work and the <u>financial commitment from other sources</u>[9] is of: 1 - very low value; 2 - low value; 3 - average value; 4 - high value; or 5 very high value.

Reviewer 00-01 (Rating: 5)

The proposed cost sharing of $543,333 relative to the request from NDIC for $200,000 represents excellent value to NDIC. Industrial contributions to and participation in the project demonstrates that the project is needed and the results will be used.

Reviewer 00-02 (Rating: 3)

As mentioned above, there is significant value associated with the project from two standpoints: (1) the potential impacts of LRCs on SCR catalyst performance and (2) the impact of SCR catalyst on the speciation of mercury. Information on both of these areas will be of benefit the coal and electric-utility industry, as well as the regulated community, the regulators (e.g., EPA), and those developing technology. However, as also noted above, there are some uncertainties associated with the project that would need to be addressed

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[8] "Value" – The value of the projected work and technical outcome for the budgeted amount of the project, based on your estimate of what the work might cost in research settings with which you are familiar.

[9] <u>Financial commitment from other sources</u> – A <u>minimum</u> of 50% of the total project must come from other than Industrial Commission sources to meet the program guidelines. Support greater than 50% from Industrial Commission sources should be evaluated as favorable to the application.

before investing research dollars in the effort: (1) Can the offeror really pull off the ambitious work scope from both a schedule and cost perspective? Have they given adequate thought to the level of effort required to field test at two different operating utilities? EERC has experience in this area, so perhaps they have, but it deserves a second look, and (2) EERC needs to clarify the relationship they will have with the catalyst vendor(s) in terms of how available the information from the project will be. Issues of conflict of interest (having a vendor evaluate the catalyst) and the propriety of data/results collected needs to be revisited.

Reviewer 00-03 (Rating: 4)

(Reviewer provided no comments.)

OVERALL COMMENTS AND RECOMMENDATION:

Please comment in a general way about the merits and flaws of the proposed project and make a recommendation whether or not to fund.

Reviewer 00-01 (Recommendation: FUND)

The project should be funded.

The results are needed to clarify the potential for SCR catalyst blinding to occur when the boiler is fueled with low rank coals. The information obtained about mercury reactions will be new and add to the store of information on the subject.

The challenge of the project is to obtain representative time-temperature histories for the flue gas flowing to the test rigs so that the materials interacting with the catalyst surface are in fact representative of actual SCR system operations.

Reviewer 00-02 (Recommendation: FUNDING MAY BE CONSIDERED)

Need to identify the number of catalysts that will be evaluated, and the catalyst vendor.

Need to better describe how the effect of catalyst blinding/deactivation will be factored into the evaluation of the catalyst ability to convert HgO to Hg++

Will any HgO spiking be done during the bench and/or field testing in the event the natural Hg
speciation does not favor elemental Hg?

Page 4 – Why does EERC propose to use the EPA M29 speciation method during the bench scale tests, while proposing to use Ontario-Hydro during field studies?
Page 4 – EERC proposes to use an online Hg analyzer. Whose instrument is this? Is this a homegrown instrument?

A third party should be used to evaluate the catalyst. This will preclude concerns that the results might be biased if the catalyst vendor is doing the analysis.

Reviewer 00-03 (Recommendation: FUND)

Since there is no SCR experience in Europe with lignite coals, this study will be the only known published information available to regulators, plant owners and catalyst vendors. This work needs to be done as soon as possible so that interested parties will have actual data rather than opinions to act upon.

TECHNICAL REVIEWER RATING SUMMARY					
LRC-XXXVI-B: "Lignite Fuel Enhancement:					
Incremental Moisture Reduction - Phase I"					
Submitted by The Falkirk Mine					
Request for $175,000; Total Project Costs $237,614					
		Technical Reviewer			Average
Rating	Weighting	00-4	00-5	00-6	Weighted
Category	Factor		Rating		Score
Objective	9	2	3	2	21.0
Availability	9	3	4	1	24.0
Methodology	7	2	2	1	11.7
Contribution	7	1	3	2	14.0
Awareness	5	2	3	2	11.7
Background	5	3	3	3	15.0
Project Management	2	3	4	3	6.7
Equipment Purchase	2	3	4	3	6.7
Facilities	2	2	5	3	6.7
Budget	2	1	4	2	4.7
Average Weighted Score		109	162	95	122.0
Maximum Weighted Score					250
OVERALL RECOMMENDATION					
FUND			X		
FUNDING TO BE CONSIDERED		X			
DO NOT FUND				X	

MEMORANDUM

TO: **John Dwyer**
Tony Rude
Rich Foss

FROM: **Clifford R. Porter**

SUBJECT: **Proposed Composition of the Lignite Vision 21 Project – Phase II Advisory Committee**

The proposed membership in the Lignite Vision 21 Project – Phase II Advisory Committee is:

Schwindt, Francis (Fritz)
PO Box 5520
Bismarck, ND 58506-5520
Bus: (701) 328-5150
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TBA
Northern States Power
Tony Schuster
Rick Gonzales

Responsibilities:
Clifford – Francis Schwindt
Tony – Steve Schurtz
John – Luther Kvernen
Clifford – Bruce Browers
John Terry Hildestad
John/Clifford – Jim K. Miller
John/Tony - NSP

TECHNICAL REVIEWER RATING SUMMARY

LRC-XXXVI-A: "Evaluation of Potential SCR Catalyst Blinding During Coal Combustion"
Submitted by EERC
Request for $200,000; Total Project Costs $733.333

Rating Category	Weighting Factor	Technical Reviewer 00-3 Rating	00-1		Average Weighted Score
Objective	9	4	4		24.0
Availability	9	3	3		18.0
Methodology	7	4	3		16.3
Contribution	7	5	4		21.0
Awareness	5	4	4		13.3
Background	5	4	4		13.3
Project Management	2	3	3		4.0
Equipment Purchase	2	5	3		5.3
Facilities	2	5	4		6.0
Budget	2	4	5		6.0
Average Weighted Score		200	182	0	**127.3**
Maximum Weighted Score					**250**

OVERALL RECOMMENDATION

	00-3	00-1	
FUND	X	X	X
FUNDING TO BE CONSIDERED			
DO NOT FUND			

LONG APPLICATION RATING FORM

Reviewer's Identification Number: **00-1** (no name please)

Date: January 26, 2000

Principal Investigator(s): Chris J. Zygarlicke; Stephen A. Benson, Ph.D.

Proposal Number: LRC-XXXVI-A

Application Title: "Evaluation of Potential SCR Catalyst Blinding During Coal Combustion"

Section A. Summary of Ratings:

Please complete the questions below, then fill in this summary.

	Statement	Circled Number		Weighting Factor		Subrating
1.	Objectives	4	X	9	=	36
2.	Achievability	3	X	9	=	27
3.	Methodology	3	X	7	=	21
4.	Contribution	4	X	7	=	28
5.	Awareness	4	X	5	=	20
6.	Background	4	X	5	=	20
7.	Project Management	3	X	2	=	6
8.	Equipment Purchase	3	X	2	=	6
9.	Facilities	4	X	2	=	8
10.	Budget	5	X	2	=	10
				Total: 50		182 250 points possible

Note: While points are necessary to establish an overall rating, comments on the various criteria are critical to truly understanding the value of a proposed project. Please elaborate in the comment sections to the maximum extent possible.

Overall Recommendation: ____X___ Fund

________ Funding May Be Considered

________ Do Not Fund

Section B. Ratings and Comments:

Please circle your response to each statement and transfer the number circled to the column entitled "Circled Number" on the first page of this form. Also, please comment on each criteria.

1. The objectives or goals of the proposed project with respect to clarity and consistency with North Dakota Industrial Commission/Lignite Research Council goals are: 1 – very unclear; 2 – unclear; 3 – clear; **(4 – very clear)**; or 5 – exceptionally clear.

   Please comment:

   This project will help to determine if SCR is Best Available Control Technology for NOx reduction in power plants that burn low rank coals. Some questions have arisen about the relative potential for SCR catalyst blinding in those power plants fueled with low rank coals that are rich in alkaline metals, sulfur and arsenic. A good understanding of the mechanisms that cause blinding or fouling of SCR catalyst surfaces is necessary to communicate potential risks or lack of risks to fuel users.

   A successful project should help preserve markets for North Dakota lignite and could avoid an unnecessary expense for the installation of SCR systems that could prove either ineffective or expensive to operate. The knowledge gained could also result in the development of more effective systems for these circumstances by vendors.

2. With the approach suggested and time and budget available, the objectives are: 1 – not achievable; 2 – possibly achievable; **(3 – likely achievable);** 4 – most likely achievable; or 5 – certainly achievable.

   Please comment:

   The most important experimental part of the project are the boiler field tests. It is important to be sure that the time-temperature history of the slip-stream of boiler effluent is the same as would be experienced in a full scale SCR installation. It is important that volatile species are not condensed out in the piping system between the boiler and test bed and that no atypical solid particulates are formed in the gas stream and carried through the catalyst surfaces.

   Simulating the proper time-temperature history in the lab apparatus and the field test and its importance is not discussed in the proposal.

3. The quality of the methodology displayed in the proposal is: 1 – well below average; 2 – below average; **(3 – average)**; 4 – above average; or 5 – well above average.

Please comment:

The approach suggested to investigate the problem seems appropriate. Adequate laboratory sample testing is proposed to help define which utility boilers would be most appropriate. Assessment by the vendor of decline in catalyst activity may or may not produce a meaningful result because of the relatively short duration, 1 to 4 months, of the two field tests.

4. The scientific and/or technical contribution of the proposed work to specifically address North Dakota Industrial Commission/Lignite Research Council goals will likely be 1 – extremely small; 2 – small; 3 – significant; **(4 – very significant)**; or 5 – extremely significant.

Please comment:

If the project is successful, the information on SCR catalyst blinding and mercury conversion in SCR systems for North Dakota lignite fired boiler effluents will provide unique information about potential issues involved in the use of north Dakota lignite. This will help maintain markets for the fuel.

5. The principal investigator's awareness of current research activity and published literature as evidenced by literature referenced and its interpretation and by the reference to unpublished research related to the proposal is: 1 – very limited; 2 – limited; 3 – adequate; **(4 – better than average)**; or 5 – exceptional.

Please comment:

The investigators understand the problem are knowledgeable about recent experiences with SCR systems in overseas locations

6. The background of the investigator(s) as related to the proposed work is: 1 – very limited; 2 – limited; 3 – adequate; **(4 – better than average);** or 5 – exceptional.

Please comment:

The team that is proposed for the project is very well qualified. They have experience with investigating combustion of low rank fuels and studies of mercury reaction pathways and analytical nuances in dealing with mercury.

7. The project management plan, including a well-defined milestone chart, schedule, financial plan, and plan for communications among the investigators and subcontractors, if any, is: 1 – very inadequate; 2 – inadequate; **(3 – adequate);** 4 – very good; or 5 – exceptionally good.

Please comment:

The general management plan appears adequate. There was no milestone chart in the proposal. The involvement of the co-sponsors in the project will result in appropriate communication between the investigators, power plant operators and the catalyst vendor that will analyze the used SCR system.

8. The proposed purchase of equipment is: 1 – extremely poorly justified; 2 – poorly justified; **(3 – justified);** 4 – well justified; or 5 – extremely well justified. (Circle 5 if no equipment is to be purchased.)

Please comment:

It is difficult to determine, from the proposal, the cost two slip stream test units will cost to fabricate and install at the power plants. A total of $21,500 is identified for equipment purchases out of a total of $733,333. The balance of the funding is to pay for the man-hour related activities, some of which may be associated with fabrication of the slip stream units. If in fact, the two units can be fabricated for a total of $21,500, that appears to be a bargain. However, the information presented does not justify the equipment cost very well.

9. The facilities and equipment available and to be purchased for the proposed research are: 1 – very inadequate; 2 – inadequate; 3 – adequate; **(4 – notably good);** or 5 – exceptionally good.

   Please comment:

   The equipment available to do the analytical and bench scale work is world-class.

10. The proposed budget "value"[1] relative to the outlined work and the financial commitment from other sources is of: 1 – very low value; 2 – low value; 3 – average value; 4 – high value; or **(5 – very high)** value. (See below)

   Please comment:

   The proposed cost sharing of $543,333 relative to the request from NDIC for $200,000 represents excellent value to NDIC. Industrial contributions to and participation in the project demonstrate that the project is needed and the results will be used.

[1] "Value" – The value of the projected work and technical outcome for the budgeted amount of the project, based on your estimate of what the work might cost in research settings with which you are familiar.

Financial commitment from other sources – A minimum of 50% of the total project must come from other than Industrial Commission sources to meet the program guidelines. Support greater than 50% from Industrial Commission sources should be evaluated as favorable to the application.

C. Overall Comments and Recommendations:

Please comment in a general way about the merits and flaws of the proposed project and make a recommendation whether or not to fund.

General comments:
The project should be funded.

The results are needed to clarify the potential for SCR catalyst blinding to occur when the boiler is fueled with low rank coals. The information obtained about mercury reactions will be new and add to the store of information on the subject.

The challenge of the project is to obtain representative time-temperature histories for the flue gas flowing to the test rigs so that the materials interacting with the catalyst surface are in fact representative of actual SCR system operations.

LONG APPLICATION RATING FORM

Reviewer's Identification Number: **00-2** (no name please)

Date: February 1, 2000

Principal Investigator(s): Chris J. Zygarlicke; Stephen A. Benson, Ph.D.

Proposal Number: LRC-XXXVI-A

Application Title: "Evaluation of Potential SCR Catalyst Blinding During Coal Combustion"

Section A. Summary of Ratings:

Please complete the questions below, then fill in this summary.

	Statement	Circled Number		Weighting Factor		Subrating
1.	Objectives	3	X	9	=	27
2.	Achievability	2	X	9	=	18
3.	Methodology	3	X	7	=	21
4.	Contribution	4	X	7	=	28
5.	Awareness	4	X	5	=	20
6.	Background	4	X	5	=	20
7.	Project Management	3	X	2	=	6
8.	Equipment Purchase	2	X	2	=	4
9.	Facilities	3	X	2	=	6
10.	Budget	3	X	2	=	6
				Total: 50		156 250 points possible

Note: While points are necessary to establish an overall rating, comments on the various criteria are critical to truly understanding the value of a proposed project. Please elaborate in the comment sections to the maximum extent possible.

Overall Recommendation:

______	Fund
X	Funding May Be Considered
______	Do Not Fund

Section B. Ratings and Comments:

Please circle your response to each statement and transfer the number circled to the column entitled "Circled Number" on the first page of this form. Also, please comment on each criterion.

1. The objectives or goals of the proposed project with respect to clarity and consistency with North Dakota Industrial Commission/Lignite Research Council goals are: 1 – very unclear; 2 – unclear; **3 – clear**; 4 – very clear; or 5 – exceptionally clear.

   Please comment: The proposal is clear in its linkage to the goals of the NDIC/LRC. That is, the need to investigate the impacts (potential) of low-rank coals on the performance of SCR systems in order that (1) low-rank coal production/usage is not negatively impacted by NOx regulations, and (2) the regional electric utilities do not invest in NOx control technologies (i.e., SCR) that does not meet performance specifications.

   Issues:
   - The offeror is silent as to how many catalysts will be screened and, more importantly, the relationship between themselves and the unidentified German catalysts vendor who will participate in the project. Will there be proprietary data issue with the vendor? If it is shown that LRC do maskblind the catalyst, will this information be made public, that is, will it be shared with the lignite coal industry and utility industry?

2. With the approach suggested and time and budget available, the objectives are: 1 – not achievable; **2 – possibly achievable**; 3 – likely achievable; 4 – most likely achievable; or 5 – certainly achievable.

   Please comment: The project schedule and budget are very ambitious in terms of the work scope. The offeror proposes to select test coals (and catalysts?), screen coals/catalysts at the bench scale – including evaluation of blinding/deactivation and the effect of catalyst on Hg oxidation, design and construct a slip-screen catalyst bed, install and test the bed on two host utilities, and evaluate results – all in a 24 month period. Of some concern is the budget required to do the work. The offeror may be underestimating the cost associated with the installation of the test bed on a slip-stream of two utilities. There is a significant effort (i.e., costs) involved in the ducting, piping, instrumenting, wiring, safety & health, etc. associated with installing the test bed on an operating, full-scale commercial power plant. And to do this on one plant, and then remove the bed and do it on another compounds the cost, time, and complexity of the task. It is not clear that the proposed budget of $733,333 (including $200,000 from the NDIC) is sufficient to complete the proposed effort.

3. The quality of the methodology displayed in the proposal is: 1 – well below average; 2 – below average; **3 – average**; 4 – above average; or 5 – well above average.

   Please comment: The offeror has put together a fairly solid proposal. However, there are some details lacking that result in a questioning of the overall value of the project. For example, as noted under #1 above, it is not clear what the relationship between EERC and the "German" vendor will be in terms of the availability of the catalyst data. On page 6 (Task 5), EERC states that it will send the catalyst from the field testing to a laboratory, possibly in Germany. The concern here is one of perception. If the company supplying the catalysts runs the laboratory, and it turns out that the catalyst is negatively impacted by LRCs, will the vendor make the data publicly available for fear of its implication on the company's competitiveness. If it is made publicly available, will there be a perception that the data is somehow skewed because the vendor supplier did the analyses. Sort of like the fox guarding the hen house.

It is also unclear as to how many catalysts will be evaluated? One, two, and half dozen? Will they be supplied by the same vendor? What criterion will be used to screen the catalysts so a decision can be made as to which will be evaluated in the field?

4. The scientific and/or technical contribution of the proposed work to specifically address North Dakota Industrial Commission/Lignite Research Council goals will likely be 1 – extremely small; 2 – small; 3 – significant; **4 – very significant**; or 5 – extremely significant.

Please comment: The concern about the impact of LRC on SCR catalyst is a real issue. There is no significant track record in this country for SCR technology on utility coal-fired boilers, particularly those burning low-rank coals, PRB coals. This should be a real concern for both the producers and consumers of LRCs. Of particular concern would be a utility that will invest in SCR to deal with NOx, and who may be currently burning LRC or may be planning to switch to LRCs. The proposed work would also be of value in regulatory debates at the local, State, and Federal level as to the availability of technology to control NOx to levels currently mandated. The proposed work will also look at the effect of catalyst on the oxidation of elemental mercury. This is an important research topic, in that EPA is looking at various regulatory options to address mercury emissions, and one of those is co-pollutant control. The benefit of Hg0 oxidation across a SCR catalyst bed would be a particular interest to those utilities that already employ wet scrubbers. All of these benefits would be accrued to electric utilities and their customers in the North Dakota region, as well as LRC producers.

5. The principal investigator's awareness of current research activity and published literature as evidenced by literature referenced and its interpretation and by the reference to unpublished research related to the proposal is: 1 – very limited; 2 – limited; 3 – adequate**; 4 – better than average**; or 5 – exceptional.

Please comment: The EERC project team appears to be very aware of ongoing research and published literature based on the background portion of the proposal. They are correct in identifying the blinding/de-activation of catalyst as a potential problem associated with the use of SCR on units that fire LRCs.

6. The background of the investigator(s) as related to the proposed work is: 1 – very limited; 2 – limited; 3 – adequate; **4 – better than average**; or 5 – exceptional.

Please comment: The proposed team possesses excellent credentials relative to the work to be performed. However, it is not apparent that this expertise transcends the research and development of catalyst-based NOx control. That is, it is clear that the team has had direct hands-on work on the development, formulation, manufacture, and/or application of the types of catalysts used in today's SCR systems. Although this is not a show stopper, it is an issue in terms of being able to interpret the results from the German vendor that will analyze the catalysts.

7. The project management plan, including a well-defined milestone chart, schedule, financial plan, and plan for communications among the investigators and subcontractors, if any, is: 1 – very inadequate; 2 – inadequate**; 3 – adequate**; 4 – very good; or 5 – exceptionally good.

Please comment: The offeror has not provided a milestone schedule for the project, although the total duration of the project and individual tasks is presented. EERC also identifies the total cost and anticipated cost sharing requirements of the project. The question again arises about the relationship between EERC and the unknown German vendor that is identified as providing $20,000/year to the project. The issue is whether or not there will be a limitation placed on the availability of the data that comes from testing the vendors catalyst. This needs to be addressed by EERC.

8. The proposed purchase of equipment is: 1 – extremely poorly justified; **2 – poorly justified**; 3 – justified; 4 – well justified; or 5 – extremely well justified. (Circle 5 if no equipment is to be purchased.)

   Please comment: The offeror does not provide adequate information on equipment requirements to evaluate the rational/justification of its purchase. EERC does state that it will design and build the catalyst test bed that will tested in the field, but there are no details as to the materials required to do so. It may be assumed that all of the necessary equipment is already in the possession of EERC, but this is only an assumption. The offeror talks about using an on-line mercury analyzer, but it is not clear whether this piece of instrumentation already exits or would need to be purchased.

9. The facilities and equipment available and to be purchased for the proposed research are: 1 – very inadequate; 2 – inadequate; **3 – adequate**; 4 – notably good; or 5 – exceptionally good.

   Please comment: See comment #8. In terms of mercury measurements, EERC certainly has in its possession such equipment. However, with as many mercury projects that EERC is involved in, will they need to purchase a separate analyzer, or sampling train, for the proposed project? What about SCR catalysts. How many different catalysts will be tested? Who will supply the catalyst? What will they cost?

10. The proposed budget "value"[1] relative to the outlined work and the <u>financial commitment from other sources</u> is of: 1 – very low value; 2 – low value; **3 – average value**; 4 – high value; or 5 – very high value. (See below)

    Please comment: As mentioned above, there is significant value associated with the project from two standpoints: (1) the potential impacts of LRCs on SCR catalyst performance and (2) the impact of SCR catalyst on the speciation of mercury. Information on both of these areas will be of benefit to the coal and electric-utility industry, as well as to the regulated community, the regulators (e.g., EPA), and those developing technology. However, as also noted above, there are some uncertainties associated with the project that would need to be addressed before investing research dollars in the effort: (1) can the offeror really pull off the ambitious work scope from both a schedule and cost

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[1] "Value" – The value of the projected work and technical outcome for the budgeted amount of the project, based on your estimate of what the work might cost in research settings with which you are familiar.

<u>Financial commitment from other sources</u> – A <u>minimum</u> of 50% of the total project must come from other than Industrial Commission sources to meet the program guidelines. Support greater than 50% from Industrial Commission sources should be evaluated as favorable to the application.

perspective – have they given adequate thought to the level-of-effort required to field test at two different operating utilities. EERC has experience in this area, so perhaps they have, but it deserves a second look, and (2) EERC needs to clarify the relationship they will have with catalyst vendor(s) in terms of how available will the information from the project be. Issues of conflict of interest (having a vendor evaluate the catalyst) and the propriety of data/results collected needs to be revisited.

C. Overall Comments and Recommendations:

Please comment in a general way about the merits and flaws of the proposed project and make a recommendation whether or not to fund.

General comments:

- Need to identify the number of catalysts that will be evaluated, and the catalyst vendor(s).
- Need to better describe how the effect of catalyst blinding/deactivation will be factored into the evaluation of the catalyst ability to convert Hg0 to Hg++.
- Will any Hg0 spiking be done during the bench and/or field testing in the effect the natural Hg speciation does not favor elemental Hg?
- Page 4 - Why does EERC propose to use the EPA M29 speciation method during the bench scale tests, while proposing to use Ontario-Hydro during field studies?
- Page 4 – EERC proposes to use an online Hg analyzer. Whose instrument is this? Is this a home grown instrument?
- A third party should be used to evaluate the catalyst. This will preclude concerns that the results might be biased if the catalyst vendor is doing the analysis.

LONG APPLICATION RATING FORM

Reviewer's Identification Number: **00-3** (no name please)

Date:January 31, 2000

Principal Investigator(s): Chris J. Zygarlicke; Stephen A. Benson, Ph.D.

Proposal Number: LRC-XXXVI-A

Application Title: "Evaluation of Potential SCR Catalyst Blinding During Coal Combustion"

Section A. Summary of Ratings:

Please complete the questions below, then fill in this summary.

	Statement	Circled Number		Weighting Factor		Subrating
1.	Objectives	4	X	9	=	36
2.	Achievability	3	X	9	=	27
3.	Methodology	4	X	7	=	28
4.	Contribution	5	X	7	=	35
5.	Awareness	4	X	5	=	20
6.	Background	4	X	5	=	20
7.	Project Management	3	X	2	=	6
8.	Equipment Purchase	5	X	2	=	10
9.	Facilities	5	X	2	=	10
10.	Budget	4	X	2	=	8
				Total: 50		200 250 points possible

Note: While points are necessary to establish an overall rating, comments on the various criteria are critical to truly understanding the value of a proposed project. Please elaborate in the comment sections to the maximum extent possible.

Overall Recommendation: ___X___ Fund

______ Funding May Be Considered

______ Do Not Fund

Section B. Ratings and Comments:

Please circle your response to each statement and transfer the number circled to the column entitled "Circled Number" on the first page of this form. Also, please comment on each criteria.

1. The objectives or goals of the proposed project with respect to clarity and consistency with North Dakota Industrial Commission/Lignite Research Council goals are: 1 – very unclear; 2 – unclear; 3 – clear; 4 – very clear; or 5 – exceptionally clear.

   Please comment:

   The authors have a good understanding of the overall potential problem and impacts on the environment, plant operations and the economy.

   The emission limits proposed for lignite boilers by USEPA is more restrictive than the limits currently in place in Germany.

2. With the approach suggested and time and budget available, the objectives are: 1 – not achievable; 2 – possibly achievable; 3 – likely achievable; 4 – most likely achievable; or 5 – certainly achievable.

   Please comment:

   Insufficient data on budgets for complete evaluation

3. The quality of the methodology displayed in the proposal is: 1 – well below average; 2 – below average; 3 – average; 4 – above average; or 5 – well above average.

Please comment:

There is limited published data available. Most data to date is unpublished. It appears that the authors did a good job in obtaining unpublished data.

4. The scientific and/or technical contribution of the proposed work to specifically address North Dakota Industrial Commission/Lignite Research Council goals will likely be 1 – extremely small; 2 – small; 3 – significant; 4 – very significant; or 5 – extremely significant.

Please comment:

It is cost beneficial to have the mercury research done at the same time. However, the authors must not lose focus on the main goal of finding if there are SCR deactivation factors associated with lignite combustion. The main focus should not be mercury. The mercury work is important in regards to future EPA regulations. There is very limit data available on the impact that SCRs have on mercury emissions.

5. The principal investigator's awareness of current research activity and published literature as evidenced by literature referenced and its interpretation and by the reference to unpublished research related to the proposal is: 1 – very limited; 2 – limited; 3 – adequate; 4 – better than average; or 5 – exceptional.

Please comment:

6. The background of the investigator(s) as related to the proposed work is: 1 – very limited; 2 – limited; 3 – adequate; 4 – better than average; or 5 – exceptional.

Please comment:

7. The project management plan, including a well-defined milestone chart, schedule, financial plan, and plan for communications among the investigators and subcontractors, if any, is: 1 – very inadequate; 2 – inadequate; 3 – adequate; 4 – very good; or 5 – exceptionally good.

Please comment:
insufficient data in proposal.

8. The proposed purchase of equipment is: 1 – extremely poorly justified; 2 – poorly justified; 3 – justified; 4 – well justified; or 5 – extremely well justified. (Circle 5 if no equipment is to be purchased.)

Please comment:

9. The facilities and equipment available and to be purchased for the proposed research are: 1 – very inadequate; 2 – inadequate; 3 – adequate; 4 – notably good; or 5 – exceptionally good.

Please comment:

10. The proposed budget "value"[1] relative to the outlined work and the financial commitment from other sources is of: 1 – very low value; 2 – low value; 3 – average value; 4 – high value; or 5 – very high value. (See below)

Please comment:

[1] "Value" – The value of the projected work and technical outcome for the budgeted amount of the project, based on your estimate of what the work might cost in research settings with which you are familiar.

Financial commitment from other sources – A minimum of 50% of the total project must come from other than Industrial Commission sources to meet the program guidelines. Support greater than 50% from Industrial Commission sources should be evaluated as favorable to the application.

C. Overall Comments and Recommendations:

Please comment in a general way about the merits and flaws of the proposed project and make a recommendation whether or not to fund.

General comments:

Since there is no SCR experience in Europe with lignite coals this study will be the only know published information available to regulators, plant owners and catalyst vendors. This work needs to be done as soon as possible so that interested parties will have actual data rather than opinions to act upon.

_ FILENAME \p

Energy & Environmental Research Center

UNIVERSITY OF NORTH DAKOTA
15 North 23rd Street — PO Box 9018 / Grand Forks, ND 58202-9018 / Phone: (701) 777-5000 Fax: 777-5181
World Wide Web Server Address: www.eerc.und.nodak.edu

Exhibit A

February 23, 2000

Ms. Karlene Fine
Executive Director
Industrial Commission of North Dakota
600 East Boulevard Avenue
State Capitol, 10th Floor
Bismarck, ND 58505-0310

Dear Ms. Fine:

Subject: EERC Proposal No. 2000-0017

As requested, enclosed is a copy of the EERC proposal entitled "Evaluation of Potential SCR Catalyst Blinding During Coal Combustion." Corrections have been made on pages 3 and 8 to address the errors on NO_x levels for North Dakota boilers; clarification has been made for the host utility sites to include both lignite and Powder River Basin coal.

Also, it is assumed that this project's implementation is contingent upon securing all commercial industry sponsors by September 1, 2000.

Please let me know if you have any questions. I can be reached at by phone at (701) 777-5258, by fax at (701) 777-5181, or by e-mail at jgunderson@eerc.und.nodak.edu.

Sincerely,

Jay R. Gunderson
Research Manager

Approved by:

2/23/00
Dr. Carl A. Fox, Director
UND Office of Research and Program Development

JRG/llh

Enclosure

c: Steve Benson, EERC
Chris Zygarlicke, EERC

Energy & Environmental Research Center

EVALUATION OF POTENTIAL SCR CATALYST BLINDING DURING COAL COMBUSTION

EERC Proposal No. 2000-0071

Submitted to:

Ms. Karlene Fine

Industrial Commission of North Dakota
600 East Boulevard Avenue
State Capitol, 10th Floor
Bismarck, ND 58505-0310

Amount Requested: $200,000 over 2 years

Submitted by:

Chris J. Zygarlicke
Steven A. Benson
Jay R. Gunderson

Energy & Environmental Research Center
PO Box 9018
Grand Forks, ND 58202-9018

Chris J. Zygarlicke, Project Manager

Dr. Carl A. Fox, Director
Office of Research and Program Development

December 1999

TABLE OF CONTENTS

EVALUATION OF POTENTIAL SCR CATALYST BLINDING DURING COAL COMBUSTION

ABSTRACT

Objectives: The goals of this Energy & Environmental Research Center (EERC) project are to determine the potential of low-rank coal ash to cause blinding or masking of selective catalytic reduction (SCR) catalysts and to determine the degree of elemental mercury conversion across the catalysts. Specific objectives include 1) identify candidate coals and blends for testing under bench-scale conditions; 2) conduct bench-scale testing to screen coals and identify key conditions for testing at the full scale; 3) design and construct a SCR slipstream test chamber for sampling at full-scale facilities; 4) conduct testing at full-scale facilities; 5) identify SCR blinding mechanisms, rates, and cleaning methods as well as mercury conversion efficiencies; 6) interpret data, prepare a report, and attend sponsor meetings to develop recommendations related to expected catalyst life and degree of mercury conversion.

Expected Results: Utilities that are contemplating the installation of SCR in their coal-fired units will gain scientific and engineering information related to potential fouling of SCR catalyst material and will be able to negotiate guarantees and performance criteria for SCR systems and materials, and SCR manufacturers and distributers will gain an appreciation for potential challenges facing utilities using low-rank coals that could cause SCR masking and will be able to adjust future systems.

Duration: 24 months

Total Project Cost: $733,333; $200,000 from the North Dakota Industrial Commission (NDIC)

Participants: EERC, U.S. Department of Energy (DOE), NDIC, and utility consortium sponsors.

EVALUATION OF POTENTIAL SCR CATALYST BLINDING DURING COAL COMBUSTION

PROJECT SUMMARY

The primary goal of this Energy & Environmental Research Center (EERC) project is to determine the potential of low-rank coal ash to cause blinding or masking of selective catalytic reduction (SCR) catalysts. A secondary goal will be to determine the degree of elemental mercury conversion across the catalysts. Specific objectives include 1) identify candidate coals and blends for testing under bench-scale conditions; 2) conduct bench-scale testing to screen coals and identify key conditions for testing at the full scale; 3) design and construct a SCR slipstream test chamber for sampling at full-scale facilities; 4) conduct testing at full-scale facilities; 5) identify SCR blinding mechanisms, rates, and cleaning methods as well as mercury conversion efficiencies; 6) interpret data, prepare a report, and attend sponsor meetings to develop recommendations related to expected catalyst life and degree of mercury conversion.

The work will be accomplished in six tasks. Task 1 will identify coals and utilities that will serve as test sites. Task 2 will be dedicated to bench-scale testing to screen coals and conditions that may be anticipated in the field testing. Task 3 focuses on the design and construction of the SCR slipstream test chamber. Task 4 will involve setting up the SCR slipstream test chamber at the various utility host sites and gathering data and SCR catalyst test sections for analysis.

In Task 5, an intense effort will be made to characterize the SCR catalyst material for blinding effects and ash deposit mechanisms. This work is the most critical and will also entail identification of SCR blinding rates, recommendations for cleaning methods, and mercury conversion efficiencies. Correlations between coal analyses, flue gas vapor and particulate

analyses, and SCR ash deposit analyses will be derived to determine potential masking impacts and mechanisms.

Finally, Task 6 will provide interpretation of the data and develop recommendations to both utilities and SCR manufacturers. This task will also serve as a project management and reporting task.

PROJECT DESCRIPTION

Objectives

Specific project objectives include:

- Identify candidate coals and blends for testing for testing under bench-scale conditions.
- Conduct bench-scale testing to screen coals and identify key test conditions.
- Design and construct a slipstream system for testing at full-scale facilities.
- Conduct testing at full-scale facilities.
- Identify SCR blinding mechanisms, rates, and cleaning methods as well as mercury conversion efficiencies.
- Interpret data, prepare a report. and attend sponsor meetings to develop recommendations related to expected catalyst life and degree of mercury conversion.

Methodology

This project is designed to determine the potential of low-rank coal ash to cause blinding or masking of SCR catalysts. Some attention will also be focused on determining the degree of elemental mercury conversion across the catalysts. Details of the methods to be used and the scope of work are given below in the framework of six tasks.

Task 1 – Identification of Test Coals and Utility Host Sites

The first task of this project will be to have a kickoff meeting between the multiclient consortium members to determine which utilities and boiler units will have the SCR slipstream test chamber installed in them and which coals should be tested. Two utility host sites will be selected for long-duration tests using the SCR slipstream test chamber. The utility sites will include at least one lignite boiler and one PRB boiler. A third host site may be selected, depending upon the number of consortium members involved and available funding. The coals that will be burned as part of the full-scale slipstream SCR testing will be part of the test pool; in addition, other coals that sponsors may want to test at the bench scale, which would not be tested at a utility host site, will be selected and acquired. The time-consuming nature of the utility field testing precludes the testing of multiple coals at full-scale units. A maximum of six test coals will be selected and acquired for this program. A final objective of Task 1 will be to finalize the project work plan.

Task 2 – Bench-Scale Testing and Screening

Bench-scale combustion testing will be used to accomplish two main objectives. The first is to obtain potentially useful information on SCR blinding propensity for several coals other than those used in the field test. The number of coals field-tested will be limited to the two accommodated by the project budget. A bench-scale test program will be able to test up to six coals for SCR catalyst blinding and reactivity degradation testing. These bench-scale tests may also lead to a more time-efficient and economical means of testing SCR blinding potential in the future. These tests may be conducted in collaboration with a project funded through the EERC's Center for Air Toxic Metals, which is focused on SCR catalyst impacts on mercury transformations.

The second objective of the bench-scale SCR reaction chamber testing will be to obtain fundamental information on the formation of phases and components that comprise SCR blinding deposits. Some studies have observed phosphate-rich ash deposits comprising SCR deposits. Calcium aluminum phosphate minerals have been observed in North Dakota lignites and Powder River Basin (PRB) coals, and there may be potential problems if indeed certain low-temperature ash deposition mechanisms for SCR systems involve phosphatic materials. Information on how these phosphate-rich phases develop and form will be invaluable for predicting SCR deposition and for formulating ash deposit mitigation measures.

Mercury conversion will be analyzed for the test coals using on-line mercury speciation measurements. Catalyst blinding will be assessed by extracting the catalyst section after long-duration tests and assessing catalyst reactivity and ash–catalyst surface reactions and ash deposition.

All test coals will be analyzed for proximate, ultimate, heating value, and bulk inorganic composition using standard American Society for Testing and Materials (ASTM) procedures. Advanced analytical techniques using scanning electron microscopy (SEM) will be used to study fly ash and deposit characteristics. Mercury sampling will be accomplished by extractive techniques using the U.S. Environmental Protection Agency (EPA) Method 29 sampling train.

Task 3 – Design and Construction of the SCR Slipstream Test Chamber

Portable test chambers will be designed and constructed for testing SCR masking at a minimum of two low-rank coal boilers (i.e., select North Dakota lignite boilers). At least two chambers will be constructed and possibly more, depending on available funding. The chamber will maintain the correct temperature, surface area, and orientation of SCR catalyst material while passing an isokenetically drawn slipstream of the boiler flue gas through the chamber using either a vacuum pump or the boiler induced-draft fan.

The EERC will procure chamber design input from project sponsors and catalyst vendors. It is anticipated that a chamber cross-sectional area 2 ft^2 and 3 ft in length will be adequate to house enough catalyst to treat a 100-scfm slipstream. The chamber will be externally heated to maintain a consistent temperature during testing.

Task 4 – SCR Test Chamber Installation and Data Collection at Utility Host Sites

SCR test chambers will be installed in a slipstream arrangement at two utility boilers. Additional boilers may be tested, depending upon available funds. Since SCR masking or blinding phenomena occur over longer periods of time, the SCR test chamber will be kept in a slipstream arrangement in the region ahead of the air heater at each boiler for a period of 1–4 months. Upon installation of the test chamber at each boiler unit, measurements of flue gas temperatures, gas composition, and gas velocity will be taken using portable equipment. Periodic checks of the chamber by a trained boiler technician will be made to assure experimental quality. The test chamber will be constructed so that periodic samples of the catalyst can be removed to assess reactivity as a function of time. After testing is completed at the first utility boiler site, the SCR slipstream test chamber will be moved to the second utility boiler site with installation of fresh catalyst.

A mercury continuous emission monitor will be used to determine mercury from across the SCR test section. The Ontario Hydro extractive mercury speciation sampling technique will be used to measure potential mercury conversion across the SCR system over a period of several hours after fresh installation of the SCR test chamber and again just prior to SCR chamber removal. An isokinetic sample of entrained ash particulate entering the experimental SCR chamber will also be taken after chamber installation. In addition, a representative coal sample will be collected after SCR chamber installation, and the coal will be fully characterized using conventional and advanced analytical techniques.

Task 5 – Determination of SCR Blinding Mechanisms

Upon completion of the SCR chamber experiments at each plant, the SCR catalyst section in the test chamber will be sent to a laboratory (possibly in Germany) for measuring any degradation in catalyst reactivity. These are standard tests routinely performed by catalyst vendors.

The nature of any ash deposition or ash–catalyst reactions will be investigated by the EERC using proven methods that include SEM, x-ray diffraction, and other analytical techniques. These same techniques and other fine-particle SEM analytical techniques will be used to analyze the entrained ash samples collected at the field sites. Correlations between the physical and chemical characteristics of any ash deposits on the SCR test section and entrained ash sample collected at the chamber inlet, and the coal inorganic composition will be made to discern mechanisms of SCR blinding. Minor and trace element analyses of deposits and SCR catalyst material will be performed in order to evaluate the effects of As, Sr, and Ba, which may act as poisoning agents.

The ability for the SCR catalyst materials to catalyze gaseous elemental mercury (Hg^0[g]) to more soluble and chemically reactive $Hg^{2+}X(g)$ forms will also be evaluated. This information will be interpreted to determine the likelihood of increasing the formation of particle-associated mercury Hg(p), thus increasing the capture efficiency of mercury by conventional control devices such as wet flue gas desulfurization (FGD) scrubbers and electrostatic precipitators (ESPs).

Task 6 – Final Interpretation, Recommendations, and Reporting

Task 6 will bring together all of the data interpretation on SCR blinding mechanisms and mercury conversion efficiencies. Potential cleaning methods, if necessary, or other blinding remedial measures will be recommended. Any increase in mercury capture efficiencies due to oxidation across the SCR catalyst will be estimated for each plant and its array of particulate and wet FGD control devices. Project reporting, periodic meetings with all consortium members, and efficient transfer of information will be facilitated in this task. Quarterly interim reports will be submitted to North Dakota Industrial Commission (NDIC) and consortium members that bullet the progress and forecast of the project and highlight any key findings. A final report will be submitted to NDIC and all sponsors at the end of the project. Any special reports requested by NDIC will be provided in a timely manner.

Expected Results

Several deliverables and benefits would result for active participating agencies in this project. Listed below are the most important of these:

1. Utilities that are contemplating the installation of SCR in their coal-fired units will gain scientific and engineering information related to potential fouling of SCR catalyst material and will be able to negotiate guarantees and performance criteria for SCR systems and materials.
2. SCR manufacturers and distributers will gain an appreciation for potential challenges facing utilities using low-rank coals that could cause SCR masking and will be able to adjust future systems.

Facilities, Resources, Techniques

The EERC has existing well-equipped and instrumented bench-scale coal combustion demonstration facilities for performing these experiments. Either a drop-tube furnace (DTF) assembly that burns coal at a grams/min rate or a downfired combustion system that burns 2–4 lb/hr of fuel, called the conversion and environmental process simulator (CEPS), will be adapted for these tests. The SCR reaction chamber will be assembled and attached in the postcombustion heat-exchange section of either the CEPS or DTF system, where combustion flue gas can be passed across the catalyst material. The combined combustor and SCR reaction chamber offer easy installation and removal of catalyst sections, hot synthetic flue gas injection, good control of gas composition, and full instrumentation for monitoring the system.

Environmental and Economic Impacts

In its 1990 Clean Air Act Amendments, Congress specifically directed EPA to establish new nitrogen oxide (NO_x) emission standards that incorporate improvements in methods for the reduction of NO_x. As a result, North Dakota utilities are required to lower NO_x emissions to between 0.40 and 0.86 lb/MMBtu for coal-fired utility boilers, depending upon boiler type. Since SCR technology is about the only choice that will be effective for lowering NO_x in North Dakota boilers, especially cyclone boilers, this project may aid in improving SCR technologies for effective NO_x control and improved environmental air quality. This research will assist in assuring continued use of the valuable coal resources of North Dakota by ensuring that effective SCR technologies can be developed for North Dakota's unique lignite-fired boilers, thereby precluding any plant shutdowns or EPA fines and preserving a valuable segment of the North Dakota energy economy.

Rationale for the Project

The 1990 Clean Air Act Amendments specifically directed EPA to exercise its delegated authority and establish new NO_x emissions standards that incorporate improvements in methods for the reduction of NO_x. As a result, EPA promulgated a rule lowering its No_x New Source Performance Standards to 0.15 lb/MMBtu for utility boilers and 0.20 lb/MMBtu for industrial boilers. Litigation from North Dakota challenged this rule because EPA's definition of "best demonstrated system" for control of NO_x is SCR technologies, which may not necessarily hold true for lower-rank coal boilers. The North Dakota challenge and petition of the NO_x ruling was denied by EPA with explanations that include insufficient evidence to show that catalyst poisoning from alkali metals occurs with low-rank coals; effectiveness of SCR is not dependent upon boiler design; and predictions of SCR performance on industrial boilers can be extrapolated from utility boiler observations in the United States and abroad. As a result, certain utilities that burn low-rank coals, including northern Great Plains lignites and PRB subbituminous coal may have difficulty meeting NO_x emission limits even after installation of low-NO_x burner systems or SCR technology. In the case of cyclone boilers, low-NO_x burners are not an option and will likely rely on SCR catalysts to provide the needed NO_x reductions.

Recent studies on German coals show an impact of sodium, calcium, sulfur, and phosphorus on the performance of SCR catalysts. Over a period of time, blinding of the SCR catalyst occurred, resulting in decreased conversion efficiency. Extrapolation of the German experience to U.S. applications reveals that catalyst deactivation may occur because of the high alkaline metals, sulfur, arsenic, and SO_3 contents in some U.S. coals. SCR systems operate in flue gas ducts downstream of the economizer and just prior to the air heater where entrained ash or dust can deposit. The high alkali and alkaline-earth element content (sodium and calcium) of entrained fly ash generated from combustion of low-rank coals reacts with gaseous SO_2 to form low-temperature sulfate-based ash deposits on catalyst surfaces. Deposit buildup of this type can effectively blind or mask the catalyst, diminishing its reactivity for converting NO_2 to N_2 and water, and potentially creating increased ammonia slip.

The end result is that research is needed to determine the true extent of potential SCR blinding for lower-rank coals. If indeed masking of SCR catalyst material is an issue, then SCR technology may not be the "best available" technology for NO_x control at North Dakota utility sites and the EPA ruling may need to be amended. Other options that may surface as result of this research include providing technological and fundamental science and engineering knowledge for manufacturing SCR catalysts that resist blinding from low-rank-coal-type ash material or designing SCR systems that can be cleaned on-line.

An additional impetus for this research relates to the possibility for SCR materials to catalyze gaseous elemental mercury to more soluble and chemically reactive forms, which may have the effect of increasing the formation of particle-associated mercury and thus increasing the capture efficiency of mercury by conventional control devices such as wet FGD scrubbers and ESPs.

It is imperative that utilities, state agencies, regulators, and SCR catalyst vendors understand fully the potential for SCR masking and mercury conversion for low-rank coals such as North Dakota lignites or PRB coals, which can generate very fine particulate fly ash and vapor components that may deteriorate the reactivity of a catalyst surface over time.

BACKGROUND

Recent studies conducted by Hartenstein et al. (1) showed an impact of sodium, calcium, sulfur, and phosphorus on the performance of SCR catalysts when German coals were fired. Over a period of time, blinding of the SCR catalyst occurred, resulting in decreased conversion efficiency. Extrapolation of the German experience to U.S. applications reveals that catalyst deactivation may occur because of the high alkaline metals, sulfur, and SO_3 contents in some U.S. coals. SCR systems operate in flue gas ducts downstream of the economizer and just prior to the air heater where entrained ash or dust can deposit. The high alkali and alkaline-earth element content (sodium and calcium) of entrained fly ash generated from combustion of low-rank coals reacts with gaseous SO_2 to form low-temperature sulfate-based ash deposits on catalyst surfaces.

The mechanisms for this type of low-temperature deposition have been examined and modeled in detail at the EERC in work termed Project Sodium and Project Calcium in the early 1990s; however, the focus of those projects was specific to primary superheater and economizer regions of boilers and not SCR systems (2–3). Deposit buildup of this type can effectively blind or mask the catalyst, diminishing its reactivity for converting NO_2 to N_2 and water, and potentially creating increased ammonia slip (3). Arsenic and phosphates, which are not uncommon in low-rank coals, may also play a role in catalyst degeneration. Arsenic is a known catalyst poison (4) in applications such as catalytic oxidation for pollution control. Phosphates can occur in low-temperature ash deposits to create blinding effects, and they also occur with arsenic and can cause catalyst poisoning (5).

In contrast to the potential masking problem caused by SCR catalyst material, a benefit to utilities may be that SCR materials catalyze gaseous elemental mercury ($Hg^0[g]$) to more soluble and chemically reactive $Hg^{2+}X(g)$ forms, which may have the effect of increasing the formation of particle-associated mercury Hg(p) and thus increasing the capture efficiency of mercury by conventional control devices such as wet flue gas FGD scrubbers and ESPs (6).

QUALIFICATIONS

The EERC of the University of North Dakota is one of the world's major energy and environmental research organizations. Since its founding in 1949, the EERC has conducted research, testing, and evaluation of fuels, combustion, and gasification technologies; emissions control technologies; ash use and disposal; analytical methods; groundwater; waste-to-energy systems; and advanced environmental control systems. Today's energy and environmental research needs typically require the expertise of a total-systems team that can focus on technical details while retaining a broad perspective. The EERC team has more than four decades of basic and applied research experience producing energy from all ranks of coal, with particular emphasis on low-rank coals. As a result, the EERC has become the world's leading low-rank coal research center. EERC research programs are designed to embrace all aspects of energy-from-coal technologies from cradle to grave, beginning with fundamental resource characterization and ending with waste utilization or disposal in mine land reclamation settings.

The future of North Dakota energy production depends upon developing interconnections between energy and environment that will allow the extraction of sufficient energy and other resources from our environment in a manner that does not jeopardize its integrity and stability. The EERC fulfills a valuable part of this future challenge by developing a SCR blinding research project that will effectively develop partnerships between industry, researchers, and state agencies.

With respect to NO_x emissions, the EERC has been performing studies in low-NO_x burner technologies, catalytic effects on NO_x conversion, fly ash quality from low-NO_x burner or overfired air technology installation, and fuel impacts on NO_x emissions for over 25 years. Several successful projects, including over 20 field tests, have been conducted at various North Dakota utilities to perform flue gas sampling, air toxic emissions monitoring, fly ash collection, and fouling and slagging deposit sampling. Several of those field tests involved working with plant slipstreams or direct sampling using custom-designed and -manufactured sampling equipment.

VALUE TO NORTH DAKOTA

The proposed project lends great value to North Dakota by preserving the use of a valuable lignite resource. EPA rules on NO_x emissions could possibly be amended as part of this research, which would effectively save utilities in North Dakota potentially \$2–\$5 million worth of SCR installation. If the EPA ruling prevails, North Dakota utilities could put the burden of developing effective SCR technologies on the manufacturers and vendors of SCR equipment by working with the industry on researching blinding issues. The research for this product would be performed almost exclusively by a the EERC, a North Dakota-based research group, therefore allowing the NDIC financial investment to remain primarily in the North Dakota economy.

MANAGEMENT

The project's overall management responsibility would fall to Dr. Steven Benson and Mr. Chris Zygarlicke. They will comanage the project to ensure proper project milestone achievements, report generation and distribution, project budget control, and effective informational meetings. Dr. Benson and Mr. Zygarlicke each have over 15 years of experience managing coal combustion-related projects. They have worked on recent NDIC projects for mercury measurement and speciation at selected North Dakota power plants and a study of coal quality impacts on boiler performance at the Coyote Power Station near Beulah, North Dakota.

Principal investigators are Mr. Donald Toman, who will oversee the design and construction of the SCR slipstream test chamber; Mr. Jay Gunderson, who will oversee the bench-scale and full-scale SCR catalyst blinding experimental activities; and Dr. Donald McCollor, who will oversee the analytical work performed on all fuels and catalyst materials. These researchers will also be responsible for cataloging and reporting all experimental results in their respective areas of focus. Resumes for key personnel are found in Appendix A.

TIMETABLE

The project would be scheduled to be completed within 24 months after a kickoff meeting with project sponsors. There would essentially be a 3-month period to select and acquire coals and determine utility host sites, a 3-month period to build the SCR slipstream test chamber, a 6–8-month period to install the test chamber and collect data at select utilities, and a 6–12-month period to analyze data and interpret results.

Quarterly interim reports that describe project progress, forecast, and key results will be submitted to NDIC and all project sponsors. A final comprehensive report will be submitted to the same parties at the end of the 2-year project.

BUDGET

This request is for $200,000 from NDIC to support a program with a total project cost of $733,333. The sources of matching funds are discussed in the next section. A budget is attached. The NDIC funds are necessary for meeting the total budget amount in order to fulfill the objectives of the project. The NDIC funds, along with DOE matching funds on the NDIC portion, constitute 45% of the project budget. Without the NDIC funding, the related DOE match would be unavailable and not enough funding to attain the project objectives.

MATCHING FUNDS

The greatest leveraging of funding and expertise for developing a fruitful project would be through a consortium project between the EERC, commercial entities, and DOE. The EERC proposes to assemble and manage a multiclient consortium consisting of the EERC as the prime contractor and administrator of the program, with consortium members consisting of utilities, catalyst vendors, and NDIC, which is active in funding research related to enhancing the utilization of North Dakota lignite. The EERC brings to this program its nearly 45 years of experience in coal combustion, ash deposition, and air toxics control to effectively guide this project toward meaningful results.

Consortium members would include a German catalyst vendor that was introduced to this project and has shown considerable interest; several utilities that have been contacted and show definite interest in the project, including Great River Energy, Minnkota Power, Otter Tail Power, Alliant Energy, and Wisconsin Electric Power Company; and EPRI, which has expressed interest in this area. Other North Dakota utilities have expressed some interest in this project, and negotiations are ongoing.

The project would be funded through the EERC–DOE Jointly Sponsored Research Program, whereby the sum total of the commercial or industrial partners' contributions would be matched by a DOE contribution equaling 40% of the total project cost. A project budget has been assembled by the EERC for addressing SCR masking potential at two utility boiler units for a total project cost of about $733,333. This is a minimum project total needed to fulfill the project objectives and the work scope as outlined in the six-task structure. The project would run over a course of 2 years. In order to reach the total budget of $733,333, five U.S. commercial sponsors, not including NDIC, will be needed to contribute $20,000 per year for 2 years to total $200,000. The NDIC would in essence match this amount and contribute $100,000 per year to total $200,000. It is anticipated that the German vendor would also contribute $20,000 per year, but this amount will not be considered as part of the NDIC match. Should total contributions increase beyond the five U.S. and one German contribution that are projected, additional utility boiler testing or analytical work will be added to the project work scope. The total commercial contribution would therefore be $440,000. DOE would be solicited to contribute a total of $293,333 as a 40% match to meet the total project cost of $733,333. The EERC is confident that a minimum of five commercial sponsors will be secured and that DOE will approve the 40% cost share.

Three items are required from NDIC for inclusion in our proposal to DOE:

- A formal commitment to the project. This can be a letter of commitment, a purchase order, or a signed contract.
- A biographical sketch or resume for NDIC's project manager and/or key technical contributor.
- A short overview of NDIC.

The EERC will submit a proposal to DOE for its approval upon receipt of NDIC commitment and the information noted above.

STANDARDS OF SUCCESS

SCR technologies have been successfully demonstrated to a large degree in Europe and other countries and to a smaller degree in U.S. utilities. Most of this work has been performed on higher-rank coals that do not possess significant organically associated alkali–alkaline-earth elemental constituents, which can cause severe blinding of catalyst material. The degree to which blinding occurs in the lower-rank coals that will be studied in this project will be compared to known cases with higher-rank coals. The EERC has years of experience studying low-temperature ash deposition, which is the likely mechanism by which SCR blinding occurs and this standard of experience will be valuable to this project. The managers and principal investigators of this project have a combined total publication list in this area of ash deposition numbering over 150 publications, and they have been involved in a combined total of over 20 field trips involving low-rank coals in North Dakota and in the Midwest over the past 5 years. This academic or mechanistic understanding of potential SCR-related blinding and the practical boiler testing experience provide a sound standard of excellence by which to gauge the progress and results of this project.

TAX LIABILITY

None.

CONFIDENTIAL INFORMATION

None.

REFERENCES

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3. Benson, S.A.; Hurley, J.P.; Zygarlicke, C.J.; Steadman, E.N.; Erickson, T.A. Predicting Ash Behavior in Utility Boilers. *Energy and Fuels* **1993**, 7, 746–754.
4. Harbison, G. Minimizing Operating Costs of VOC Control. *Pollution Engineering* [Online] Summer, **1998**, 6 p.
5. Swaine, D.J.; Taylor, G.F. Arsenic in Phosphatic Boiler Deposits. *Journal of the Institute of Fuel* July, **1970**, p 261.
6. Gutberlet, H.; Spiesberger, A.; Kastner, F.; Tembrink, J. Behavior of the Trace Element Mercury in Bituminous Coal-Burning Furnaces with Flue Gas Cleaning Systems. *VGB Kraftwerkstechnik* **1992**, 72, 636–641.

EVALUATION OF POTENTIAL SCR CATALYST MASKING DURING COAL COMBUSTION
MULTI CLIENT / DOE
PROPOSED START DATE: 01-Jul-00
EERC PROPOSAL #2000-0071 29-Dec-99

CATEGORY		TOTAL HOURS	TOTAL $ COST	NDIC SHARE HOURS	NDIC SHARE $ COST	OTHER COMMERCIAL SHARE HOURS	OTHER COMMERCIAL SHARE $ COST	EERC JSRP SHARE HOURS	EERC JSRP SHARE $ COST
TOTAL DIRECT LABOR		8187	$220,670	2202	$59,685	2594	$70,098	3391	$90,887
FRINGE BENEFITS - % OF DIRECT LABOR	52%		$114,748		$31,036		$36,451		$47,261
TOTAL LABOR			$335,418		$90,721		$106,549		$138,148
OTHER DIRECT COSTS									
TRAVEL			$14,696		$4,000		$5,295		$5,401
SUPPLIES			$12,200		$3,320		$4,500		$4,380
EQUIPMENT > $750			$21,500		$0		$0		$21,500
COMMUNICATIONS - PHONES & POSTAGE			$2,200		$600		$800		$800
OFFICE (PROJECT SPECIFIC SUPPLIES)			$3,731		$950		$1,400		$1,381
GENERAL (FREIGHT, FOOD, MEMBERSHIPS, ETC.)			$300		$80		$100		$120
FEES			$103,356		$30,200		$37,200		$35,956
TOTAL OTHER DIRECT COST			$157,983		$39,150		$49,295		$69,538
TOTAL DIRECT COST			$493,401		$129,871		$155,844		$207,686
INDIRECT COST - % OF MTDC		VAR	$239,932	54%	$70,129	54%	$84,156	46%	$85,647
TOTAL ESTIMATED COST			$733,333		$200,000		$240,000		$293,333

DETAILED BUDGET - TRAVEL

EVALUATION OF POTENTIAL SCR CATALYST MASKING DURING COAL COMBUSTION
EERC PROPOSAL #2000-0071

RATES USED TO CALCULATE ESTIMATED TRAVEL EXPENSES

DESTINATION	LODGING	PER DIEM	STATE VEHICLE
Unspecified Destination (USA)	$125	$46	$0.37 per mile

PURPOSE/DESTINATION	TRIPS	MILES	NUMBER OF VEHICLES	PEOPLE	DAYS	MILEAGE	LODGING	PER DIEM	MISC.	TOTAL
Site Sampling / Unspecified Dest. (USA)	2	1800	1	5	8	$666	$8,750	$3,680	$1,600	$14,696

NOTE: Used estimated 500 miles round-trip and 50 miles per day per trip.

DETAILED BUDGET - EQUIPMENT

ITEM DESCRIPTION	COST
stainless steel	$2,000
fittings	$400
heaters	$3,500
thermocouples	$500
pumps / fans	$8,000
catalyst	$4,800
miscellaneous	$2,300

TOTAL EQUIPMENT	**$21,500**
	======

BUDGET NOTES

ENERGY & ENVIRONMENTAL RESEARCH CENTER (EERC)

Background

The EERC is an independently organized multidisciplinary research center within the University of North Dakota. The EERC receives no appropriated funding from the state of North Dakota and is funded through federal and nonfederal grants, contracts, or other agreements. Although the EERC is not affiliated with any one academic department, university academic faculty may participate in a project, depending on the scope of work and expertise required to perform the project.

The proposed work will be done on a cost-reimbursable basis. The distribution of costs between budget categories (labor, travel, supplies, equipment, subcontracts) is for planning purposes only. The principal investigator may, as dictated by the needs of the work, reallocate the budget among approved items or use the funds for other items directly related to the project, subject only to staying within the total dollars authorized for the overall program. The budget prepared for this proposal is based on a specific start date; this start date is indicated at the top of the EERC budget or identified in the body of the proposal. Please be aware that any delay in the start of this project may result in an increase in the budget. Financial reporting will be at the total project level.

Salaries and Fringe Benefits

As an interdisciplinary, multiprogram, and multiproject research center, the EERC employs an administrative staff to provide required services for various direct and indirect support functions. Direct project salary estimates are based on the scope of work and prior experience on projects of similar scope. Technical and administrative salary charges are based on direct hourly effort on the project. The labor rate used for specifically identified personnel is the current hourly rate for that individual. The labor category rate is the current average rate of a personnel group with a similar job description. For faculty, if the effort occurs during the academic year and crosses departmental lines, the salary will be in addition to the normal base salary. University policy allows faculty who perform work in addition to their academic contract to receive no more than 20% over the base salary. Costs for general support services such as grants and contracts administration, accounting, personnel, and purchasing and receiving, as well as clerical support of these functions, are included in the indirect cost of the EERC.

Fringe benefits are estimated on the basis of historical data. The fringe benefits actually charged consist of two components. The first component covers average vacation, holiday, and sick leave (VSL) for the EERC. This component is approved by the UND cognizant audit agency and charged as a percentage of direct labor for permanent staff employees eligible for VSL benefits. The second component covers actual expenses for items such as health, life, and unemployment insurance; social security matching; worker's compensation; and UND retirement contributions.

Travel

Travel is estimated on the basis of UND travel policies, which include estimated General Services Administration (GSA) daily meal rates. Travel includes scheduled meetings and conference participation as indicated in the scope of work.

Communications (phones and postage)

Monthly telephone services and fax telephone lines are included in indirect cost. Direct project cost includes long-distance telephone, including fax-related long-distance calls; postage for regular, air, and express mail; and other data or document transportation costs.

Office (project-specific supplies)

General purpose office supplies (pencils, pens, paper clips, staples, Post-it notes, etc.) are provided through a central storeroom at no cost to individual projects. Budgeted project office supplies include items specifically related to the project: special research notebooks, binders, and other project organizational materials; duplicating, printing, special covers or paper, and binding of reports; project data forms, transparencies, or other presentation materials; literature searches and technical information procurement, including subscriptions; manuals, computer diskettes, memory chips, laser printer paper, and toner cartridges; and other miscellaneous supplies required to complete the project.

Data Processing

Data processing includes items such as site licenses and computer software.

Supplies

Supplies in this category include scientific supply items such as chemicals, gases, glassware, and/or other project items such as nuts, bolts, and piping necessary for pilot plant operations.

Fees

Laboratory and analytical fees are established and approved at the beginning of each fiscal year, and charges are based on a per sample or hourly rate depending on the analytical services performed. Additionally, laboratory analyses may be performed outside the University when necessary.

Engineering support fees are based on an established per hour rate for drafting services related to the production of drawings as part of the EERC's quality assurance/quality control program for complying with piping and pressure vessel codes.

Graphic services fees are based on an established per hour rate for overall graphics production such as report figures, posters for poster sessions, standard word or table slides, simple maps, schematic slides, desktop publishing, photographs, and printing or copying.

Shop and operation fees are for expenses directly associated with the operation of the pilot plant facility. These fees cover such items as training, safety (protective eye glasses, boots, gloves), and physicals for pilot plant and shop personnel.

General

Membership fees (if included) are for memberships in technical areas directly related to work on this project. Technical journals and newsletters received as a result of a membership are used throughout development and execution of the project as well as by the research team directly involved in project activity.

General expenditures for project meetings, workshops, and conferences where the primary purpose is dissemination of technical information may include costs of food (some of which may exceed the institutional limit), transportation, rental of facilities, and other items incidental to such meetings or conferences.

Indirect Cost

The indirect cost rate included in this proposal is the rate that became effective July 1, 1995. Indirect cost is calculated on modified total direct costs (MTDC). MTDC is defined as total direct costs less individual items of equipment in excess of $750 and subcontracts/subgrants in excess of the first $25,000 of each award.

APPENDIX A

RESUMES OF KEY PERSONNEL

DR. STEVEN A. BENSON
Associate Director for Technology Development
Energy & Environmental Research Center (EERC)
University of North Dakota (UND)
PO Box 9018, Grand Forks, ND 58202-9018 USA
Phone (701) 777-5000 Fax (701) 777-5181
E-mail: sbenson@eerc.und.nodak.edu

Principal Areas of Expertise

Dr. Benson's principal areas of interest and expertise include management of complex multidisciplinary programs focused on solving energy production and environmental problems. The program areas include the development of 1) methodologies to minimize the effects of inorganic components on the performance of combustion/gasification and air pollution control systems; 2) air toxic substances in combustion and gasification systems; 3) advanced analytical techniques to determine the chemical and physical transformations of inorganic species in combustion gases; 4) computer-based codes to predict the effects of coal quality on system performance; 5) advanced materials for coal-based power systems; and 6) training programs designed to improve the global quality of life through energy and environmental research activities.

Qualifications

Ph.D., Fuel Science, Materials Science and Engineering, The Pennsylvania State University, 1987.
B.S., Chemistry, Moorhead State University (Minnesota), 1977.

Professional Experience

1999 – Associate Director for Technology Development, EERC. UND.

1994 – 1999 Associate Director for Research, EERC, UND. Dr. Benson is responsible for the direction of programs related to integrated energy and environmental system development. The research, development, and demonstration programs involve fuel quality effects on power system performance, advanced power systems development/demonstration, computational modeling, advanced materials for power systems, and analytical methods for the characterization of materials. Specific areas of focus include the direction of the EPA Center for Air Toxic Metals at the EERC, ash behavior in combustion and gasification systems, hot-gas cleanup, and analytical methods of analysis. He is responsible for the identification of research opportunities and the preparation of proposals and reports for clients.

1986 – 1994 Senior Research Manager, Fuels and Materials Science, EERC, UND. Dr. Benson was responsible for management and supervision of research on the behavior of inorganic constituents, including air toxic metals during related material. In addition, research was performed on the use of x-ray analysis to measure trace elements in fuels and conversion products.

1977 – 1979	Chemist, U.S. Department of Energy Grand Forks Energy Technology Center. Dr. Benson performed analysis on coal and coal derivatives by techniques such as wavelength-dispersive x-ray analysis, argon plasma spectrometry, atomic absorption spectrometry, thermal analysis, and elemental analysis (CHN).
1976 – 1977	Teaching Assistant, Department of Chemistry, Moorhead State University. Dr. Benson was responsible for teaching labs for first-year chemistry students.

Professional Memberships

- The Combustion Institute
- Advisory Member, ASME Committee on Corrosion and Deposition Resulting from Impurities in Gas Streams
- American Chemical Society, Fuel Division Member
- Industrial Liaison, Fuel Division, American Chemical Society

Publications and Presentations

- Has authored or coauthored over 170 publications and is the editor of four books and Special Issues.

CHRISTOPHER J. ZYGARLICKE
Research Manager
Energy & Environmental Research Center (EERC)
University of North Dakota (UND)
PO Box 9018, Grand Forks, North Dakota 58202-9018 USA
Phone (701) 777-5000 Fax (701) 777-5181
E-Mail: czygarlicke@eerc.und.nodak.edu

Principal Areas of Expertise

Mr. Zygarlicke's principal areas of interest and expertise include biomass and fossil fuel conversion for energy production, with an emphasis on ash effects on system performance. He also has experience with trace element emissions and control for fossil fuel combustion systems, with a particular emphasis on air pollution issues related to Hg, Ni, As, and fine particulates. He routinely gives tutorials and presentations on current issues facing the public, industry, and government with respect to Hg and fine particulate emissions and impending regulations. He has experience in the design and implementation of new methods and technologies related to energy efficiency and air pollution. He is currently one of five program area managers in the Center for Air Toxic Metals in charge of the program area entitled "Air Toxic Metals Transformation Mechanisms."

Qualifications

M.S., Geology, University of North Dakota, 1987.
B.S., Geology, University of Wisconsin-Platteville, 1983.

Professional Experience

1991 – Research Manager, EERC, UND. Mr. Zygarlicke's responsibilities include supervising projects involving bench-scale combustion testing of various fuels and wastes; supervising a laboratory that performs bench-scale combustion and gasification testing; managerial and principal investigator duties for projects related to the inorganic composition of coal, coal ash formation, deposition of ash in conventional and advanced power systems, mechanisms of trace metal transformations during coal or waste conversion; and writing proposals and reports applicable to energy and environmental research.

1987 – 1991 Research Associate, Combustion Studies, EERC, UND. Mr. Zygarlicke's responsibilities included fundamental research of the processes of inorganic transformations during coal combustion and writing proposals and reports applicable to ongoing coal research.

1984 – 1986 Graduate Research Fellow, Energy Research Center, UND. Mr. Zygarlicke's responsibilities included megascopic description and quantification of coal lithotypes, standard coal petrology, chemical and scanning electron microprobe analysis of inorganic constituents in coal, lignite sample collection, and statistical analysis of adsorbed inorganic constituents in low-rank coal.

Summer 1983 Research Fellow, Associated Western Universities. Mr. Zygarlicke's responsibilities consisted of optical and scanning electron microscopy of mineral matter in coal, mine sampling, and statistical analysis of inorganic constituents in low-rank coal.

Publications and Presentations

- Has authored or coauthored over 140 publications

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Principal Areas of Expertise

Coal combustion technology including coal–water fuel combustion and ash fouling.

Qualifications

M.S. Studies, Chemical Engineering, University of North Dakota, 1987–present.
B.S., Chemical Engineering, University of North Dakota, 1987.

Professional Experience

July 1988 – Research Engineer, Fuels Performance, EERC, UND.

Responsibilities involve pilot-scale combustion projects for residential-, commercial-, and utility-scale applications of coal-fired combustion systems, including ash fouling and fuel characterization. Duties include documentation and reporting of pilot-scale testing results and relating these results to the operation of full-scale units.

Jan. – June 1988 Research Assistant, Combustion and Environmental Systems Research Institute, Energy and Mineral Research Center, University of North Dakota, Grand Forks, North Dakota.

Responsibilities involved the development of a coal–water fuel-fired residential- and commercial-scale furnace.

Professional Memberships

- American Institute of Chemical Engineers

Publications and Presentations

- Has coauthored numerous publications

DR. DONALD P. McCOLLOR
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Principal Areas of Expertise

Dr. McCollor's principal areas of interest and expertise include coal combustion kinetics and inorganic transformation and deposition processes. He has experience in the collection, analysis, and interpretation of data from bench-, pilot-, and full-scale combustion systems as well as in the development of predictive models to assess combustion and ash deposition behavior.

Qualifications

Ph.D., Physical Chemistry, University of North Dakota, 1981.
B.A., Chemistry, University of Minnesota, Morris, 1974.

Professional Experience

1983 – Research Associate, Conversion Systems, EERC, UND. Dr. McCollor's responsibilities include design, construction, and operation of equipment and instrumentation for combustion research and planning experiments and analyses of results from fundamental combustion units.

1981 – 1983 AWU Postdoctoral Fellow and Research Chemist, Grand Forks Energy Technology Center, U.S. Department of Energy, Grand Forks, North Dakota. Dr. McCollor's responsibilities included conducting research to characterize inorganic species in coal and products from coal combustion. Computer-based statistical and data reduction methods were extensively used to interpret data from a variety of analytical instruments. Position included research to develop and modify sampling techniques and analytical methods.

DONALD L. TOMAN
Research Associate
Energy & Environmental Research Center (EERC)
University of North Dakota (UND)
PO Box 9018, Grand Forks, North Dakota 58202-9018 USA
Phone (701) 777-5000 Fax (701) 777-5181
E-Mail: dtoman@eerc.und.nodak.edu

Principal Areas of Expertise

Mr. Toman's principal areas of interest and expertise include design, fabrication, and operation of bench-, intermediate-, and pilot-scale combustion systems and full-scale testing of gaseous and particulate emissions.

Qualifications

B.S., Natural Sciences, University of North Dakota, 1980.

Professional Experience

1989 – Research Associate, Systems Development, EERC, UND. Mr. Toman's responsibilities include designing, fabricating, and operating various types of bench-scale systems to produce and collect chars and ash from coal under closely controlled conditions; full-scale utility boiler testing and collection of gaseous and particulate emissions; collecting, interpreting and reporting of data; and preparing budgets, proposals, and reports.

1985 – 1989 Pilot Plant Operator Supervisor, Operations Division, EERC, UND. Mr. Toman's responsibilities included supervision and evaluation of operations personnel; assigning and inspecting work for quality and quantity; planning project and work schedules and ensuring that regulations and rules were observed on housekeeping, conduct, and safety; maintaining production records; and performing operator duties when required.

1983 – 1985 Pilot Plant Operator III, Pilot Plant Operations, Coal Utilization Research Division, Energy Research Center, UND. Mr. Toman's responsibilities included operations, maintenance, and trouble-shooting of pilot plant test equipment. He was responsible for facility operation and supervision of assigned personnel during shift. Pilot plant equipment included two pc-fired combustors, a coal slurry unit, a slurry erosion unit, two AFBC coal-fired units, a pressure hydrator unit, a direct – injection flue gas desulfurization test unit, various sorbent injection feeders, and coal processing equipment. Experience also included performance of EPA-5 dust loadings and the operation of ash-fouling probes used in the performance of field tests.

1982 Operations Group Supervisor, EG&G Washington Analytical Services Center, Inc., Grand Forks, North Dakota. Mr. Toman's responsibilities included all aspects of combustion pilot plant operations, including supervision and evaluation of operations personnel, scheduling, and supervising performance of combustion pilot plant testing, reviewing data collected from combustion pilot plant testing before submission to Technical Support Group, preparing weekly summaries and monthly reports, and documenting work performed by the Operations Group.

1982 – Shift Supervisor, Operations Group, EG&G Washington Analytical Services Center, Inc., Grand Forks, North Dakota. Mr. Toman's responsibilities included operations, maintenance, and trouble-shooting of pilot plant equipment. He was responsible for all aspects of facility operation and supervision of assigned operations personnel during shift.

1980 – 1982 Pilot Plant Operator, Operations Groups, EG&G Washington Analytical Services Center, Inc., Grand Forks, North Dakota. Mr. Toman's responsibilities included operations, maintenance, data collection, and trouble-shooting of pilot plant equipment. Pilot plant equipment included two pc/coal-fired combustors, an AFBC coal-fired combustor, a wet scrubber flue gas desulfurization test unit, a direct injection flue gas desulfurization test unit, and various coal processing equipment (pulverizer, crusher, classifier, dryer, conveyors, and lift trucks). Experienced in the operation of solid feeders, particulate collection equipment, flue gas sampling equipment and process instrumentation.

1980 Lab Technician, Grand Forks Energy Technology Center, UND, Grand Forks, North Dakota. Mr. Toman's responsibilities included preparing samples for analysis and performing routine coal and ash analysis.

Professional Memberships

- American Chemical Society

Publications and Presentations

- Has authored or coauthored numerous publications

Professional Memberships

- American Chemical Society
- American Crystallographic Association
- The Combustion Institute
- North Dakota Academy of Science

Publications and Presentations

- Has authored or coauthored numerous publications

Energy & Environmental Research Center

UNIVERSITY OF NORTH DAKOTA

15 North 23rd Street — PO Box 9018 / Grand Forks, ND 58202-9018 / Phone: (701) 777-5000 Fax: 777-5181
World Wide Web Server Address: www.eerc.und.nodak.edu

May 2, 2000

Ms. Karlene K. Fine
Executive Director and Secretary
North Dakota Industrial Commission
State Capitol, 10th Floor
600 East Boulevard Avenue, Department 405
Bismarck, ND 58505-0840

Dear Karlene:

Subject: North Dakota Industrial Commission Contract No. FY00-XXXVI-101 100
Evaluation of Potential SCR Catalyst Blinding During Coal Combustion

Enclosed for your records is one original of the above agreement that has been signed for the University of North Dakota Energy & Environmental Research Center.

Thank you very much for your attention to this matter. Should you have any questions, please contact me at (701) 777-4581 or by e-mail at jzola@undeerc.org.

Sincerely,

Jill M. Zola

Jill M. Zola
Contracts Officer
Business and Operations

JMZ/kal

Enclosure

c: Chris Zygarlicke, EERC

INDUSTRIAL COMMISSION OF NORTH DAKOTA

Edward T. Schafer
Governor

Heidi Heitkamp
Attorney General

Roger Johnson
Commissioner of Agriculture

March 17, 2000

Jill M. Zola
EERC Grants & Contracts Office
Energy & Environmental Research Center
Box 9018
Grand Forks, ND 58202-9018

Dear Jill:

Enclosed are two copies of the Lignite Research Program Contract No. FY00-XXXVI-100.

If you want any changes in the contract, please give me a call. If no changes are needed, please sign the contracts and return one to my office. The first payment will be processed as noted in the contract.

If you have any questions, please give me a call at (701) 328-3722.

Sincerely,

Karlene Fine
Executive Director and
Secretary of the Industrial Commission

Enclosure

Karlene K. Fine, Executive Director and Secretary
State Capitol, 10th Floor - 600 E Boulevard Ave Dept 405 - Bismarck, ND 58505-0840
E-Mail: kfine@state.nd.us
Phone: (701) 328-3722 FAX: (701) 328-2820

Energy & Environmental Research Center

UNIVERSITY OF NORTH DAKOTA

15 North 23rd Street — PO Box 9018 / Grand Forks, ND 58202-9018 / Phone: (701) 777-5000 Fax: 777-5181
Web Site: www.undeerc.org

January 5, 2001

Ms. Karlene K. Fine
Executive Director and Secretary
Industrial Commission of North Dakota
State Capitol, 10th Floor
600 East Boulevard Avenue, Department 405
Bismarck, ND 58505-0840

Dear Karlene:

Subject: Lignite Research Council Contract No. FY00-XXXVI-100
Evaluation of Potential SCR Catalyst Blinding During Coal Combustion
UND Fund 4869

In accordance with Article 3. Consideration of the subject agreement, the Energy & Environmental Research Center (EERC) herewith provides the required documentation for industrial participation as well as U.S. Department of Energy approval for the subject project.

Industrial participation has been requested at $40,000 per organization. Enclosed are commitment letters from Alliant Energy, AmerenUE, EPRI, and Otter Tail Power Company that identify each entity's participation at the requested amount of $40,000. Dynegy Midwest Generation, Inc. (DMG), and Ontario Power Generation (OPG) are also participating in the project. As DMG and OPG did not send initial commitment letters for the project, pertinent pages from each organization's respective agreement are enclosed as evidence of participation in the project.

The U.S. Department of Energy (DOE) has also given its approval for the above project through its Cooperative Agreement DE-FC26-98FT40321. The project has been identified as Task 32 and funded at the requested level of $335,333. Copies of the pertinent pages to the DOE amendment authorizing the funds for Task 32 are also enclosed for your records.

Thank you very much for your attention to this matter. Should you have any questions regarding the information provided or require additional documentation, please contact me at (701) 777-4581 or by e-mail at jzola@undeerc.org.

Sincerely,

Jill M. Zola

Jill M. Zola
Contracts Officer
Business and Operations

JMZ/jdk

Enclosures

c/enc: Corey Graves, UND Grant and Contract Administration

c: Clifford Porter, Lignite Research Council
Steve Benson, EERC

ALLIANT ENERGY.

Alliant Energy Corporation
Alliant Tower
200 First Street SE
P.O. Box 351
Cedar Rapids, IA 52406-0351

Office: 319.398.4411
www.alliant-energy.com

March 16, 2000

Mr. Jay R. Gunderson
Research Engineer
Energy & Environmental Research Center
University of North Dakota
15 North 23rd Street- P.O. Box 9018
Grand Forks, ND 58202-9018

Ref.: EERC Proposal No. 2000-0071

Dear Mr. Gunderson:

Alliant Energy is interested in becoming a partner in the consortium of parties to evaluate the long-term effectiveness of selective catalytic reduction (SCR) for NO_x control in low-rank coal-fired boilers. Alliant Energy will contribute the required sum of $20,000 per year over the 2 years to support a program with a total cost of $733,333.

Alliant Energy objective is the evaluation of Power River Basin coal ash to cause blinding or masking on SCR catalyst surfaces, the identification of mechanisms and the development of recommendations regarding expected life of a selection of catalysts.

We would like to discuss the goals, objectives and work plan and, in particular the 2-year duration of the study, as a shorter term would be beneficial to Alliant Energy.

The key technical contributor to the project will be Dr. Edmundo Vasquez, Principal Research Engineer, who can be contacted at 608-252-3492.

Sincerely,

Dan Mineck
Vice President
Energy & Environmental

Cc: Gary Walling
Edmundo Vasquez

Union Electric

One Ameren Plaza
1901 Chouteau Avenue
PO Box 66149
St. Louis, MO 63166-6149
314.621.3222

June 28, 2000

Mr. Christopher J. Zygarlicke
Research Manager
Energy and Environmental Research Center
University of North Dakota
PO Box 9018
Grand Forks, ND 58202-9018

Ameren UE

Dear Mr. Zygarlicke:

I have reviewed EERC proposal 2000-0071, including the revised pages 3, 4, and 5 transmitted via email on 6/21/00 from Sheryl Landis, from yourself, Mr. Steve Benson and Mr. Jay Gunderson, dated June 2000, to conduct an Evaluation of Potential SCR Catalyst Blinding during Coal Combustion. This letter is to confirm acceptance of this proposal and is your authorization to proceed.

Mr. Ken Stuckmeyer, Consulting Engineer, Power Plant Maintenance and Engineering, is Ameren's primary contact for this project. All coordination of meetings, information, testing results, etc. should be made through Mr. Stuckmeyer.

All invoices should refer to the purchase order and be sent to Mr. R. J. Kenney, Construction Audit Department, Mail Code 290.

A copy of AmerenUE's Minimum Insurance Requirements, Invoicing Requirements, General Safety Guidelines, Federal Requirements, and Contractors' Temporary Labs Relative to OSHA Lab Safety Regulations are attached; we ask that you adhere to the applicable paragraphs.

Ameren recognizes the contractor is also receiving federal funding for this project that is the subject of this agreement letter and as a result the Contractor's obligations to Ameren regarding intellectual property such as patents, data, and copyrights, may be secondary to Contractor's obligations to the federal government. Nothing in this agreement prevents Ameren from asserting its rights in such property against the federal government.

Each party, Ameren and the Contractor, shall coordinate in advance with the other party on all public information releases to be issued concerning this project if the release contains a reference to the other party or the U.S. Department of Energy. Such releases shall not be issued without prior approval from the referenced parties' authorized representatives.

AmerenUE may require drug or alcohol testing of a contractor's employee who is reasonably suspected of substance abuse or who is involved in an accident involving personal injury or property damage on the job. When appropriate, such testing shall occur in accordance with the Contractor's Substance Abuse Policy.

If Contractor, in the performance of the work, generates any wastes considered hazardous pursuant to any federal, state, or local statute, regulation, or ordinance, Contractor shall promptly remove such wastes from the premises and treat, store, and/or dispose of such wastes in full compliance with all applicable laws, regulations, and ordinances.

Sincerely,

Thomas Swigunski

T. J. Swigunski
Manager
Power Plant Maintenance & Engineering

KBS/akp

Attachments

cc: K. B. Stuckmeyer
R. A. Phillips
File: Date File

POWERING PROGRESS THROUGH
SCIENCE AND TECHNOLOGY

EPRI

April 14, 2000

Jay R. Gunderson
University of North Dakota Energy and Environmental Research Center
15 North 23rd Street
Grand Forks, ND 58202

Subject: EERC Proposal "Evaluation of Potential SCR Catalyst Blinding During Coal Combustion"

Dear Jay:

On behalf of EPRI, it is my pleasure to inform you of EPRI's intent to participate in the UND-EERC program "Evaluation of Potential SCR Catalyst Blinding During Coal Combustion". We will be joining in 2000 for $20,000 and again in 2001 for another $20,000. Additionally, we will encourage EPRI Post Combustion NOx Control Target members to join us in the program.

Sincerely,

Dave O'Connor
Project Manager, Fuels and Combustion

c: D. Broske
R. Chang
T. Facchiano

215 South Cascade Street
PO Box 496
Fergus Falls, Minnesota 56538-0496
218 739-8200
www.otpco.com (web site)

RECEIVED
APR 6 2000
EERC-SAB

April 5, 2000

OTTER TAIL
Power Company

Dr. Steven A. Benson
Associate Director of Technology Development
Energy & Environmental Research Center
University of North Dakota
P.O. Box 9018
Grand Forks, ND 58202-9018

Dear Dr. Benson:

SUBJECT: LETTER OF COMMITMENT - EERC PROPOSAL NO. 2000-0071 EVALUATION OF POTENTIAL SCR CATALYST BLINDING DURING COAL COMBUSTION

Thank you for the opportunity of reviewing EERC proposal No. 2000-0071 "Evaluation of Potential SCR Catalyst Blinding During Coal Combustion." Otter Tail is very interested in this research project, particularly because EPA has been targeting SCR for NOx control as Best Available Control Technology.

I was pleased to learn that other utilities share our interest in including subbituminous coal as well as lignite in the evaluation and that subbituminous coal will be included in the study. On that basis, Otter Tail Power Company is willing to commit to project funding of $20,000 per year for a period of two years. Please direct any invoices or formal agreements to my attention.

As you requested in the proposal, I am including a copy of my resume and a short overview of Otter Tail Power Company.

I look forward to working with you on this project.

Sincerely,

Terry Graumann
Manager, Environmental Services

Enclosures

Dynegy Midwest Generation, Inc.
2828 North Monroe Street
Decatur, Illinois 62526-3269

December 5, 2000

DYNEGY

Ms. Jill M. Zola
Contacts Officer
Business and Operations
University of North Dakota
15 North 23rd Street
P. O. Box 908
Grand Forks, ND 58202-9018

Dear Jill:

Subject: Agreement for EER Proposal No. 2000-0071-R1 Entitled "Evaluation of Potential SCR Catalyst Blinding During Coal Combustion"

Please find enclosed a fully executed original of the subject proposed agreement between Dynegy Midwest Generation, Inc., and the Energy & Environmental Research Center (EERC) for the above project. Also enclosed is a check in the amount of $20,000 for Invoice No. xxxx-0997-01.

If you have any questions, please contact me at 217-872-2350.

Sincerely,

Ted Lindenbusch
Manager - Process Engineering and Chemistry

blf
Enclosures (2)
c: Mark Liefer, Baldwin Energy Complex, P-08
Keith McFarland, Baldwin Energy Complex, P-08

DTL00005

AGREEMENT

THIS AGREEMENT is made and entered into between Dynegy Midwest Generation, Inc. ("Sponsor"), having its principal place of business at 1000 Louisiana, Houston, Texas, and the University of North Dakota Energy & Environmental Research Center (UNDEERC) ("Contractor"), having its principal place of business at 15 North 23rd Street, Grand Forks, North Dakota. The parties to this Agreement are sometimes hereinafter referred to individually as a "Party" and collectively as the "parties."

WITNESSETH THAT:

WHEREAS Contractor is willing to conduct an evaluation of Potential SCR Catalyst Blinding During Coal Combustion, and Sponsor desires to receive the results of said study;

NOW, THEREFORE, in consideration of the mutual promises exchanged below, Contractor and Sponsor have agreed as follows:

ARTICLE 1 – DEFINITIONS

1.01 As used herein, the term "Program" shall mean a multiclient study known as "Evaluation of Potential SCR Catalyst Blinding During Coal Combustion,"described more fully in APPENDIX A hereto.

1.02 As used herein, the term "Sponsor" shall mean each party, other than Contractor, who enters into an Agreement having terms and conditions similar to those contained in this Agreement. However, it is understood that the U.S. Department of Energy (DOE) and the North Dakota Industrial Commission (NDIC) will be funding their contributions under separate agreements with Contractor. As the funding provided herein will be used as federal matching funds to the DOE agreement, it will follow the guidelines detailed in paragraph 4.05 of this Agreement.

1.03 As used herein, the term "Affiliate" of a party shall mean and include "the ultimate parent company or companies of such party, and all companies (other than such party) whenever and however and in whatever countries organized, as to which such parent company(ies) shall, at the time in question and directly or indirectly, have the right to elect a majority of the directors, or otherwise to control the selection of management of the same."

ARTICLE 2 – THE PROGRAM

2.01 Upon this Agreement becoming effective, Contractor will conduct the Program in accordance with the terms of this Agreement. This Agreement shall become effective and the program shall commence on June 26, 2000. Contractor will use its best efforts to complete the Program within twenty-four (24) months from the date of the kick-off meeting, which was held July 15, 2000, and to complete the individual tasks as scheduled in APPENDIX A (Proposal No. 2000-0071, dated 10/11/00). Sponsors will be notified in writing if the planned completion date is changed as determined by the Contractor.

2.02 Contractor will act in the capacity of an independent contractor with respect to Sponsors and will perform its work hereunder using its own methods, free from direction by any individual sponsor.

ARTICLE 3 – SPONSORS

3.01 Participation in the Program is open to all interested parties entering into an Agreement having similar terms and conditions to those contained in this Agreement. The fees to be charged to Sponsors will be determined in accordance with the provisions of Article 4 of this Agreement.

ARTICLE 4 – COMPENSATION AND FEES

4.01 The total cost of the Program described in APPENDIX A will be US$823,333. A funding commitment in the amount of US$335,333 is being requested from DOE, a contract from NDIC in the amount of US$200,000 has been received, and US$40,000 is being sought from each of five utility consortium sponsors and a catalyst vendor. Contractor will contribute US$48,000 for equipment to be purchased under the Program.

4.02 All Sponsors will pay membership fees of US$40,000, of which US$20,000 is payable upon execution of this agreement, and the remaining US$20,000 is payable upon the anniversary date of the kick-off meeting.

4.03 The Contractor and Sponsors will decide mutually whether to use any excess funds collected as a result of having more than the original Sponsors to enhance the program or to distribute equally to each original Sponsor. In the event that the Sponsors and Contractor cannot agree, the majority vote of the Sponsors will prevail.

4.04 If costs are expected to exceed funding, an attempt will be made to secure additional funding from existing sponsors and other sources or the Scope of Work will be modified appropriately.

4.05 The distribution of costs between budget categories (labor, travel, supplies, equipment, subcontracts) is for planning purposes only. Contractor may, as dictated by the needs of the work, reallocate the budget among approved items or use the funds for other items directly related to the project, subject only to staying within the total dollars authorized.

ARTICLE 5 – TITLE OF EQUIPMENT

5.01 Title to equipment acquired shall vest in the University of North Dakota.

ARTICLE 6 – INVENTIONS AND WORK PRODUCT

6.01 It is not anticipated that this Program will result in any inventions, discoveries, computer software, or improvements. However, the Contractor will promptly notify all Sponsors of any inventions, discoveries, computer software, or improvements developed under this Program that it believes are potentially patentable or otherwise protectable.

6.02 All patents and copyrights resulting from work under this Program will be the property of the University of North Dakota.

6.03 Each Sponsor shall have a nonexclusive, perpetual, royalty-free, worldwide license to practice any invention, discovery, or improvement conceived or made by Contractor as a result of this program, whether patentable or not, and to contract with others to manufacture for the Sponsor's internal operations. The rights to practice or manufacture for internal operations is not the right to practice or manufacture for

13.04 In the event that the Contractor's objectives hereunder require or contemplate performance of services by the Contractor's employees or persons under contract to the Contractor to be done on Sponsor's property or property of Sponsor's customers or vendors, the Contractor agrees that its employees or subcontractors conducting all such work shall not be considered employees of the Sponsor.

13.05 All notices, reports, and other correspondence with respect to the Program shall be mailed postage-paid to the addresses given below:

Contractor: Jill Zola
Contracts Office
University of North Dakota Energy & Environmental
Research Center
PO Box 9018
Grand Forks, ND 58202-9018
Phone: (701) 777-4581
E-mail: jzola@undeerc.org

Sponsor: Ted Lindenbusch
Manager, Process Engineering and Chemistry
Dynegy Midwest Generation, Inc.
2828 North Monroe Street
Decatur, IL 62526
Phone: (217) 872-2350 Fax: (217) 876-7475
E-mail: ted_lindenbusch@dynegy.com

13.06 This Agreement supersedes and cancels all previous understandings, negotiations, representations, and agreements between the parties with respect to the subject thereof, whether oral or written. If Sponsor issues a purchase order or other document purporting to relate to this Agreement, either as an original contract or as an amendment of this Agreement, such document issued by Sponsor shall be considered to be for Sponsor's internal use only, and the provisions contained therein shall not amend this Agreement except as may be expressly agreed to by Contractor in writing. No changes, alterations, or modifications to this Agreement will be effective unless in writing and signed by the parties hereto.

IN WITNESS WHEREOF, the parties have executed this Agreement in duplicate originals which shall be of equal dignity.

DYNEGY MIDWEST GENERATION, INC.		UNIVERSITY OF NORTH DAKOTA ENERGY & ENVIRONMENTAL RESEARCH CENTER	
By	[signature]	By	[signature]
Name	Ted Lindenbusch	Name	Dr. Sally Eckert-Tilotta
Title	Manager, Process Engineering and Chemistry	Title	Interim Director, Office of Research & Program Development
Date	11/27/02	Date	11/16/02

ONTARIOPOWER GENERATION

Services Purchase Order

Purchase Order Number 4400002368

Page: 1

Ship To: See PO Body

Attention:

Bill To: See P.O. Body

Attention:

Issue Date: 2000/04/18
Contract Number:
Required Date:
Effective Date: 2000/04/05
Expiration Date: 2001/11/01

Vendor Number: 1003977
Vendor Name: UNIVERSITY OF NORTH DAKOTA
ENERGY & ENVIRONMENTAL RESE
15 NORTH 23RD ST PO BOX 901
GRAND FORKS ND 58202-9018
USA
Vendor Phone: 701-777-5000
Vendor Fax#: 701-777-5181
Customer Account:
Buyer Name: Michael Dudycz H15D17
Telephone No: 416-592-8114

Delivery: FOB not applicable 700 University Ave
Payment Terms: Net 30 days from date of Invoice

Instruction Notice #2, dated Sept 8, 2000
===
Attn Christopher J Zygarlicke

This instruction notice add item #3 to the contract.

All other terms and conditions remain the same.

ATTN DENNIS L LAUDAL (PROJECT MANAGER)

INSTRUCTION NOTICE #1, 08/04/00
===============================
THE PURPOSE OF THIS INSTRUCTION NOTICE IS TO ADD THE WORK AS PROPOSED IN MEMO DATED JULY 21, 2000.

ALL OTHER TERMS AND CONDITIONS

RE: EERC PROPOSAL No 2000-0103

CONTRACT DOCUMENTS AND ORDER OF PRECEDENCE
==
1. THIS PURCHASE ORDER
2. EERC PROPOSAL No 2000-0103 DATED MARCH 31, 2000

INSTRUCTIONS WILL BE CONTRACTUALLY BINDING ONLY WHEN ISSUED IN WRITING BY SUPPLY MANAGEMENT DIC. OF ONTARIO POWER GENERATION INC. COMMUNICATIONS (VERBAL OR OTHERWISE) FROM OTHER ONTARIO POWER GENERATION DEPARTMENTS WILL NOT BE RECOGNIZED AS CHANGING THE SCOPE, PRICE OR TERMS OF THE CONTRACT.

1.0 PRICING SUMMARY
===============
VALUE OF THIS AWARD WILL NOT EXCEED THE VALUE LISTED IN THE ITEMS OF THIS CONTRACT.

2.0 TERMS OF PAYMENT
================
ONTARIO POWER GENERATION SHALL ACCEPT BILLING FOR 100% OF THE VALUE OF THE WORK. PAYMENT WILL BE MADE WITHIN 30 DAYS OF RECEIPT OF AN ACCEPTABLE INVOICE AND APPROVAL OF THE ENGINEER.

3.0 INVOICES

ONTARIOPOWER GENERATION

Services Purchase Order

Purchase Order Number
4400002268

IMMEDIATELY UPON RECEIPT OF THE PURCHASE ORDER, PLEASE SIGN, DATE AND RETURN THE ATTACHED ACCEPTANCE.

Item	Material	Order Qty	Unit	Price per Unit	Net value USD
00001		1.000	PU	15,000.00	15,000.00

Pilot Scale Evaluation

No GST & No PST

Please deliver according to the following schedule:

Qty.	Unit	Delivery date
1.000	PU	11/01/2000

We require an order acknowledgment for this item

The item covers the following services:
Expected value of unplanned services: 15,000.00

Item	Material	Order Qty	Unit	Price per Unit	Net value USD
00002		1.000	PU	5,400.00	5,400.00

Delivery date 11/01/2000
Evaluation proposal - July 21, 2000

No GST & No PST

The item covers the following services:
Expected value of unplanned services: 5,400.00

Item	Material	Order Qty	Unit	Price per Unit	Net value USD
00003		1.000	PU	40,000.00	40,000.00

Strategic Studies

No GST & No PST

OPGI sponsorship for two year in a collabrative program at a cost of $20,000.00 US dollars per year to determine the mechanism and fundamental causes of SCR catalyst blinding during coal combustion as per EERC proposal No 2000-0071.

Please deliver according to the following schedule:

Qty.	Unit	Delivery date
1.000	PU	12/31/2001

The item covers the following services:
Expected value of unplanned services: 40,000.00

Total net value excl. tax USD 60,400.00

OPG SHIPPING INSTRUCTIONS

NOT APPLICABLE for this purchase order.

The purpose of this amendment is to approve and incorporate Budget Period Three (BP3) task proposals into Attachment A1, Total Authorized Budget Per Task, and revise Attachment F, List of Property -- Participant Acquired. Accordingly, the agreement is amended as follows:

1. Attachment A1, TOTAL AUTHORIZED BUDGET PER TASK, is revised to incorporate the following proposals into BP3.

   Task 3, Proposal No. 1999-0110-R2 (Add-on) - "2000-2001 Gas Industry Groundwater Program;" Budget: $1,140,000 (DOE - $512,965/EERC - $627,035)

   Task 12, Proposal No. 99-0093-A1 (Add-on) - "Bench- and Field-Scale Evaluation of the Use of SVE and Bioventing Procedures to Remediate a Petroleum-Contaminated Site: The Former Circle K, 1001 East Front Street, Butte, Montana;" Budget: $14,686 (DOE - $7,343/EERC - $7,343)

   Task 13, Proposal No. 99-0076-A1 (Add-on) - "Environmental Evaluation for Utilization of Ash in Soil Stabilization;" Budget: $122,600 (DOE - $49,040/EERC - $73,560)

   Task 28, Proposal No. 2000-0103-R1 (Add-on) - "Pilot Scale Evaluation of the impact of Selective Catalytic Reduction for NO_x on Mercury Speciation: Add-on Research;" Budget: $93,050 (DOE - $37,250/EERC - $55,800)

   Task 31, Proposal No. 2000-0071-R1 (New) - "Evaluation of Potential SCR Catalyst Blinding During Coal Combustion;" Budget: $823,333 (DOE - $335,333/EERC - $488,000)

   DOE Task Monitor assignments are as follows: Task 3 and Task 12 - reassigned to Paula Flenory; Task 14 remains Robert Patton, Task 28 remains Richard Read and Task 31 assigned to Anthony Mayne.

2. Attachment A1, TOTAL AUTHORIZED BUDGET PER TASK, is revised to incorporate the following BP3 funding authorizations. The Participant is hereby authorized to utilize the BP3 funds delineated below which have already been obligated to this Cooperative Agreement for performance of project activities.

	Previous Funding Authorizations		BP3 Funding Authorizations		Total Authorizations to Date		
Task	DOE	EERC	DOE	EERC	DOE	EERC	TOTAL
3	231,060	240,820	512,965	627,035	744,025	867,855	1,611,880
12	75,000	75,000	7,343	7,343	82,343	82,343	164,686
13	72,420	106,405	49,040	73,560	121,460	179,965	301,425
28	103,880	155,790	37,250	55,800	141,130	211,590	352,720
31			335,333	488,000	335,333	488,000	823,333
Total			$941,931	$1,251,738			

3. Attachment F, LIST OF PROPERTY -- PARTICIPANT ACQUIRED, is revised to incorporate property being purchased under the Task 3 add-on and new Task 31.

4. All other terms and conditions remain the same and in full force and effect.

END OF AMENDMENT M004

Energy & Environmental Research Center

UNIVERSITY OF NORTH DAKOTA

15 North 23rd Street — PO Box 9018 / Grand Forks, ND 58202-9018 / Phone: (701) 777-5000 Fax: 777-5181
Web Site: www.undeerc.org

December 12, 2000

Ms. Karlene Fine
Executive Director
Industrial Commission of North Dakota
600 East Boulevard
Capitol 10th Floor
Bismarck, ND 58505-0310

Dear Karlene:

Subject: Request to Have Material Designated as Confidential under ND Industrial Commission Contract No. FY00-XXXVI-~~101~~ 100; UND Fund 4869

In performing the project entitled "Evaluation of Potential SCR Catalyst Blinding During Coal Combustion" under subject contract, we will need to obtain SCR catalysts from various vendors. The vendors generally consider certain aspects, for example, the catalyst design and make-up, to be proprietary and required to be kept confidential. In order for us to obtain the catalysts, we must agree to keep certain information in confidence.

Therefore, as directed by Mr. Clifford Porter, I am supplying the information as specified in Subsection 2 of ND Century Code 54-17.5-06, Access to Commission Records, and requesting approval of the Commission to designate the information as "confidential:"

a. "A general description of the nature of the information sought to be protected." The catalyst vendors do not want the formulation and design of their catalyst disclosed. The EERC through the process of the analysis will characterize the catalyst and materials blinding the catalyst. The composition of the catalyst and the design will need to remain confidential. The information on the ash-related materials that blind the catalyst will not be confidential and will be available to project participants.

b. "An explanation of why the information derives independent economic value, actual or potential, from not being generally known to other persons." The formulation and design of the catalyst are unique to each vendor participating in the project. The specific formulations and designs have been developed by the vendor to control NO emissions, and they consider this information confidential since it gives them a competitive edge.

c. "An explanation of why the information is not readily ascertainable by proper means by other persons." This information is held confidential by the catalyst vendor and not available to outside persons.

d. "A general description of any person or entity that may obtain economic value from disclosure or use of the information, and how the person or entity may obtain this value." Another catalyst vendor would obtain economic benefit from disclosure of this information.

e. "A description of the efforts used to maintain the secrecy of the information." All information on the formulation and design of the catalyst will be marked confidential and will be reviewed by the specific catalyst vendor to determine whether or not it should be released or remain confidential.

If the information meets with the Commission's approval, please provide documentation to that effect. If you have any questions, please feel free to contact either Steve Benson, EERC Project Manager, at (701) 777-5177 or me at 777-5124.

Sincerely,

Sheryl E. Landis

Sheryl E. Landis
Manager, Contracts and Intellectual Property
Business and Operations

SEL/slk

c: Clifford Porter, Lignite Energy Council
Steve Benson, EERC
John Hendrikson, EERC

INDUSTRIAL COMMISSION OF NORTH DAKOTA

LIGNITE RESEARCH, DEVELOPMENT AND MARKETING PROGRAM

MEMORANDUM

December 15, 2000

TO: Karlene Fine, Executive Director and Secretary
North Dakota Industrial Commission

FROM: Clifford R. Porter, Director CRP
Lignite Research, Development and Marketing Program

SUBJECT: FY00-XXXVI-100: "Evaluation of Potential SCR Catalyst Blinding During Coal Combustion"; Contractor: Energy & Environmental Research Center; Request to Have Material Designated as Confidential

---

I have reviewed the December 12, 2000 letter (copy attached) from the contractor (Energy & Environmental Research Center) regarding Contract No. FY00-XXXVI-100 for the project titled "Evaluation of Potential SCR Catalyst Blinding During Coal Combustion".

I recommend that the North Dakota Industrial Commission approve the contractor's request to have material designated as confidential under Contract No. FY00-XXXVI-100, as specified in the attached letter from the contractor.

CRP/vg: 24.S.30.A
Attachment

LIGNITE RESEARCH COUNCIL
John Dwyer, Chairman
Clifford Porter, Director & Technical Advisor
P.O. Box 2277
Bismarck, N.D. 58502
(701) 258-7117 (701) 258-2755 Fax

INDUSTRIAL COMMISSION OF NORTH DAKOTA
Karlene Fine
Contracts Officer
600 E. Blvd., State Capitol
Bismarck, N.D. 58505
(701) 328-3722 (701) 328-2820 Fax

Energy & Environmental Research Center

UNIVERSITY OF NORTH DAKOTA

15 North 23rd Street — PO Box 9018 / Grand Forks, ND 58202-9018 / Phone: (701) 777-5000 Fax: 777-5181
Web Site: www.undeerc.org

December 12, 2000

Ms. Karlene Fine
Executive Director
Industrial Commission of North Dakota
600 East Boulevard
Capitol 10th Floor
Bismarck, ND 58505-0310

Dear Karlene:

Subject: Request to Have Material Designated as Confidential under ND Industrial Commission Contract No. FY00-XXXVI-~~101~~ 100; UND Fund 4869

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Sincerely,

Sheryl E Landis

Sheryl E. Landis
Manager, Contracts and Intellectual Property
Business and Operations

SEL/slk

c: Clifford Porter, Lignite Energy Council
Steve Benson, EERC
John Hendrikson, EERC

Cont. 100

Lignite Research, Development & Marketing Program
CONFIDENTIAL Minutes 1999 to 3-1-01

July 30, 1999
It was moved by Attorney General Heitkamp and seconded by Commissioner Johnson that the Industrial Commission meeting be closed to discuss a request for confidentiality pursuant to 54-17.5-06. The motion carried unanimously.

Governor Schafer reconvened the Lignite Research, Development & Marketing Program portion of the meeting.

It was moved by Attorney General Heitkamp and seconded by Commissioner Johnson that the grant application and reports for which a confidentially request was received in relation to the Implementation of Regional Lignite Energy Marketing Plan are determined to be confidential pursuant to 54-17.5-06. The motion carried unanimously.

It was moved by Attorney General Heitkamp and seconded by Commissioner Johnson that the Industrial Commission accept the recommendation of the Lignite Research Council Executive Committee and fund the application "Implementation of Regional Lignite Energy Marketing Plan" submitted by the Lignite Energy Council and to authorize Karlene Fine, Executive Director of the Industrial Commission, to execute a contract for an amount not to exceed $325,000 a year for three years for a total of $975,000 with the conditions as outlined by the Technical Advisor. 98

March 8, 2000
It was moved by Commissioner Johnson and seconded by Attorney General Heitkamp that the Industrial Commission meeting be closed to discuss a request for confidentiality pursuant to 54-17.5-06. The motion carried unanimously.

Being no further non-confidential business, Governor Schafer adjourned this portion of the meeting and the Commission took up confidential Lignite Marketing, Research and Development Program business.

Following the completion of confidential business, Governor Schafer reconvened the non-confidential portion of the meeting.

It was moved by Commissioner Johnson and seconded by Attorney General Heitkamp that the pages 5 through 9 of the Lignite Vision 21 Project – Phase II, Project Marketing and Development grant application and marketing contracts, engineering study results and project financing strategies for which a confidentiality request was received be determined

to be confidential pursuant to 54-17.5-06. The motion carried unanimously.

It was moved by Attorney General Heitkamp and seconded by Commissioner Johnson that the Industrial Commission accept the recommendation of the Lignite Research Council Executive Committee and fund the Lignite Vision 21 Project Phase II Marketing and Development application submitted by the Lignite Energy Council from the marketing (non-matching) funds and to authorize Karlene Fine, Executive Director of the Industrial Commission, to execute a contract for an amount not to exceed $500,000. The motion carried unanimously.

April 20, 2000
It was moved by Commissioner Johnson and seconded by Attorney General Heitkamp that the Industrial Commission meeting be closed to receive a report on Lignite Vision 21 Project – Phase II that had been granted confidentiality pursuant to 54-17.5-06. The motion carried unanimously.

June 2, 2000
It was moved by Attorney General Heitkamp and seconded by Commissioner Johnson that the meeting be closed to receive an update on Lignite Vision 21 Project Phase II which has previously been determined to be confidential pursuant to 54-17.5-06. The motion carried unanimously.

August 24, 2000
It was moved by Commissioner Johnson and seconded by Attorney General Heitkamp that the Industrial Commission meeting be closed to discuss a request for confidentiality pursuant to 54-17.5-06. The motion carried unanimously.

Being no further non-confidential business, Governor Schafer adjourned this portion of the meeting and the Commission took up confidential Lignite Marketing, Research and Development Program business.

Following the completion of confidential business, Governor Schafer reconvened the non-confidential portion of the meeting.

It was moved by Commissioner Johnson and seconded by Attorney General Heitkamp that the partial grant application, studies and reports for which a confidentially request was received in relation to the Lignite Vision 21 Project Phase II Transmission Studies are determined to be confidential pursuant to 54-17.5-06. The motion carried unanimously.

It was moved by Attorney General Heitkamp and seconded by Commissioner Johnson that the Industrial Commission accept the recommendation of the Lignite Research Council Executive Committee and

fund the application "Lignite Vision 21 Project Phase II Transmission Studies" submitted by the Lignite Energy Council; Project Manager Rich Voss in an amount of $140,000 and to authorize Karlene Fine, Executive 104
Director of the Industrial Commission, to execute a contract in an amount not to exceed $140,000 with the conditions as outlined by the Technical Advisor. The motion carried unanimously.

<u>January 29, 2001</u>

It was moved by Commissioner Johnson and seconded by Attorney General Stenehjem that the Industrial Commission pursuant to 54-17.5-06 NDCC approve the confidentiality request of the contractor (Energy & Environmental Research Center) for Contract FY00-XXXVI-100 "Evaluation 100
of Potential SCR Catalyst Blinding During Coal Combustion" and further authorize the Industrial Commission's Executive Director to execute the Non-Disclosure Agreement after consultation with the Attorney General's Office regarding the content in the proposed Non-Disclosure Agreement. The motion carried unanimously.

INDUSTRIAL COMMISSION OF NORTH DAKOTA

October 30, 2001

Ms. Sheryl E. Landis
Manager, Contracts and Intellectual Property
Business and Operations
Energy & Environmental Research Center
P. O. Box 9018
Grand Forks, North Dakota 58202-9018

Dear Sheryl:

This is in response to your letter of December 12, 2000 requesting certain material to be designated as confidential as it relates to North Dakota Industrial Commission Contract No. FY00-XXXVI-100. The Industrial Commission ("Commission") has reviewed your request and has authorized me to sign the following Non-Disclosure Agreement regarding certain material.

<u>Non-Disclosure Agreement</u>

It is the Commission's understanding that the Energy & Environmental Research Center in conducting the research under Contract No. FY00-XXXVI-100 will be receiving catalysts from various vendors. In accordance with North Dakota Century Code 44-04-18.4 and North Dakota Century Code 54-17.5-06 the Commission has found the following to be confidential and not a public record:

The Commission hereby determines as proprietary information and confidential the formulation, composition and design of the venders' catalysts. However, the information on the ash-related materials that blind the catalysts will not be confidential and will be available to project participants. It is further understood that all information on the formulation, composition and design of the catalyst will be marked confidential and will be reviewed by the specific catalyst vendor to determine whether or not it should be released or remain confidential.

If you need anything further from me regarding your request, please give me a call at 701-328-3722.

Sincerely,

Karlene Fine
Executive Director and Secretary
to the Commission

Karlene K. Fine, Executive Director and Secretary
State Capitol, 10th Floor - 600 E Boulevard Ave Dept 405 - Bismarck, ND 58505-0840
E-Mail: kfine@state.nd.us
Phone: (701) 328-3722 FAX: (701) 328-2820
"Your Gateway to North Dakota": discovernd.com

File Contract
100

INDUSTRIAL COMMISSION OF NORTH DAKOTA

John Hoeven
Governor

Wayne Stenehjem
Attorney General

Roger Johnson
Commissioner of Agriculture

TELECOPIER COVER SHEET

PLEASE DELIVER THE FOLLOWING PAGES TO:

NAME: Carmen Miller

LOCATION: A.G. Dixie

DATE: 10/30/01 TELECOPIER NO: ____________

2 PAGES INCLUDING COVER SHEET

****

SENT FROM:

Karlene Fine, Executive Director & Secretary
Industrial Commission of North Dakota
State Capitol, 10th Floor
600 E Boulevard Ave Dept 405
Bismarck, ND 58505-0840
Telephone No. 701-328-3722
Telecopier No. 701-328-2820
e-mail: kfine@state.nd.us

****

MEMORANDUM:

As per my phone message

K

IF YOU DID NOT RECEIVE ALL PAGES-PLEASE CALL SHIRLEY 701-328-3726

October 30, 2001

Ms. Sheryl E. Landis
Manager, Contracts and Intellectual Property
Business and Operations
Energy & Environmental Research Center
P. O. Box 9018
Grand Forks, North Dakota 58202-9018

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Sincerely,

Karlene Fine
Executive Director and Secretary
to the Commission

Energy & Environmental Research Center

FAX TRANSMISSION

EERC Fax Number (701) 777-5181
EERC Fax Operator (701) 777-5274

University of North Dakota, PO Box 9018, Grand Forks, ND 58202-9018; (701) 777-5000

TO:	FROM:
Ms. Karlene Fine Executive Director Industrial Commission of ND	Sheryl E. Landis Manager, Contracts and Intellectual Property EERC Business and Operations PHONE #: (701) 777-5124
FAX: (701) 328-2820	# OF PAGES: 3 DATE: 10-23-01
COUNTRY: USA	FUND NUMBER: 2481

SUBJECT: NDIC Contract No. FY00-XXXVI-100; UND Fund 4869

I'm enclosing another copy of the December 12, 2000 letter request for the NDIC to approve keeping certain information confidential under subject contract. We have previously received input from Clifford Porter that the Industrial Commission had approved this letter request in their January, 2001 meeting.

As we still haven't received the written authorization granting the necessary approval, I would like to suggest another alternative to resolve this outstanding issue. It would be acceptable to us if we could simply have a copy of the minutes from that January Industrial Commission meeting that addressed the issue. In this manner, a formal separate document would not be necessary. Would you be able to fax or mail me those minutes?

I can be reached at (701) 777-5124, via fax 777-5181 or e-mail at slandis@undeerc.org.

I look forward to hearing from you.

IF YOU EXPERIENCE PROBLEMS WITH THIS TRANSMISSION, PLEASE CONTACT THE FAX OPERATOR AT (701) 777-5274.

These sections are to be completed by the person who transmits the fax.	INDIVIDUAL FAXING	TIME OF FAX
	Ciara	9:45

Energy & Environmental Research Center

UNIVERSITY OF NORTH DAKOTA

15 North 23rd Street — PO Box 9018 / Grand Forks, ND 58202-9018 / Phone: (701) 777-5000 Fax: 777-5181
Web Site: www.undeerc.org

December 12, 2000

Ms. Karlene Fine — (701) 328-3722
Executive Director
Industrial Commission of North Dakota
600 East Boulevard
Capitol 10th Floor
Bismarck, ND 58505-0310

Dear Karlene:

Subject: Request to Have Material Designated as Confidential under ND Industrial Commission Contract No. FY00-XXXVI-101, UND Fund 4869

In performing the project entitled "Evaluation of Potential SCR Catalyst Blinding During Coal Combustion" under subject contract, we will need to obtain SCR catalysts from various vendors. The vendors generally consider certain aspects, for example, the catalyst design and make-up, to be proprietary and required to be kept confidential. In order for us to obtain the catalysts, we must agree to keep certain information in confidence.

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Sincerely,

Sheryl E. Landis

Sheryl E. Landis
Manager, Contracts and Intellectual Property
Business and Operations

SEL/slk

c: Clifford Porter, Lignite Energy Council
Steve Benson, EERC
John Hendrikson, EERC

Fine, Karlene K.

From: Clifford Porter [cporter@lignite.com]
Sent: Tuesday, December 05, 2000 2:15 PM
To: Karlene Fine (E-mail)
Subject: FW: Addendum to SCR Catalyst Non-Disclosure Agreement

Addendum to SCT Catalyst Blind...

I need some direction and help with this non-disclosure item.

Thanks

Clifford

-----Original Message-----
From: Moore, Kathryn R. [mailto:MooreKR@Cormetech.com]
Sent: Tuesday, December 05, 2000 1:58 PM
To: 'tgraumann@otpco.com'; 'kenneth_b_stuckmeyer@ameren.com'; 'blair.seckington@ontariopowergeneration.com'; 'sbenson@eerc.und.nodak.edu'; 'cporter@lignite.com'; 'edmundovasquez@alliant-energy.com'; 'doconnor@epri.com'; 'ted_lindenbusch@dynegy.com'; 'feeley@netl.doe.gov'
Cc: Iskandar, Reda S.
Subject: Addendum to SCR Catalyst Non-Disclosure Agreement

On November 17th, 2000 we emailed you a Non-Disclosure Agreement pertaining to the SCR Catalyst Blinding Test. This document is meant to serve as clarification that only the members within the study may discuss findings, etc. among each other and that there is to be no discussions, etc. with regards to this test with anyone outside this group.

It has come to our attention that our Non-Disclosure Agreement was not developed to use in a "multi-faceted" fashion. Therefore, we have attached an addendum to our Non-Disclosure, so as to clarify that everyone would be aware of the other parties involved in the est and that discussions could take place between these members, but no discussions outside the group will be allowed.

Attached is an addendum to be added to the original email sent to you on November 17th. Please print 2 copies, attaching one to each of the 2 Non-Disclosure Agreements you previously received. Once you have signed, please return to Kathryn R. Moore.

Thank you for your understanding and patience.

Kathryn R. Moore
Executive Assistant to the President/CEO
CORMETECH, Inc.
5000 International Drive
Durham, NC 27712
(919)620-3058
<<Addendum to SCT Catalyst Blinding.doc>>

ADDENDUM TO
NON-DISCLOSURE AGREEMENT

BETWEEN

PARTICIPANTS OF SCR CATALYST BLINDING TEST

AND

CORMETECH, INC.

The names and companies listed below are participants in the SCR Catalyst Blinding Test and a part of contemplated discussions between personnel of ("Cormetech") Inc. and each other.

Ontario Power Generation	Blair Seckington
Ottertail Power Company	Terry Garumann
Ontario Power Technologies	Rene Mangal
EPRI	Dave O'Connor
AmerenUE	Ken Stuckmeyer
Alliant Energy	Ednumdo Vasquez
Cormetech, Inc.	Reda Iskandar
North Dakota Industrial Commission, Lignite Energy Council	Cliff Porter
US DOE NETL	Thomas Feeley
EERC	Chris Zygarlicke
EERC	Steve Benson
EERC	Jay Gunderson
EERC	Don Toman
EERC	Jason Laumb
Dyneg	Ted Lindenbusch

In view of contemplated discussions between personnel of Cormetech, Inc. ("Cormetech") and Participants Of SCR Catalyst Blinding Test, and the fact that product samples, specifications, process techniques, composition data, equipment designs, or other types of information may be submitted to Participants of SCR Catalyst Blinding Test to enable the latter to conduct evaluations and tests on Cormetech SCR catalysts, which materials or samples, specifications, process techniques, composition data, equipment designs and other types of information, all of which, including without limitation the results of such evaluations and tests, shall be deemed to constitute proprietary information of Cormetech ("INFORMATION"). The purpose of this Addendum is to acknowledge and recognize the actual parties involved in this Agreement.

AGREED AND ACCEPTED:

NAME OF COMPANY	**CORMETECH, INC.**
By ____________________	By ____________________
Name __________________	Name __________________
Title __________________	Title __________________

Energy & Environmental Research Center

UNIVERSITY OF NORTH DAKOTA

15 North 23rd Street — PO Box 9018 / Grand Forks, ND 58202-9018 / Phone: (701) 777-5000 Fax: 777-5181
Web Site: www.undeerc.org

Attachment 4

December 12, 2000

Ms. Karlene Fine
Executive Director
Industrial Commission of North Dakota
600 East Boulevard
Capitol 10th Floor
Bismarck, ND 58505-0310

Dear Karlene:

Subject: Request to Have Material Designated as Confidential under ND Industrial Commission Contract No. FY00-XXXVI-100, UND Fund 4869

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Sincerely,

Sheryl E. Landis

Sheryl E. Landis
Manager, Contracts and Intellectual Property
Business and Operations

SEL/slk

c: Clifford Porter, Lignite Energy Council
Steve Benson, EERC
John Hendrikson, EERC

INDUSTRIAL COMMISSION OF NORTH DAKOTA

LIGNITE RESEARCH, DEVELOPMENT AND MARKETING PROGRAM

this needs to go to IC mtg 1/18/01

MEMORANDUM
December 15, 2000

TO: Karlene Fine, Executive Director and Secretary
North Dakota Industrial Commission

FROM: Clifford R. Porter, Director CRP
Lignite Research, Development and Marketing Program

SUBJECT: FY00-XXXVI-100: "Evaluation of Potential SCR Catalyst Blinding During Coal Combustion"; Contractor: Energy & Environmental Research Center; Request to Have Material Designated as Confidential

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CRP/vg: 24.S.30.A
Attachment

LIGNITE RESEARCH COUNCIL
John Dwyer, Chairman
Clifford Porter, Director & Technical Advisor
P.O. Box 2277
Bismarck, N.D. 58502
(701) 258-7117 (701) 258-2755 Fax

INDUSTRIAL COMMISSION OF NORTH DAKOTA
Karlene Fine
Contracts Officer
600 E. Blvd., State Capitol
Bismarck, N.D. 58505
(701) 328-3722 (701) 328-2820 Fax

Energy &
Environmental
Research
Center

UNIVERSITY OF NORTH DAKOTA

15 North 23rd Street — PO Box 9018 / Grand Forks, ND 58202-9018 / Phone: (701) 777-5000 Fax: 777-5181
Web Site: www.undeerc.org

December 12, 2000

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Executive Director
Industrial Commission of North Dakota
600 East Boulevard
Capitol 10th Floor
Bismarck, ND 58505-0310

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Sincerely,

Sheryl E Landis

Sheryl E. Landis
Manager, Contracts and Intellectual Property
Business and Operations

SEL/slk

c: Clifford Porter, Lignite Energy Council
Steve Benson, EERC
John Hendrikson, EERC

Fine, Karlene K.

From: Clifford Porter [cporter@lignite.com]
Sent: Monday, November 20, 2000 1:11 PM
To: Karlene Fine (E-mail)
Subject: FW: SCR Catalyst Blinding Test

NDakota Industrial Commission....

Karlene I have attached a copy of the Cormetech Non-disclosure agreement. I think we should hold this until we receive a letter from EERC and then review the document in that context. Generally, I think this is a reasonable request. However, the request should reflect the NDCC statute and the request from EERC.

Thanks

Clifford

-----Original Message-----
From: Moore, Kathryn R. [mailto:MooreKR@Cormetech.com]
Sent: Monday, November 20, 2000 12:40 PM
To: 'cporter@lignite.com'
Subject: RE: SCR Catalyst Blinding Test

Clifford,

Please find attached a corrected non-disclosure document, relative to only N. Dakota Industrial Commission.

Please accept my apologies for this error.

Thank you.

Kathy Moore

-----Original Message-----
From: Clifford Porter [mailto:cporter@lignite.com]
Sent: Monday, November 20, 2000 9:19 AM
To: 'Moore, Kathryn R.'
Cc: Chris J. Zygarlicke (E-mail); Steve Benson Ph. D. (E-mail)
Subject: RE: SCR Catalyst Blinding Test

Kathryn R. Moore:
The Non-disclosure Agreement should be between Cormetech, Inc. and the North Dakota Industrial Commission (Commission). The Lignite Energy Council (LEC) is not a party to the study. The North Dakota Industrial Commission is a North Dakota State Agency consisting of the Governor, Attorney General and Commissioner of Agriculture. The Commission approves funding for lignite research project through the North Dakota Lignite Research, Development and Marketing Program (Program). The Commission has approved $200,000 for the "Evaluation of Potential SCR Catalyst Blinding During Coal Combustion".

I spoke with Chris Zygarlicke and explained the process for obtaining confidentiality. The Commission has the authority to grant request for confidentiality. I don't see this as a problem. Chris or I will keep you posted.

Regards

Clifford

-----Original Message-----
From: Moore, Kathryn R. [mailto:MooreKR@Cormetech.com]
Sent: Friday, November 17, 2000 3:20 PM
To: 'cporter@lignite.com'
Subject: SCR Catalyst Blinding Test

<<NDakota Execution Letter.doc>> <<NDakota Industrial Commission.doc>>

Fine, Karlene K.

To: cporter@lignite.com
Subject: RE: Non-Disclosures

Clifford--I can't remember if I talked to you about this or not. I got your memo recommending that we grant the confidentiality. I think we need to take this to the IC as they are the only ones that can make reports confidential. I have tentatively put this on the tentative IC meeting date of January 18. Karlene

-----Original Message-----
From: Clifford Porter [mailto:cporter@lignite.com]
Sent: Monday, December 11, 2000 10:59 AM
To: Karlene Fine (E-mail)
Subject: Non-Disclosures

I sent you a copy of proposed non-disclosure documents for Project 100. I need some guidance on this request. I think it is appropriate to grant the request to hold the information confidential. How should we proceed?

Thanks

Clifford

Clifford R. Porter
Director of Research & Development
Lignite Energy Council
Technical Advisor
Lignite Research Council
Director
Lignite Research, Development & Marketing Program
1016 E. Owens Avenue, Suite 200
P.O. Box 2277
Bismarck, ND 58502-
701-258-7117 (O)
701-220-1117 (cell)
701-258-2755 (fax)
cporter@lignite.com
<http://www.lignite.com/>
<http://www.state.nd.us/ndic/#Lignite>
http://www.lignitevision21.com

INDUSTRIAL COMMISSION OF NORTH DAKOTA

John Hoeven	Wayne Stenehjem	Roger Johnson
Governor	Attorney General	Commissioner of Agriculture

TELECOPIER COVER SHEET

PLEASE DELIVER THE FOLLOWING PAGES TO:

NAME: Carmen Miller

LOCATION: A.G. Office

DATE: 3/13/01 TELECOPIER NO: __________

_____ PAGES INCLUDING COVER SHEET

****

SENT FROM:

Karlene Fine, Executive Director & Secretary
Industrial Commission of North Dakota
State Capitol, 10th Floor
600 E Boulevard Ave Dept 405
Bismarck, ND 58505-0840
Telephone No. 701-328-3722
Telecopier No. 701-328-2820
e-mail: kfine@state.nd.us

****

MEMORANDUM:

I've had this on my desk for over 6 weeks but now I need to finalize. The Commission did pass a motion granting confidentiality on this project but before I sign this agreement I would like you to review. Please let me know if I can sign by

IF YOU DID NOT RECEIVE ALL PAGES-PLEASE CALL SHIRLEY 701-328-3726

the end of the week. Thanks Karlene

Fine, Karlene K.

From: Pat Fricke [PFricke@ndhfa.org]
Sent: Monday, October 29, 2001 4:13 PM
To: John Hoeven (E-mail); Roger Johnson (E-mail); Wayne Stenehjem (E-mail)
Cc: Karlene Fine (E-mail); John Fox (E-mail); Maurice Cook (E-mail)
Subject: NDHFA Housing Bond-IRS Rebate

During the last IC meeting the question was raised as to whether the HFA is taking steps to minimize rebate liability (payments) to the IRS on our various housing bond issues. My initial response was correct (but needed confirmation/clarification). Finance team member comments were requested and are included herein.

In general, there are two types of rebate liability that NDHFA could accrue. The first is "purpose" rebate that relates to any excess spread between the yield on our mortgage loans and the yield on our bonds. As the Agency establishes its mortgage rates to be within (i.e. under) the permissible 1.125% earnings spread, the Agency does not generate any "purpose" rebate on its issues. To avoid rebate and stay within Mortgage yield imitations for Purpose Investments, we use several techniques such as blending loan interest rates within the bond series pool, creation of 0% loan participations, and offer targeted borrower programs (HomeKey, Community Lenders, Start, Habitat for Humanity, etc.). We did opt for "Mortgage Forgiveness" on early 1980's issues, however, that created an accounting challenge which could last until the loans of those series are retired (possibly 30 years).

The other type of rebate liability relates to "Non-Purpose Investments" that includes investment income on debt service reserves funds, float funds, and acquisition funds. In general, any earnings on these funds in excess of the calculated bond yield must be paid to the Federal Government. Section 148 of the Code specifically requires positive arbitrage on non-purpose investments to be paid to IRS on 5 year anniversaries. Unlike "Purpose" excess interest earnings, there is no alternative to making these IRS payments.

Please advise if you desire any additional info.

Pat Fricke

ADDENDUM TO
NON-DISCLOSURE AGREEMENT

BETWEEN

PARTICIPANTS OF SCR CATALYST BLINDING TEST

AND

CORMETECH, INC.

The names and companies listed below are participants in the SCR Catalyst Blinding Test and a part of contemplated discussions between personnel of ("Cormetech") Inc. and each other.

Ontario Power Generation	Blair Seckington
Ottertail Power Company	Terry Garumann
Ontario Power Technologies	Rene Mangal
EPRI	Dave O'Connor
AmerenUE	Ken Stuckmeyer
Alliant Energy	Ednumdo Vasquez
Cormetech, Inc.	Reda Iskandar
North Dakota Industrial Commission, Lignite Energy Council	Cliff Porter
US DOE NETL	Thomas Feeley
EERC	Chris Zygarlicke
EERC	Steve Benson
EERC	Jay Gunderson
EERC	Don Toman
EERC	Jason Laumb
Dyneg	Ted Lindenbusch

In view of contemplated discussions between personnel of Cormetech, Inc. ("Cormetech") and Participants Of SCR Catalyst Blinding Test, and the fact that product samples, specifications, process techniques, composition data, equipment designs, or other types of information may be submitted to Participants of SCR Catalyst Blinding Test to enable the latter to conduct evaluations and tests on Cormetech SCR catalysts, which materials or samples, specifications, process techniques, composition data, equipment designs and other types of information, all of which, including without limitation the results of such evaluations and tests, shall be deemed to constitute proprietary information of Cormetech ("INFORMATION"). The purpose of this Addendum is to acknowledge and recognize the actual parties involved in this Agreement.

AGREED AND ACCEPTED:

NAME OF COMPANY	**CORMETECH, INC.**
By ______________________	By ______________________
Name ______________________	Name ______________________
Title ______________________	Title ______________________

NON-DISCLOSURE AGREEMENT

BETWEEN

NORTH DAKOTA INDUSTRIAL COMMISSION

AND

CORMETECH, INC.

In view of contemplated discussions between personnel of Cormetech, Inc. ("Cormetech") and North Dakota Industrial Commission and the fact that product samples, specifications, process techniques, composition data, equipment designs, or other types of information may be submitted to North Dakota Industrial Commission to enable the latter to conduct evaluations and tests on Cormetech SCR catalysts, which materials or samples, specifications, process techniques, composition data, equipment designs and other types of information, all of which, including without limitation the results of such evaluations and tests, shall be deemed to constitute proprietary information of Cormetech ("INFORMATION"). The purpose of this Agreement is to obtain acknowledgment by North Dakota Industrial Commission concerning the treatment that is to be accorded to such INFORMATION. INFORMATION shall be marked proprietary or, if provided orally or visually except for samples of Cormetech SCR catalysts, will be described in a writing or other tangible from within thirty (30) days of disclosure.

(1) It is understood and agreed that INFORMATION, which may, from time-to-time be made available to North Dakota Industrial Commission is to be treated as confidential from the date of each disclosure. INFORMATION is to be used solely in connection with the evaluation to be conducted by North Dakota Industrial Commission for this agreed upon purpose and is not to be disclosed to persons other than personnel having a clear and reasonable need for access in connection with said evaluation. North Dakota Industrial Commission shall treat INFORMATION received from Cormetech as confidential by taking reasonable precautions in accordance with procedure yfollows to prevent disclosure of its own confidential information of like importance; shall not disclose INFORMATION, directly of indirectly, to any third party without Cormetech's written permission; and shall not use any of the INFORMATION except for evaluation. All INFORMATION shall be returned to Cormetech upon its request or when the need therefore terminates; provided, however, that the above requirements shall not apply to any INFORMATION which:

(a) is now, or which hereafter, through no act or failure to act on the part of North Dakota Industrial Commission becomes within the knowledge of the general public;

(b) is known by North Dakota Industrial Commission at the time of receiving such INFORMATION as can be supported by competent evidence;

(c) is hereafter furnished to North Dakota Industrial Commission by a third party as a matter of right and without restriction on disclosure. Catalyst materials manufactured by Cormetech are restricted from any test or disclosure by North Dakota Industrial Commission except as expressly authorized by Cormetech.

(d) is independently developed by North Dakota Industrial Commission and can be proven by competent evidence.

(e) is required to be disclosed by North Dakota Industrial Commission pursuant to a court or government order provided North Dakota Industrial Commission first notifies Cormetech in time to seek an appropriate protective order or other confidential protection.

(2) North Dakota Industrial Commission also agrees that it will not make any commercial use, in whole or in part, of any INFORMATION received from Cormetech without the prior written consent of Cormetech.

(3) Title to the above-described materials or samples provided by Cormetech hereunder, including without limitation those for test and evaluation, shall remain in Cormetech and such portions of such samples as are not consumed to an unrecoverable state in the course of the above-described testing and evaluation shall be disposed of by North Dakota Industrial Commission safely and in accordance with all Federal and State laws, as agreed by Cormetech.

(4) North Dakota Industrial Commission will (i) disclose in writing to Cormetech the types of and results of its evaluations or tests (including any composition analyses) of Cormetech materials or samples (including without limitation catalysts or products); (ii) not disclose the results of such test or evaluations to the public or third parties or use such results for any purpose other than as described above, without Cormetech's written consent; and (iii) otherwise treat the results of such tests, evaluations, and analyses as INFORMATION hereunder.

(5) The period for disclosure of INFORMATION under this Agreement begins on the effective Date and ends two (2) years thereafter. All obligations of confidentiality, limited use and nondisclosure hereunder with respect to any item of INFORMATION expires ten (10) years from the Effective Date of this Agreement. The "Effective Date" means the date of signature below by the last party to sign this Agreement.

(6) This Agreement shall be construed and interpreted according to the laws of the State of New York, not including, however, rules relating to choice or conflict of laws.

This Agreement is being submitted in duplicate. Please return one (1) copy, after being executed by an authorized representative, as an acknowledgment of the treatment to be accorded INFORMATION.

ACCEPTED AND AGREED:

NORTH DAKOTA INDUSTRIAL COMMISSION	**CORMETECH, INC.**
By__________________________	By__________________________
Name_______________________	Name_______________________
Title________________________	Title________________________
Date________________________	Date________________________

Fine, Karlene K.

From: Fine, Karlene K.
Sent: Tuesday, December 26, 2000 11:16 AM
To: 'cporter@lignite.com'
Subject: RE: Non-Disclosures

Clifford--I can't remember if I talked to you about this or not. I got your memo recommending that we grant the confidentiality. I think we need to take this to the IC as they are the only ones that can make reports confidential. I have tentatively put this on the tentative IC meeting date of January 18. Karlene

-----Original Message-----
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Sent: Monday, December 11, 2000 10:59 AM
To: Karlene Fine (E-mail)
Subject: Non-Disclosures

I sent you a copy of proposed non-disclosure documents for Project 100.
I
need some guidance on this request. I think it is appropriate to grant
the
request to hold the information confidential. How should we proceed?

Thanks

Clifford

Clifford R. Porter
Director of Research & Development
Lignite Energy Council
Technical Advisor
Lignite Research Council
Director
Lignite Research, Development & Marketing Program
1016 E. Owens Avenue, Suite 200
P.O. Box 2277
Bismarck, ND 58502-
701-258-7117 (O)
701-220-1117 (cell)
701-258-2755 (fax)
cporter@lignite.com
<http://www.lignite.com/>
<http://www.state.nd.us/ndic/#Lignite>
http://www.lignitevision21.com

NON-DISCLOSURE AGREEMENT
BETWEEN
NORTH DAKOTA INDUSTRIAL COMMISSION
AND
CORMETECH, INC.

In view of contemplated discussions between personnel of Cormetech, Inc. ("Cormetech") and the North Dakota Industrial Commission and the fact that product samples, specifications, process techniques, composition data, equipment designs, or other types of information may be submitted to the North Dakota Industrial Commission to enable the Commission to conduct evaluations and tests on Cormetech SCR catalysts, which materials or samples, specifications, process techniques, composition data, equipment designs and other types of information, all of which, ~~including without limitation the results of such evaluations and tests,~~ shall be deemed to constitute proprietary information of Cormetech ("INFORMATION"). The purpose of this Agreement is to obtain acknowledgment by the North Dakota Industrial Commission concerning the treatment that is to be accorded to such INFORMATION. INFORMATION shall be marked proprietary or, if provided orally or visually except for samples of Cormetech SCR catalysts, will be described in writing or other tangible form within thirty (30) days of disclosure to the Commission.

In accordance with North Dakota Century Code 44-04-18.4 and North Dakota Century Code 54-17.5-06, the North Dakota Industrial Commission has found the INFORMATION to be confidential and not a public record.

(1) It is understood and agreed that INFORMATION, which may, from time-to-time be made available to the North Dakota Industrial Commission is to be treated as confidential from the date of each disclosure. INFORMATION is to be used solely in connection with the evaluation to be conducted by the North Dakota Industrial Commission for this agreed upon purpose and is not to be disclosed to persons other than personnel having a clear and reasonable need for access in connection with said evaluation. The North Dakota Industrial Commission shall treat INFORMATION received from Cormetech as confidential by taking reasonable precautions in accordance with procedures the Commission follows to prevent disclosure of its own confidential information of like importance; shall not disclose INFORMATION, directly or indirectly, to any third party without Cormetech's written permission; and shall not use any of the INFORMATION except for evaluation.

(2) The North Dakota Industrial Commission also agrees that it will not make any commercial use, in whole or in part, of any INFORMATION received from Cormetech without the prior written consent of Cormetech.

(3) Title to the above-described materials or samples provided by Cormetech hereunder, including without limitation those for test and evaluation, shall remain in Cormetech and such portions of such samples as are not consumed to an unrecoverable state in the course of the above-described testing and evaluation shall be disposed of by the North Dakotas Industrial Commission safely and in accordance with all Federal and State laws, as agreed by Cormetech.

(4) The North Dakota Industrial Commission will (i) disclose in writing to Cormetech the types of and results of its evaluations or tests (including any composition analyses) of Cormetech materials or samples (including without limitation catalysts or products); (ii) not disclose the results of such test or evaluations to the public or third parties or use such results for any purpose other than as described above, without Cormetech's written consent; (iii) otherwise treat the results of such tests, evaluations, and analyses as INFORMATION hereunder and (iv) disclose information on the ash-related materials that blind the catalyst ~~will be made~~ to the public.

(5) The period for disclosure of INFORMATION under this Agreement begins on the effective Date and ends two (2) years thereafter. All obligations of confidentiality, limited use and nondisclosure hereunder with respect to any item of INFORMATION expires ten (10) years from the Effective date of this Agreement. The "Effective Date" means the date of signature below by the last party to sign this Agreement.

(6) This Agreement shall be construed and interpreted according to the laws of the State of North Dakota.

This Agreement is being submitted in duplicate. Please return one (1) copy, after being executed by an authorized representative, as an acknowledgment of the treatment to be accorded INFORMATION.

ACCEPTED AND AGREED:

North Dakota Industrial Commission

By ______________________________
Name: Karlene Fine
Title: Contracts Officer
Date: October 30, 2001

Cormetech, Inc.

By: ______________________
Name: ______________________
Title: ______________________
Date: ______________________

FY00-XXXVI-100
EVALUATION OF POTENTIAL SCR CATALYST BLINDING DURING COAL COMBUSTION

CONTRACTOR: Energy & Environmental Research Center

PRINCIPAL INVESTIGATOR: Steven A. Benson, Ph.D.
701-777-5177 (O)
701-777-5181 (FAX)
sbenson@undeerc.org

PARTICIPANTS

Sponsors	Cost Share
Department of Energy (EERC/JSR/DOE)	$335,333
Industry:	$240,000
Alliant Energy	
EPRI	
Otter Tail Power Company	
Dynegy Midwest Generation	
Ontario Power Generation	
Ameren UE	
ND Industrial Commission	$200,000
Total Project Costs	$775,333

Project Schedule – 30 Months
Contract Date – 3/17/2000
Start Date – 3/17/2000
Completion Date – 3/31/2003
Time Extension – 6-30-04

Project Deliverables
Status Reports – 12/31/00√
3/30/01√; 6/30/01√; 9/30/01√
12/30/01√; 3/30/02√; 6/30/02√
3/31/03√; 6/30/03 √ ; 9/30/03√
Final Report – 6/30/04_√__

OBJECTIVE / STATEMENT OF WORK

The primary goal of this project is to determine the potential of low-rank coal ash to cause blinding or masking of selective catalytic reduction (SCR) catalysts and to determine the degree of elemental mercury conversion across the catalyst. Specific objectives include: 1) identify candidate coals and blends for testing under bench-scale conditions; 2) conduct bench-scale testing to screen coals and identify key conditions for testing at the full scale; 3) design and construct a SCR slipstream test chamber for sampling at full-scale facilities; 4) conduct testing at full-scale facilities; 5) identify SCR blinding mechanisms, rates, and cleaning methods as well as mercury conversion efficiencies; 6) interpret data, prepare a report, and 7) conduct sponsor meetings to develop recommendation to extend catalyst life and efficiency.

STATUS

Installation at Baldwin Station – The report from Haldor Topsoe on the reactivity of the 2-month sample from Baldwin was received. The analysis showed no loss of activity. The 4-month sample was also removed. Similar sulfate-rich materials were observed as in the previous sample. The sample has been submitted to Haldor Topsoe for the same analysis.

Installation at Columbia Station – All of the reactor parts have been delivered and are approximately 60% installed. We are awaiting a permit from the Wisconsin DNR to finish the project. The DNR is well beyond the 45-day period in which they were supposed to respond to the request from Alliant Energy. We expect the DNR to act very soon.

Installation at Coyote Station – EERC personnel have been in contact with the people at Otter Tail Power to arrange for the installation of the nozzle at this plant. Bland flanges have been installed at the reactor inlet and outlet. The nozzle will be inserted when the reactor is ready to be installed. The reactor installation will be completed when the testing at the Baldwin Station is complete. The testing at Baldwin will be completed in mid July.

July 1 – September 30, 2002 Quarterly Report

Testing at the Baldwin Station was completed this quarter. The sample from this testing will be retrieved when the reactor is dismantled. Plans are being made to dismantle the reactor and move it to the Coyote Station in the next month. The reactivity testing on the 4-month sample should be received soon from Haldor Topsoe.

Columbia Station activities. The permit for the Wisconsin Department of Natural Resources was finally received late this quarter and installation of the reactor was completed.

Coyote Station activities. Otter Tail Power has begun arrangements for installation of the slip-stream reactor. The reactor at the Baldwin Station will be moved to the Coyote Station during the first quarter of 2003.

Oct – Dec, 2002
The reactor at Baldwin will be moved to the Coyote Station during the next quarter. The installation at Columbia will also be completed.

The Coyote plant has a scheduled outage in March, 2003. The slipstream SCR test unit will be installed during the outage; testing will begin when the plant is put back in service. In addition to the objective of the SCR slipstream test program, an overlay project will address oxidation of elemental mercury to ionic mercury due to the SCR unit. Previous tests have shown significant reduction of the reaction in lignite-derive flue gas. The SCR catalyst have also been degraded. The overlay project will document these reactions over a six-month time frame.

Jan-Mar, 2003
The reactor at the Baldwin Station has been removed and shipped to EERC for routine maintenance prior to installation at the Coyote Station in May, 2003.

Installation of the reactor installed at the Columbia station has been completed and has logged 477 hours of on-line results. No major indications of plugging have been observed to date.

Summary: In August of 2003, a pilot-scale SCR reactor was installed at Coyote Station, a nominal 420-megawatt lignite-fired generating facility that is located near Beulah, North Dakota. The installation was in conjunction with a study entitled "Impact of SCR Catalyst on Mercury Oxidation in Lignite-Fired Combustion Systems" that is being conducted by the Energy and Environmental Research Center. One goal of the SCR project was to determine the ability of new and aged catalyst to oxidize mercury at full-scale power plants. The researchers have found that the SCR technology was not effective in oxidizing mercury and that the sulfation of calcium and sodium ash deposits foul the catalyst rendering the SCR technology ineffective for NOx control. A paper describing the research and findings has been submitted for peer review and publication in *Fuel Processing Technology*.

FY00-XXXVI-100

Name of Project: Evaluation of Potential SCR Catalyst Blinding During Coal Combustion

Contact Person: Jay Gunderson

Mailing Address: Energy & Environmental Research Center
15 North 23rd Street
PO Box 9018
Grand Forks ND 58202-9018

Phone: (701) 777-5000 Fax: (701) 777-5181 Total Grant Awarded: **$200,000**

Date Industrial Commission Approved: 3-8-00

Date Contract Signed: 3-17-00 Industrial Commission ____________ Project

---

Payment Schedule:	Amount:	Date Paid	Check #
Execution (conditions)	$21,250.00	3-14-01	15356
10/31/00 - 12/31/00	$22,500.00	3-14-01	15356
1/30/01 - 3/30/01	$22,500.00	6-7-01	15663
4/30/01 - 6/30/01	$22,500.00	8-16-01	15906
7/30/01 - 9/30/01	$22,500.00	11-5-01	16223
10/30/01 - 12/30/01	$22,500.00	3-21-02	16615
1/30/02 - 3/30/02	$22,500.00	6-10-02	16986
4/30/02 - 6/30/02	$22,500.00	8-15-02	17167
~~9/30/02~~ ~~12-31-03~~	$21,250.00	12-9-04	8000204

Report Due: 6-30-04	Date Due	Date Received
	2-·	
Final		

Comments:
quarterly status reports (7)
extension request
addendum

Returned
$ 49.43
3-8-05

100

UNIVERSITY OF UND NORTH DAKOTA

GRANTS AND CONTRACTS ADMINISTRATION
DIVISION OF RESEARCH
P.O. BOX 7306
GRAND FORKS, NORTH DAKOTA 58202-7306
(701) 777-4151
FAX (701) 777-2504

March 8, 2005

Industrial Commission of North Dakota
Attn: Karlene Fine
State Capitol 14th Floor
600 E Boulevard Ave Dept. 405
Bismarck, ND 58505-0840

RE: Return of Credit Balance for NDIC Contract s FY00-XXXVI-100 and FY03-XLIX-119

Enclosed are two checks made out to the Industrial Commission of North Dakota. One is in the amount of $49.43 for NDIC Contract No. FY00-XXXVI-100 (UND Project UND0004869) and the other in the amount of $202.56 for NDIC contract FY03-XLIX-119 (UND Project UND0004951). These are the cash balances remaining at the end of these cost reimbursable agreements.

If you have any questions or concerns, please contact Wayde Anderson at (701) 777-6739.

Sincerely,

Wayde Anderson

Wayde Anderson
Grants and Contracts Officer

Encl

cc:

Deb Johnson, EERC Accounting

Check Date: Mar/07/2005		Vendor Number: 0000000248				Check No. 005713
Invoice Number	**Invoice Date**	**Voucher ID**	**Gross Amount**	**Discount Taken**	**Late Charge**	**Paid Amount**
24819T	Mar/07/2005	24819T	202.56	0.00	0.00	202.56

Wagle 7-6739
Grants

Check Number	Date	Total Gross Amount	Total Discounts	Total Late Charges	Total Paid Amount
005713	Mar/07/2005	$202.56	$0.00	$0.00	$202.56

UNIVERSITY OF NORTH DAKOTA
264 CENTENNIAL DRIVE
GRAND FORKS, ND 58202-8370

BANK OF NORTH DAKOTA
700 EAST MAIN AVENUE
BISMARCK, ND 58506-5509

77-28/0913

005713

Date 03/07/2005 **Pay Amount** **$202.56*****

Pay ****TWO HUNDRED TWO AND 56 / 100 DOLLAR****

To The Order Of
INDUSTRIAL COMMISSION,ND
STATE CAPITAL 10TH FLOOR
600 EAST BOULEVARD AVENUE DPT 405
BISMARCK, ND 58505-0840

Robert C. Gallager
Authorized Signature

⑈005713⑈ ⑆091300285⑆ 05⑉20⑉727⑈

Contract No. FY00-XXXVI-100

This contract is between the State of North Dakota acting by and through its Industrial Commission, hereafter called Commission, and Energy & Environmental Research Center (EERC), hereafter called Contractor.

1. Retirement System Status
   Contractor will be responsible for any federal or state taxes applicable to this grant made under this contract. Contractor will not be eligible for any benefits from these contract payments of federal Social Security, unemployment insurance, worker's compensation, or the Public Employees' Retirement System. Contractor is an independent contractor, and neither it nor its employees, agents, and representatives are employees of the Industrial Commission.

2. Statement of Work
   a. Contractor agrees to accomplish the following work under this contract: The statement of work to be accomplished is contained in Corrected Exhibit A, entitled "Evaluation of Potential SCR Catalyst Blinding During Coal Combustion" which is attached to this contract and is made a part of it. In addition the Contractor agrees to include testing with North Dakota lignite (which is noted in the "Corrected" Exhibit A).

   b. Contractor agrees to provide quarterly interim reports (every three months) for 24 months with a final comprehensive report following the final quarter of this project:

      The Final Report shall be in compliance with 43-03-05-08 of the North Dakota Administrative Code. Specifically, the Final Report must include a single page project summary describing the purpose of the project, the work accomplished, the project's results, and the potential applications of the project. The Final Report must provide documentation verifying the receipt of the private matching funds.

3. Consideration
   a. Commission agrees to grant to Contractor an amount not to exceed the sum of $200,000.00 for accomplishment of the work contingent upon the Contractor providing industry matching funding letters of commitment totaling $200,000.00 (exclusive of the contribution by a German vendor) by September 1, 2000 and a commitment from DOE of $293,333.00.

   b. The Commission will transfer the $200,000.00 to the Contractor by interim payments. Payments shall be made according to the following schedule:

Upon execution of the contract and written confirmation that the Contractor has received commitment letters by 9/1/00 for industry matching funding totaling $200,000.00 and a commitment from the EERC-DOE JSRP of $293,333.00	$21,250.00
Upon receipt and consideration of each quarterly report (7)	$22,500.00 each
Upon receipt of the Final Report	$21,250.00

   c. Should the Commission, upon consideration of a Report, believe that the Report is inadequate or that the Contractor is not complying with the statement of work or satisfactorily carrying out the work, the Commission may withhold all or part of a scheduled payment until the Contractor, in the opinion of the Commission, has remedied the problem causing the withholding.

4. Authority to Contract and Subcontract
   The Contractor shall not have the authority to contract for or on behalf of or incur obligations on behalf of the Commission.

The Contractor shall not enter into any subcontracts for any of the work scheduled under this contract other than described in Exhibit A without obtaining prior written approval from the Commission.

Should the Contractor obtain prior written approval to enter into a subcontract with a qualified provider of services, the Subcontractor shall acknowledge the binding nature of this agreement and incorporate this agreement together with its attachments as appropriate. The Contractor must agree to be solely responsible for the performance of any Subcontractor.

5. <u>Funds Available and Authorized</u>
Commission certifies that at the time the contract is written that sufficient funds are available and authorized for expenditure to finance costs of this contract within the Commission's current appropriation or limitation to July 1, 2001. The Commission certifies that it will seek an appropriation for the proposed payments scheduled to be made in Fiscal Years 2002 and 2003. It is agreed that in the event the appropriation or funding to the Commission is not obtained and continued at a level sufficient to allow for payments to the Contractor, for the services identified in Paragraph 2, the obligations of each party hereunder terminate upon delivery of written notice to the Contractor.

6. <u>Termination</u>
This contract may be terminated by mutual consent of both parties, in writing and delivered by certified mail or in person.

Upon delivery of written notice to the Contractor, the Commission may immediately terminate the whole or any part of this contract if:

a. The Contractor fails to provide services called for by this contract within the time specified herein or any extension thereof; or

b. The Contractor fails to perform any of the other provisions of this contract, or so fails to pursue the work as to endanger performance of this contract in accordance with its terms, and after receipt of written notice from the Commission, fails to correct such failures within ten days or such longer period as the Commission may authorize.

The rights and remedies of the Commission provided in the above clause related to defaults (including breach of contract) by the Contractor shall not be exclusive and are in addition to any other rights and remedies provided by law or under this contract. Any such termination of this contract, other than from breach of contract, shall be without prejudice to any obligations or liabilities of either party already accrued prior to such termination.

Should the Commission terminate this contract because the Contractor has breached it, it is understood that no further funding will be provided to the Contractor.

7. <u>Contract Management</u>
Notwithstanding the Contractor's responsibility for total management responsibility during the performance of the contract, the administration of the contract will require maximum coordination between the Lignite Research Council, the Commission and the Contractor.

Commission's Technical Representative
The Commission's Technical Representative (TR) will be designated on authority of the Commission to monitor all technical aspects and assist in administration of the contract. The types of actions within the purview of the TR's authority are to assure that the Contractor performs the technical requirements of the contract; to perform or cause to be performed inspections necessary

in connection with the performance of the contract; to maintain both written and oral communications with the Contractor concerning the aspects of the written interpretations of the technical requirements of the statement of work; to monitor the Contractor's performance under the contract and notify the Commission of any deficiencies observed.

Commission's Authorized Officer
All contractual administration will be carried out by the Commission's Authorized Officer. Communications pertaining to contract administration matters will be addressed to:

Industrial Commission of North Dakota
Attention: Karlene Fine
State Capitol 10th Floor
600 E Boulevard Ave Dept 405
Bismarck, North Dakota 58505-0840

The Commission's Authorized Officer is the only person authorized to approve changes in any of the requirements under the contract.

8. Access to Records
The Commission, Office of the Attorney General of the State of North Dakota, the North Dakota State Auditor, the federal government and their duly authorized representatives shall have access to the books, documents, papers and records of the Contractor which are directly pertinent to the specific contract for the purpose of making audit, examination, excerpts, and transcripts.

9. Compliance with Law
The Contractor shall comply with all federal, state, and local laws and ordinances applicable to the work to be done under this agreement.

10. Indemnity and Insurance
The Contractor is a state agency. The liability of the Contractor is as provided by Chapter 32-12.02 of the North Dakota Century Code and is subject to the limitations contained therein. The Contractor shall require that all subcontractors obtain adequate liability insurance coverage, including, at a minimum, the maximum limits on damages established pursuant to N.D.C.C. §32-12.2-02.

11. Ownership of Work Product
All work products of the Contractor, which result from this contract, shall be governed by North Dakota Administrative Code Chapter 43-03-06.

The Commission is aware that the Contractor is also receiving federal funding for the project that is the subject of this contract and that the Contractor's obligations to the Commission regarding intellectual property such as patents, data, and copyrights, may be secondary to Contractor's obligations to the federal government (U.S. Department of Energy). Nothing in this contract prevents the Commission from asserting its rights in such property against the federal government.

12. Nondiscrimination
Contractor agrees to comply with all applicable requirements of federal and state civil rights and rehabilitation statutes, rules, and regulations.

13. Applicable Law
This agreement shall be governed by and construed in accordance with the laws of the State of North Dakota.

14. Captions
The captions or headings in this agreement are for convenience only and in no way define, limit, or describe the scope or intent of any provisions of this agreement.

15. Execution and Counterparts
This agreement may be executed in several counterparts, each of which shall be an original, all of which shall constitute but one and the same instrument.

16. Amendments
The terms of this agreement shall not be waived, altered, modified, supplemented, or amended, in any manner whatsoever, except by written instrument signed by the parties.

17. Notices
All notices, certificates or other communications shall be sufficiently given when delivered or mailed, postage prepaid, to the parties at their respective places of business as set forth below or at a place designated hereafter in writing by the parties.

Industrial Commission of North Dakota
State Capitol 10th Floor
600 E Boulevard Ave Dept 405
Bismarck, ND 58505-0840

Energy & Environmental Research Center
University of North Dakota
PO Box 9018
Grand Forks, ND 58202-9018

18. Successors in Interest
The provisions of this agreement shall be binding upon and shall inure to the benefit of the parties hereto, and their respective successors and assigns.

19. Severability
The parties agree that if any term or provision of this contract is declared by a court of competent jurisdiction to be illegal or in conflict with any law, the validity of the remaining terms and provisions shall not be affected, and the rights and obligations of the parties shall be construed and enforced as if the contract did not contain the particular term or provision held to be invalid.

20. Waiver
The failure of the Commission to enforce any provisions of this contract shall not constitute a waiver by the state of that or any other provision.

21. Merger Clause
This agreement constitutes the entire agreement between the parties. No waiver, consent, modification or change of terms of this agreement shall bind either party unless in writing and signed by both parties. Such waiver, consent, modification or change, if made shall be effective only in the specific instance and for the specific purpose given. There are no understandings, agreements, or representations, oral or written, not specified herein regarding this agreement. Contractor, by the signature below of its authorized representative, hereby acknowledges that the Contractor has read this agreement, understands it, and agrees to be bound by its terms and conditions.

22. Legal Notice/Disclaimer
The following notice shall be contained in all reports intended to be released to the public:

This report was prepared by the Energy & Environmental Research Center pursuant to an agreement partially funded by the Industrial Commission of North Dakota and neither the Energy & Environmental Research Center nor any of its subcontractors nor the Industrial Commission of

North Dakota nor any person acting on behalf of either:

(A) Makes any warranty or representation, express or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately-owned rights; or

(B) Assumes any liabilities with respect to the use of, or for damages resulting from the use of, any information, apparatus, method or process disclosed in this report.

Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the Industrial Commission of North Dakota. The views and opinions of authors expressed herein do not necessarily state or reflect those of the Industrial Commission of North Dakota.

23. Public Information Releases
The Commission shall coordinate in advance with the Contractor's Contracts Office on all Public Information Releases (releases made specifically for the news media) to be issued by the Commission concerning this contract if the release contains either a reference to the U.S. Department of Energy (DOE) or to the Contractor. Such releases shall not be issued without prior approval from the DOE Contracting Officer or his authorized representative and approval from the Contractor.

ENERGY & ENVIRONMENTAL RESEARCH CENTER NORTH DAKOTA INDUSTRIAL COMMISSION

ENERGY & ENVIRONMENTAL RESEARCH CENTER	NORTH DAKOTA INDUSTRIAL COMMISSION
By: [signature]	By: [signature]
Name Carl Fox	Karlene Fine
Director, Office of Research & Program Development Title	Executive Director
Date: 4/28/00	Date: 3-17-00

Energy & Environmental Research Center

UNIVERSITY OF NORTH DAKOTA

15 North 23rd Street — PO Box 9018 / Grand Forks, ND 58202-9018 / Phone: (701) 777-5000 Fax: 777-5181
World Wide Web Server Address: www.eerc.und.nodak.edu

May 2, 2000

Ms. Karlene K. Fine
Executive Director and Secretary
North Dakota Industrial Commission
State Capitol, 10th Floor
600 East Boulevard Avenue, Department 405
Bismarck, ND 58505-0840

Dear Karlene:

Subject: North Dakota Industrial Commission Contract No. FY00-XXXVI-~~101.~~ 100
Evaluation of Potential SCR Catalyst Blinding During Coal Combustion

Enclosed for your records is one original of the above agreement that has been signed for the University of North Dakota Energy & Environmental Research Center.

Thank you very much for your attention to this matter. Should you have any questions, please contact me at (701) 777-4581 or by e-mail at jzola@undeerc.org.

Sincerely,

Jill M. Zola

Jill M. Zola
Contracts Officer
Business and Operations

JMZ/kal

Enclosure

c: Chris Zygarlicke, EERC

Addendum to Contract No. FY00-XXXVI-100

This addendum is between the State of North Dakota acting by and through its Industrial Commission, hereafter called Commission, and The University of North Dakota Energy & Environmental Research Center (EERC), hereafter called Contractor.

This addendum is to Contract No. FY00-XXXVI-100 which was originally executed by the Commission on March 17, 2000. As per the attached letter from the Contractor dated October 14, 2003, requesting an extension of the completion date of the project, Contract FY00-XXXVI-100 is amended and restated as follows:

2. Statement of Work
   a. Contractor agrees to accomplish the following work under this contract: The statement of work to be accomplished is contained in Corrected Exhibit A, entitled "Evaluation of Potential SCR Catalyst Blinding During Coal Combustion" which is attached to this contract and is made a part of it. In addition the Contractor agrees to include testing with North Dakota lignite (which is noted in the "Corrected" Exhibit A).

   b. Contractor agrees to provide quarterly interim reports (every three months) during the project* with a final comprehensive report following the final quarter of this project to be submitted June 30, 2004.*

   The Final Report shall be in compliance with 43-03-05-08 of the North Dakota Administrative Code. Specifically, the Final Report must include a single page project summary describing the purpose of the project, the work accomplished, the project's results, and the potential applications of the project. The Final Report must provide documentation verifying the receipt of the private matching funds.

UNIVERSITY OF NORTH DAKOTA
ENERGY & ENVIRONMENTAL RESEARCH CENTER

By: W.D. Gosnold

Name
William J. Gosnold, Jr. Interim Director

Title

Date: 2-11-04

NORTH DAKOTA INDUSTRIAL COMMISSION

By: Karlene Fine

Karlene Fine
Executive Director

Date: 2/3/04

*provisions changed in the contract

EERC
Energy & Environmental Research Center
UNIVERSITY OF NORTH DAKOTA
15 North 23rd Street — PO Box 9018 / Grand Forks, ND 58202-9018 / Phone: (701) 777-5000 Fax: 777-5181
Web Site: www.undeerc.org

October 14, 2003

Ms. Karlene K. Fine
Executive Director and Secretary
North Dakota Industrial Commission
State Capitol, 10th Floor
600 East Boulevard Avenue, Department 405
Bismarck, ND 58505-0840

Dear Karlene:

Subject: North Dakota Industrial Commission Contract No. FY00-XXXVI-~~101~~ 100; Evaluation of Potential SCR Catalyst Blinding During Coal Combustion; UND Fund 4869

In accordance with the provisions of the subject agreement between the North Dakota Industrial Commission (NDIC) and the Energy & Environmental Research Center (EERC), the EERC may extend the completion date of the project.

Please be advised that the EERC has extended the completion date for the above project to June 30, 2004. The additional time is necessary because the installation of the reactor was delayed. We believe the additional time will be adequate to complete the project.

Should you have any questions or require further information regarding the extension, please contact me at (701) 777-5036 or by e-mail at parnason@undeerc.org. Thank you very much for your attention to this matter.

Sincerely,

Paul A. Arnason
Contracts Officer
Business and Operations

PAA/nfp

c: Wayde Anderson, UND Grants and Contracts Administration
Steve Benson, EERC

INDUSTRIAL COMMISSION OF NORTH DAKOTA

John Hoeven
Governor

Wayne Stenehjem
Attorney General

Roger Johnson
Agriculture Commissioner

February 3, 2004

Mr. Paul A. Arnason
Contracts Officer
Business and Operations
Energy and Environmental Research Center
P. O. Box 9018
Grand Forks, ND 58202-9018

Dear Paul:

Enclosed are two signed copies of the Addendum to Lignite Research Council Contract No. FY00-XXXVI-100 in response to your letter of October 14, 2003.

If no changes to the Addendum are needed, please have the Addendum signed and return one original to my office.

If you have any questions, please give me a call at (701) 328-3722.

Sincerely,

Karlene Fine
Executive Director and
Secretary of the Industrial Commission

Enclosure
C: H. Ness

Karlene K. Fine, Executive Director and Secretary
State Capitol, 14th Floor - 600 E Boulevard Ave Dept 405 - Bismarck, ND 58505-0840
E-Mail: kfine@state.nd.us
Phone: (701) 328-3722 FAX: (701) 328-2820
"Your Gateway to North Dakota": discovernd.com

EERC
Energy & Environmental Research Center
UNIVERSITY OF NORTH DAKOTA
15 North 23rd Street — PO Box 9018 / Grand Forks, ND 58202-9018 / Phone: (701) 777-5000 Fax: 777-5181
Web Site: www.undeerc.org

February 11, 2004

Ms. Karlene K. Fine
Executive Director and Secretary
Industrial Commission of North Dakota
State Capitol, 10th Floor
600 East Boulevard Avenue
Bismarck, ND 58505-0840

Dear Karlene:

Subject: Addendum to NDIC Contract No. FY00-XXXVI-100
Evaluation of Potential SCR Catalyst Blinding During Coal Combustion
UND Fund 4869

Enclosed for your records is one fully executed original of the subject addendum that has been signed by an authorized official of the University of North Dakota Energy & Environmental Research Center.

Thank you very much for your attention to this matter. Should you have any questions, please contact me at (701) 777-5036 or by e-mail at parnason@undeerc.org.

Sincerely,

Paul A. Arnason
Contracts Officer
Business and Operations

PAA/jdk

Enclosure

c: Steve Benson, EERC

EERC
Energy & Environmental Research Center
UNIVERSITY OF NORTH DAKOTA
15 North 23rd Street — PO Box 9018 / Grand Forks, ND 58202-9018 / Phone: (701) 777-5000 Fax: 777-5181
Web Site: www.undeerc.org

February 10, 2003

Shirley- Note the extension date

Ms. Karlene K. Fine
Executive Director and Secretary
North Dakota Industrial Commission
State Capitol, 10th Floor
600 East Boulevard Avenue, Department 405
Bismarck, ND 58505-0840

Dear Karlene:

Subject: North Dakota Industrial Commission Contract No. FY00-XXXVI-100; Evaluation of Potential SCR Catalyst Blinding During Coal Combustion; UND Fund 4869

In accordance with the provisions of the subject agreement between the North Dakota Industrial Commission (NDIC) and the Energy & Environmental Research Center (EERC), the EERC may extend the completion date of the above project.

Please be advised that the EERC has extended the completion date for the above project from March 31, 2003, to December 31, 2003. The extension has been implemented because of delays in scheduling tests at the host utilities and coordinating with the Wisconsin Department of Natural Resources. We believe the additional time will be adequate to complete the project.

Should you have any questions or require further information regarding the extension, please contact me at (701) 777-5036 or by e-mail at parnason@undeerc.org. Thank you very much for your attention to this matter.

Sincerely,

Paul A. Arnason
Contracts Officer
Business and Operations

PAA/slk

c: Wayde Anderson, UND Grants and Contracts Administration
Steve Benson, EERC

INDUSTRIAL COMMISSION OF NORTH DAKOTA

LIGNITE RESEARCH, DEVELOPMENT AND MARKETING PROGRAM

Governor,
John Hoeven
Attorney General,
Wayne Stenehjem
Commissioner of Agriculture,
Roger Johnson

MEMORANDUM

February 14, 2003

TO: Karlene Fine, Executive Director and Secretary
North Dakota Industrial Commission

FROM: Harvey M. Ness, Director and Technical Advisor
Lignite Research, Development and Marketing Program

cc: John W. Dwyer, Chairman
Lignite Research Council

SUBJECT: FY00-XXXVI-100: "Evaluation of Potential SCR Catalyst Blinding During Coal Combustion"; Contractor: Energy & Environmental Research Center; Recommendation for Contract Time Extension.

I have reviewed the request for a time extension from the contractor (Energy & Environmental Research Center) regarding Contract No. FY00-XXXVI-100 for the project titled "Evaluation of Potential SCR Catalyst Blinding During Coal Combustion".

I concur with the contractor's request for the time extension.

HMN/vg: 24.S.30.A

LIGNITE RESEARCH COUNCIL
John Dwyer, Chairman
Harvey Ness, Director & Technical Advisor
P.O. Box 2277
Bismarck, N.D. 58502
(701) 258-7117 (701) 258-2755 Fax

INDUSTRIAL COMMISSION OF NORTH DAKOTA
Karlene Fine
Executive Director
600 East Boulevard, State Capitol
Bismarck, N.D. 58505
(701) 328-3722 (701) 328-2820 Fax

MEETING NOTES

Project Kickoff Meeting

Evaluation of Potential SCR Catalyst Blinding During Coal Combustion

Grand Forks, North Dakota, USA

Thursday, August 3, 2000

Meeting Format and Attendees

A kickoff meeting for the project entitled Evaluation of Potential SCR Catalyst Blinding During Coal Combustion was held at the Energy & Environmental Research Center (EERC) in Grand Forks, North Dakota, on August 3, 2000. Technical presentations were delivered by the EERC on the project background, objectives, and work plan. Discussions between the EERC and project sponsors ensued.

Those in attendance included:

Chris Zygarlicke, EERC
Steve Benson, EERC
Jay Gunderson, EERC
Don Toman, EERC
John Pavlish, EERC
Terry Graumann, Otter Tail Power Company
Rene Mangal, Ontario Power Technologies
Dave O'Connor, EPRI
Ken Stuckmeyer, AmerenUE
Edmundo Vasquez, Alliant Energy
Reda Iskandar, Cormetech Inc.

Bill Rogers from Detroit Edison was unable to attend the meeting but remains optimistic that his company will be able to join the project. He will be copied in these meeting notes, and information was received from him on a potential candidate boiler for the SCR test reactor. The remainder of these meeting minutes are organized to provide an overview of the meeting, details of discussion items, and action items.

Meeting Overview

The meeting began at about 8:30 a.m. with a welcome from EERC Director Dr. Gerry Groenewold. Chris Zygarlicke then gave a brief overview of the SCR Blinding project background, goals, objectives, drivers, deliverables, and scope of work. It was emphasized that the project will focus on mechanisms of blinding and not necessarily be an exercise in testing specific catalyst types or designs. John Pavlish gave a short synopsis of work being done under an ongoing project between EPRI, several utilities, the U.S. Department of Energy (DOE), and the EERC to evaluate the conversion of mercury across SCR systems. Discussions were free-flowing throughout the entire meeting.

After the opening presentations, Steve Benson presented background information on mechanisms of ash formation and deposition in coal-fired boilers. He included information on low-temperature ash deposition mechanisms which may apply to SCR blinding deposits. He then commenced to discuss the scope of work involved in the bench-scale testing part of the project. Next on the agenda was Jay Gunderson who discussed the SCR test reactor design and installation. After lunch, Jason Laumb from the EERC discussed the analytical approach that will be used to determine the blinding mechanisms.

The meeting concluded around mid-afternoon after discussions on various action items and decision points. Details of the discussions are contained in the Discussion and Action Item sections of this document. A tour of EERC facilities was given to all interested parties.

As a result of this meeting, a revised work scope will be issued to all project sponsors in the next few weeks, followed by a conference call meeting.

Discussion Items

Several discussion items which evolved during the course of the meeting are listed below.

1. **What units should be tested and what coals and in what order?**

   It was discussed that the EERC SCR test reactor will be installed at up to four different units to operate for at least 6 months. It may be necessary during the time that the reactor is installed to have an operator check the SCR reactor every day (going through a checklist). Regulatory requirements for 147-lb cylinders of ammonia that will be used in conjunction with the SCR reactor should be checked by plant staff. Boiler access may be an issue with respect to getting the reactor positioned in the right place.

   If it is decided that four units are to be tested, then the types of coals and boilers selected may include a lignite fired in a cyclone boiler, a PRB coal fired in a cyclone boiler, a PRB fired in a p.c.-fired boiler, and an alternate PRB fired in either a cyclone or p.c. boiler

   <u>AmerenUE Sioux Plant</u>

   The Sioux Unit 2 is the best candidate. It is a 500-MW cyclone that burns an 85–15 blend of PRB–Illinois coal. Ken Stuckmeyer did not foresee any problems with including this unit as one of the test sites. Ongoing testing of SCR blinding using a small SCR test reactor is being done in this unit under a different project and these data may be available for comparison. There will be a scheduled outage sometime in September 2000. On-site ammonia is not a problem.

Otter Tail Power Coyote Station

The Otter Tail Power Coyote Station is a 350-MW cyclone boiler that burns 100% lignite from the Beulah mine. Terry Graumann will check into on-site ammonia issues, and he will discuss with plant staff the availability of operating staff and time commitments.

Ontario Power Generation Nanticoke

Ontario Power Generation's Nanticoke Thermal Power Station, situated on Lake Erie near Port Dover, Ontario, Canada, is Ontario Power Generation's largest, and one of the world's largest, coal-fueled plants. Nanticoke plant has eight units that are designed as opposed-wall pulverized coal-fired units with a capacity of 4000 MW from eight Parsons 500-MW turbine generator sets. Nanticoke is looking at burning a 50–50 blend of PRB–bituminous coal.

Ontario Power Generation Lambton Plant

The Ontario Power Generation Lambton Plant is a 500-MW t-fired unit. Bringing ammonia on-site is not an issue.

Alliant Energy Edgewater Plant

The Alliant Energy Edgewater Plant has a 340-MW cyclone boiler that burns an 85–13–2 blend of PRB–bituminous coal–tires.

Alliant Energy Nelson Dewey

The Alliant Energy Nelson Dewey plant contains a 200-MW cyclone-fired boiler that burns a 85–15 blend of PRB–bituminous coal.

Alliant Energy Columbia Energy Station

The Alliant Energy Columbia Energy Station has two 500-MW t-fired units that burn 100% PRB coal. There is no SOFA at the plant.

Detroit Edison Monroe Power Plant

The Detroit Edison Monroe Power Plant consists of four 750-MW BW boilers equipped with cell burners (slightly similar to wall-fired burners only with much higher heat release rates and NO_x generation). The units burn a mixture of 55%–65% PRB and 35%–45% mid-sulfur (1.5%–2.5%) bituminous coal.

2. **What coals or blends should be tested at the bench scale?**

   Coals to be tested for SCR blinding mechanisms using bench-scale testing will consist of:

   - Whatever coals are being fired at the host utility test sites (up to 4 coals).
   - 4–6 other coals selected from a pool of suggestions by the project sponsors.

   Sponsors are requested to send 5–10 gallons (buckets) of each coal or blend coal that they want tested and specify the blend ratio if that applies. The EERC will blend coal samples based on sponsor suggestions. Steve Benson will coordinate which coals get tested.

3. **How can we incorporate data that could be received from the New Madrid plant?**

   Associated Electric Inc.'s New Madrid Power Plant is comprised of two electric generating units. Unit 1 was constructed in 1972, and Unit 2 was completed in 1977. New Madrid's 600-MW generating units can each burn about 8000 tons of PRB coal per day. Cormetech is doing some work at the plant and may have some catalyst samples for the EERC to analyze.

   The EERC will wait to hear from Cormetech on how to possibly integrate New Madrid samples with this project.

4. **Can we test different catalysts?**

   The original plan was to study one type of catalyst in the field and focus on mechanisms. We may want to work with only one vendor such as Cormetech to help design and build the SCR reactors, but then entertain getting catalysts from other vendors to place in the reactor. The project does not have an abundance of analytical dollars to be doing extensive analysis of several types of catalysts sampled at different times at 3–4 different power plants; however, some select analyses could possibly be worked in for multiple catalysts.

5. **SCR Test Reactor Design**

   There was a good deal of discussion about the SCR test reactor design. Some issues that were settled in the meeting include the following:

   - A slipstream design will be implemented and made to be able to be dismantled, since a total skid mount will have accessibility problems in most boilers.
   - Instrumentation will be able to monitor whether NO_x control is occurring.
   - It will not matter if we use honeycomb or plate catalyst types.
   - Ammonia injection will be used.

- Carbon steel and not stainless (as originally planned) will be used, unless for some improbable reason stainless steel would be cheaper.
- An upfront blank SCR flow conditioner section will be used followed by an undetermined number of catalyst sections (but only up to 4) that will be sampled.

Jay Gunderson from the EERC will be initiating discussions with various individuals to finalize a design for the SCR test reactor. Suggestions on who Jay should talk to included Scott Pritchard (Cormetech), Dave Broske (EPRI), Rich Phillips (AmerenUE), and someone from FERCO. Their discussions will center around key elements of the SCR design which were brought up in the meeting including:

- Slipstream design and how to interface with existing boiler ports.
- Length and number of catalyst sections after the flow conditioner.
- Catalyst cube design (multiple cubes for analysis in lateral arrangement).
- Gas flow issues, the effects of velocity in the reactor or SCR banks, methods for preventing plugging, and minimizing wall effects.
- Sootblowing and cleaning of the reactor.
- The effect, if any, on changing efficiency if sections or cubes of catalyst are removed during field testing.
- Potential for speeding up the deactivation process experimentally.
- The importance of different catalyst types and pitches and how to incorporate these variables in the field testing.
- Maintaining or allowing the catalyst test reactor temperature to fluctuate with boiler flue gas temperature.
- Controls and instrumentation that would be used in case of a plant shutdown, such as a nitrogen purge.
- Approaching other catalyst vendors (Hitachi, Siemens, KWH) to be involved in testing their catalysts in the test reactor.

Action Items

Several action items have resulted from this initial meeting:

- Chris Zygarlicke has contacted Detroit Edison, which will let us know in the next 2 weeks if it will be a part of the project. They are hopeful about being a part of the team and are looking into funding approval.
- The EERC will also be contacting Keith McFarland or Mark Leifer from Illinois Power/Dynegy and Tom Watkins from AECI to see if they are interested in the project.
- Dave O'Connor (EPRI) will be getting names for TXU and Central and Southwest for the EERC to possibly contact for joining the project.
- The EERC will send out the proposal to DOE for JV funding the week of August 7–11, 2000.
- Jay Gunderson will set up and hold a conference call with various individuals to finalize a design for the SCR test reactor. Suggestions on who Jay should talk to

included Scott Pritchard (Cormetech), Dave Broske (EPRI), Rich Phillips (AmerenUE), and someone from FERCO.

- Reda Iskandar (Cormetech) will look into the possibility of getting catalyst from the New Madrid power plant for analysis.
- Terry Graumann (Otter Tail Power Company), Rene Mangal (Ontario Power Technologies), Ken Stuckmeyer (AmerenUE), Edmundo Vasquez (Alliant Energy), and Bill Rogers (Detroit Edison) need to:
    1. Provide Steve Benson with coals for the bench-scale testing (send 5–10 gallons of each coal).
    2. Obtain permission and check into any hurdles with respect to their candidate boilers having the SCR test chamber set up there sometime in the next 18 months.
- The EERC will begin working on a revised work scope, which will be issued to all project sponsors in the next few weeks, followed by a conference call meeting.
- A conference call meeting has been set up for Thursday, September 7, 2000, 1:00 p.m. CST.

Agenda
Evaluation of Potential SCR Catalyst Blinding During Coal Combustion
Kickoff Meeting Grand Forks, ND, August 3, 2000

8:30 a.m.	Welcome from EERC	Gerry Groenewold/Tom Erickson
8:45 a.m.	Agenda and Project Overview	Chris Zygarlicke
9:00 a.m.	Background in Ash Deposition	Steve Benson
9:30 a.m.	Bench-Scale Work	Steve Benson
10:00 a.m.	Break	
10:15 a.m.	SCR Test Reactor Design and Installation	Jay Gunderson
10:45 a.m.	Sponsor Input and Discussion of Test Sites	Jay Gunderson
11:15 p.m.	Analysis of SCR Deposits and Mechanisms	Jason Laumb
11:45 a.m.	General Project Discussion	Chris Zygarlicke and Steve Benson
12:15 p.m.	Lunch	
1:30 p.m.	Final Discussions and Tours	Chris Zygarlicke and Steve Benson
2:30 p.m	Meeting Adjourned	

Evaluation of Potential SCR Catalyst Blinding During Coal Combustion

Project Kickoff Meeting

Energy and Environmental Research Center

Chris J. Zygarlicke, Steven A. Benson, Jason Laumb, and Jay R. Gunderson

Grand Forks, North Dakota

Thursday, August 3, 2000

Project Participants

- Electric Utilities:
  - Ontario Power Technologies
  - Otter Tail Power Company
  - Alliant Energy
  - AmerenUE
  - Detroit Edison (expressed interest)
- EPRI
- North Dakota Industrial Commission
- U.S. Department of Energy – National Energy Technology Laboratory
- Catalyst Vendor: PreussenElektra Engineering?, Cormetech?

Energy & Environmental Research Center

Objectives

- Determine potential for low rank coal ash to cause blinding of selective catalytic reduction (SCR) catalysts
- Determine mechanisms of SCR blinding
- *Determine the degree of elemental mercury conversion across SCR catalyst material*

Background

- EPA:
  - Phase II (Year 2000) NO_x Emissions Rule for Coal Boilers:
  - EPA rule (1998) to lower new source performance standards for NO_x
  - Required that states develop state implementation plans (SIPs) for reducing nitrogen oxide (NOx) emissions. These plans must be developed by 22 states and the District of Columbia between now and September 1999
- SCR considered a "best demonstrated system" for NO_x control
- NO_x reduction costs estimated at ~$1100/ton removal or $40-90/Kwhr
- Potential rules for mercury: 2000 – Regulatory determination; 2004 – Final rule; 2007 – Mercury compliance (if rule issued)

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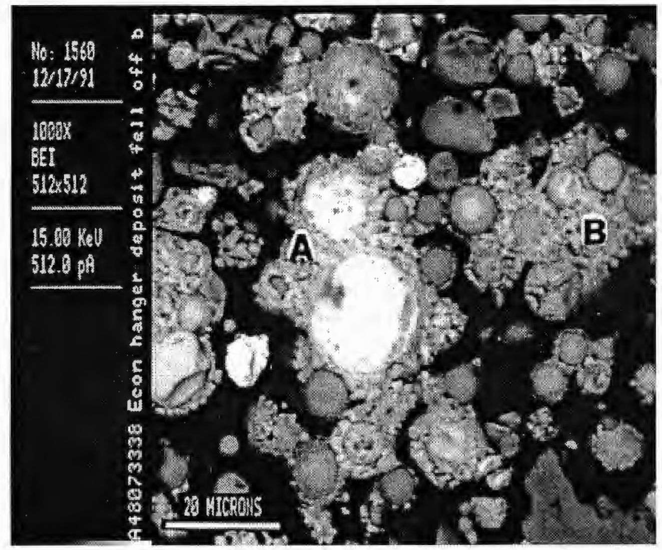
Justification

- SCR may be the only option for many utilities, especially those with cyclone-fired boilers and there may be problems with SCR for low rank coals
- Utilities, SCR vendors, and regulating agencies need sound scientific information on SCR performance for low rank coals
  - Recent utility boiler tests show rapid deactivation of catalyst material in relatively short times
  - Knowledge of blinding mechanisms is critical
- Potential to challenge EPA or other state rulings (i.e. SCR may not being "best" system for control due to blinding or poisoning issues)
- SCR may convert mercury to a form more likely to be captured

Issues Involving Low Rank Coals and SCR

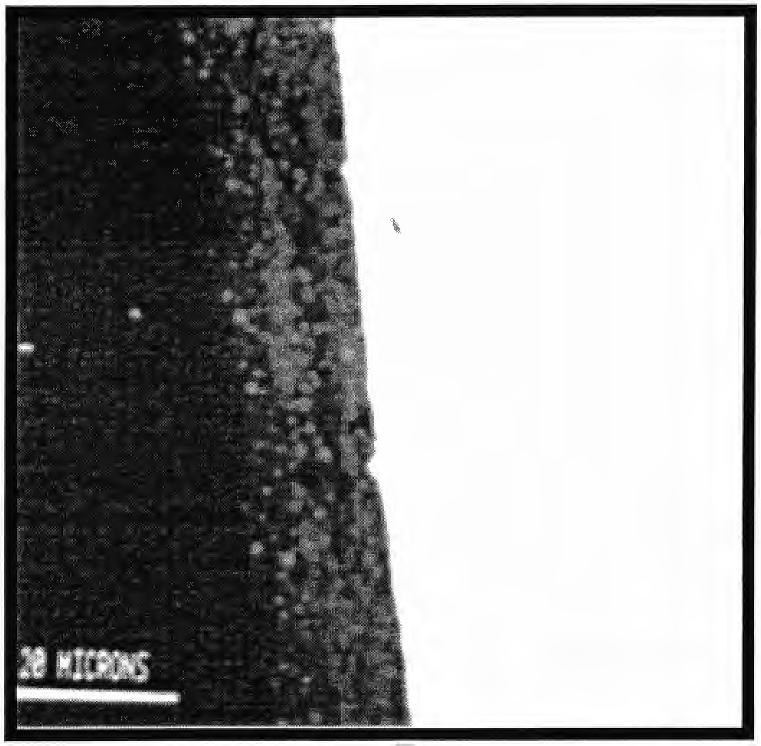
- Research by Germans, Cormetech, EPRI, and other utilities showed that physical blinding caused by alkali sulfates (Na, K, Ca)
- Recent Siemens work ASME Joint Power Conf.) describes small calcium sulfate crystals/particles blocking catalyst pores with 50% catalyst deactivation after 3000 hours for PRB coal.
- Trade off between lessening arsenic poisoning (> Ca) and lessening Ca-sulfate blinding (<reactive Ca)



SEM micrograph showing Ca-Na-rich fly ash sulfating with time at low temperatures

Issues Involving Low Rank Coals and SCR (Continued)

Fine particulate deposits at low temperature (full-scale boiler)



Ca-sulfate-rich deposit, particles <3µm | Steel deposition probe

- Fine particle production more prevalent with North Dakota lignite and Powder River Basin type lower rank coals compared to bituminous coals
- PRB and lignites produce large concentrations of reactive Ca (for sulfation)
- Catalytic activity of metals in SCR may enhance deposition (sulfation)
- Certain phosphate compounds are stable in SCR regime

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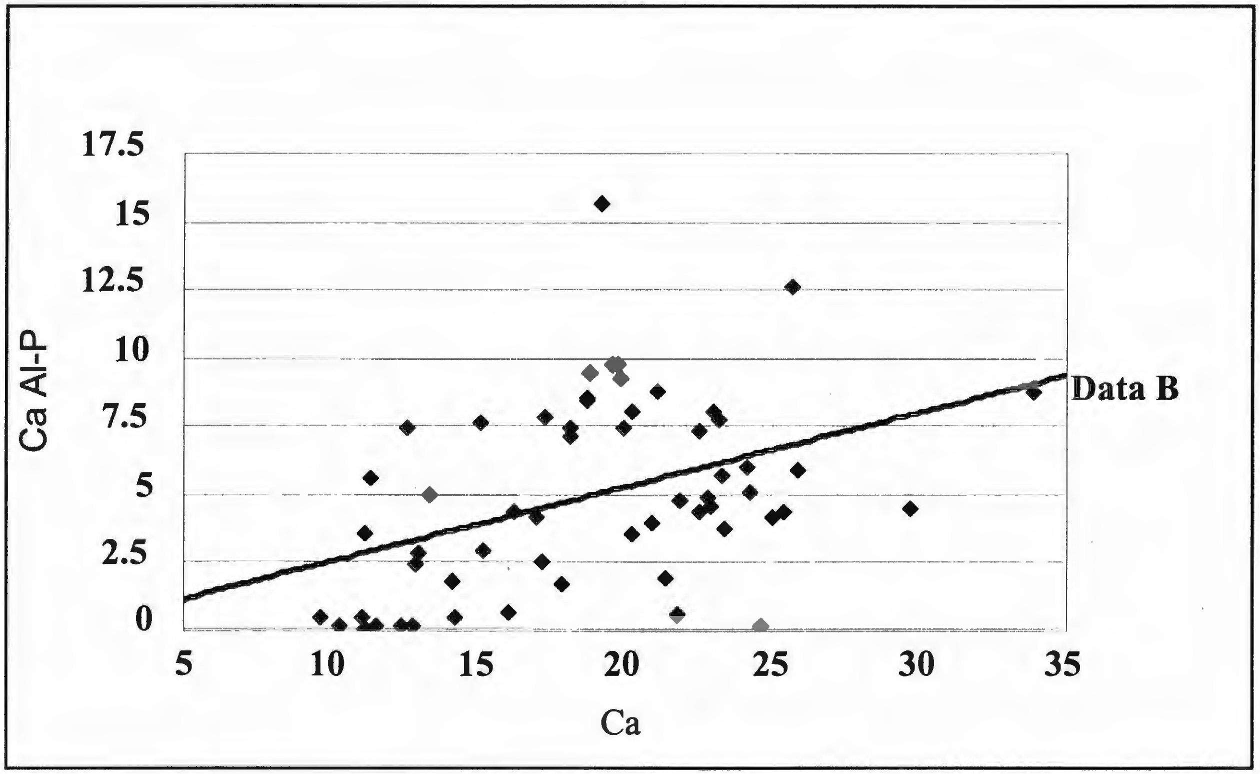
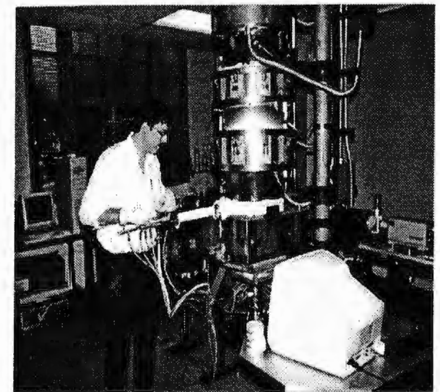
Ca-Al-P Rich Mineral Occurrence vs. Calcium Content

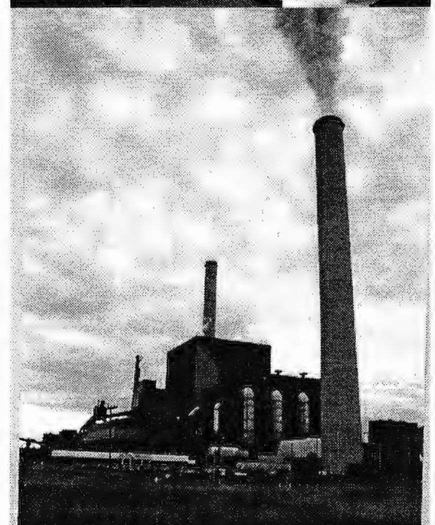
(CCSEM and XRF analysis data for 50 U.S. lignite and PRB coals)

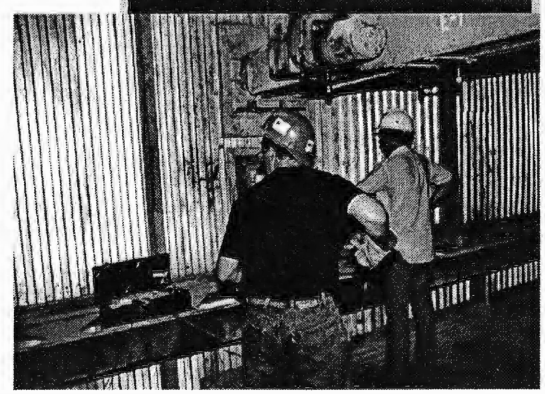


Project Work Plan

- Task 1 – Identification of Test Coals, Utility Host Sites, and Final Work Plan
- Task 2 – Bench-Scale Testing and Screening
- Task 3 – Design and Construction of SCR Slipstream Test Chamber
- Task 4 – SCR Test Chamber Installation and Data Collection at Utility Host Sites
- Task 5 – Determination of SCR Blinding Mechanisms
- Task 6 – Final Interpretation, Recommendations, and Reporting







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Deliverables

- Utilities gain mechanistic information on SCR catalyst blinding to aid in:
  - Selection of SCR vendors
  - Negotiating guarantees on SCR performance
- Additional scientific data to challenge EPA
- SCR industry improves its products for low rank coals
- Continued positive promotion of North Dakota lignite
- Insight on mercury emissions
  - Very minimal task
  - John Pavlish – brief overview of SCR-Hg project with EPRI et al.

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Project Budget and Cost Structure

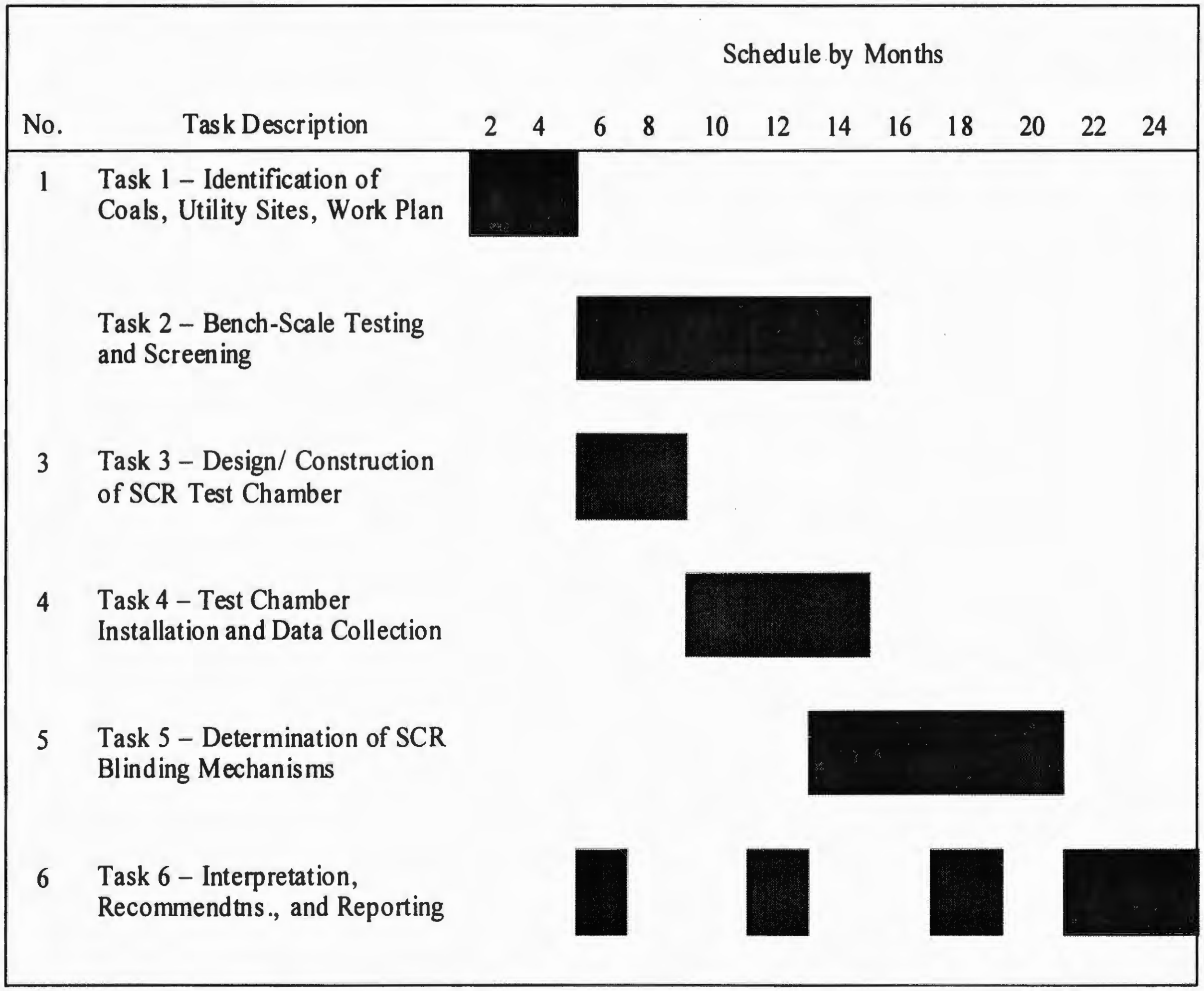
- Multiclient consortium with U.S. DOE joint venture funding
- $240,000 industry (utilities, catalyst vendor[s])
- $200,000 NDIC funding
- $293,000 U.S. DOE

- Total Project Budget $733,000

Budget by Task

Task 1 –	Identification of Test Coals and Utility Host Sites and Final Work Plan	$33,000
Task 2 –	Bench-Scale Testing and Screening	$103,000
Task 3 –	Design and Construction of SCR Slipstream Test Chamber	$121,000
Task 4 –	SCR Test Chamber Installation and Data Collection at Utility Host Sites	$205,000
Task 5 –	Determination of SCR Blinding Mechanisms	$167,000
Task 6 –	Final Interpretation, Recommendations, and Reporting	$104,000

Schedule
(24-month duration)



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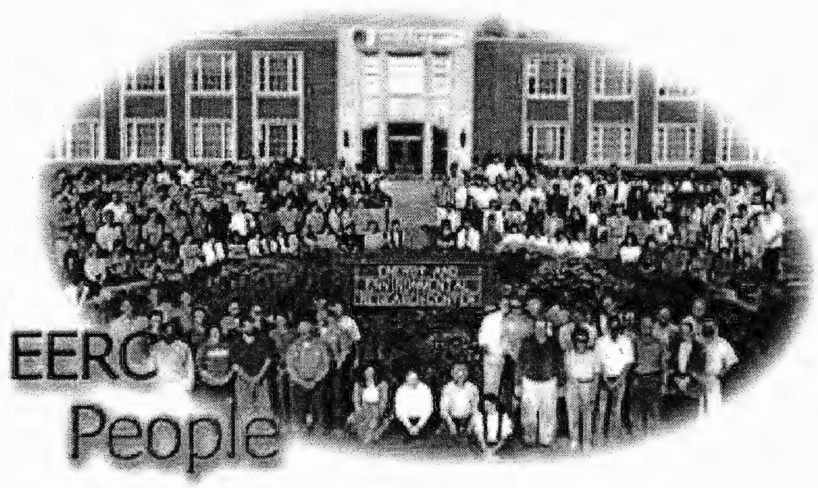
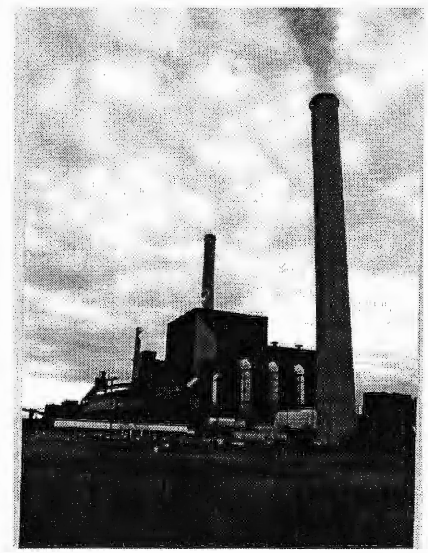
Project Personnel

- Managers: Steve Benson and Chris Zygarlicke
- PI's: Jay Gunderson, Jason Laumb, Don Toman
- Other key technical staff: John Pavlish, Don McCollor and Dean Evenstad
- Administrative: LaRae Foerster



Objectives of Remainder of Meeting

- Get acquainted – consortium team
- Input on specific research approaches
- Input on project work scope
- Insight on SCR reactor design and installation
- Selection of host utilities for testing
- Input on coals for bench-scale testing



Background: SCR Ash Deposition

Steve Benson

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Issues Related to Blinding of SCR Catalysts

- Coal composition – association of elements
- Ash formation – small particle and gas phase formation – alkali and alkaline earth-rich phases and sulfur and phosphorus gas phase components
- Ash transport – transport of particles to catalyst surface
- Sintering and reaction with gas phase components

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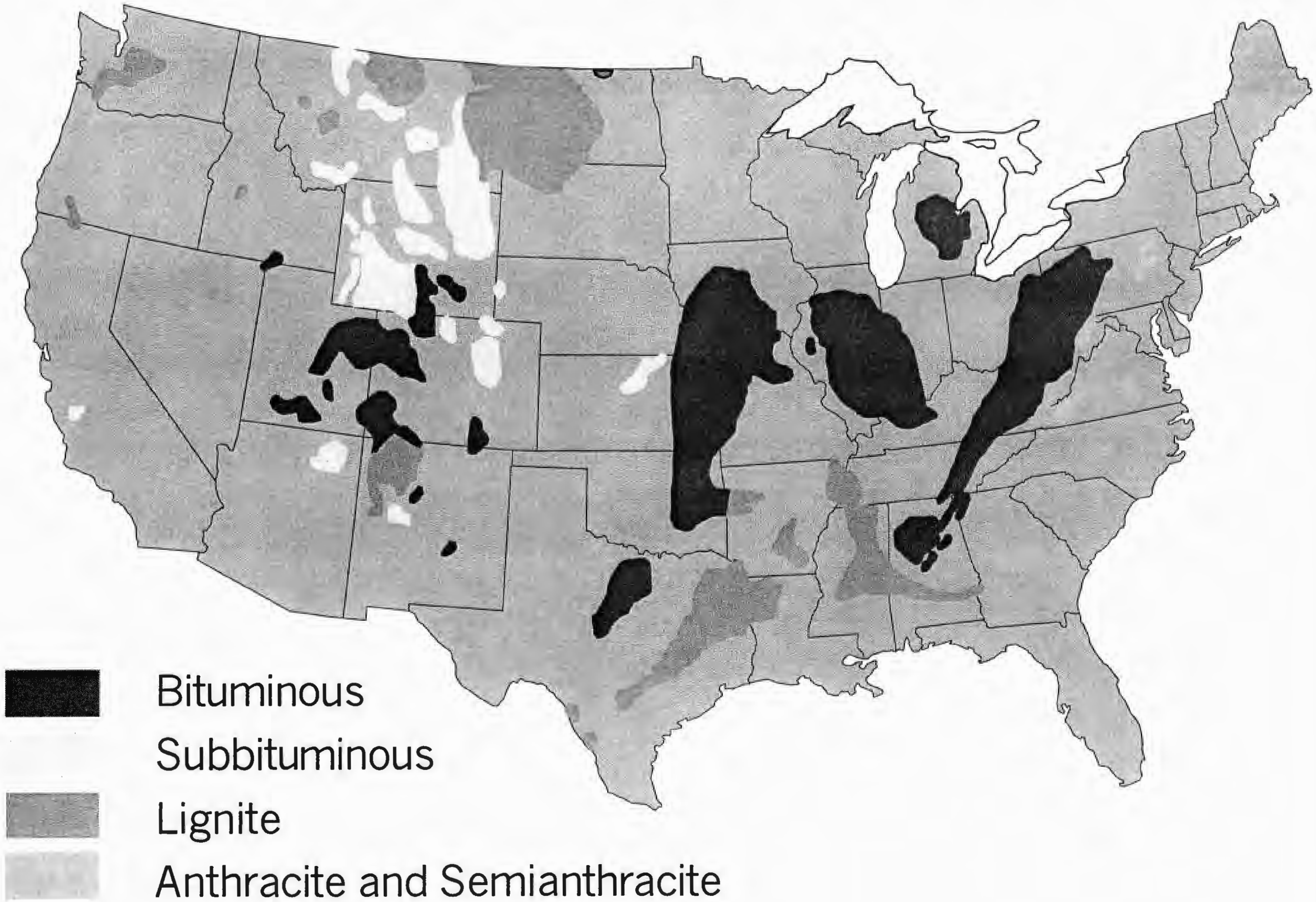
Background Overview

- Inorganic Composition of Coal
- Ash formation mechanisms
- Transport mechanisms
- Chemical reaction mechanisms
- Modeling of ash behavior

Coal Map of the United States



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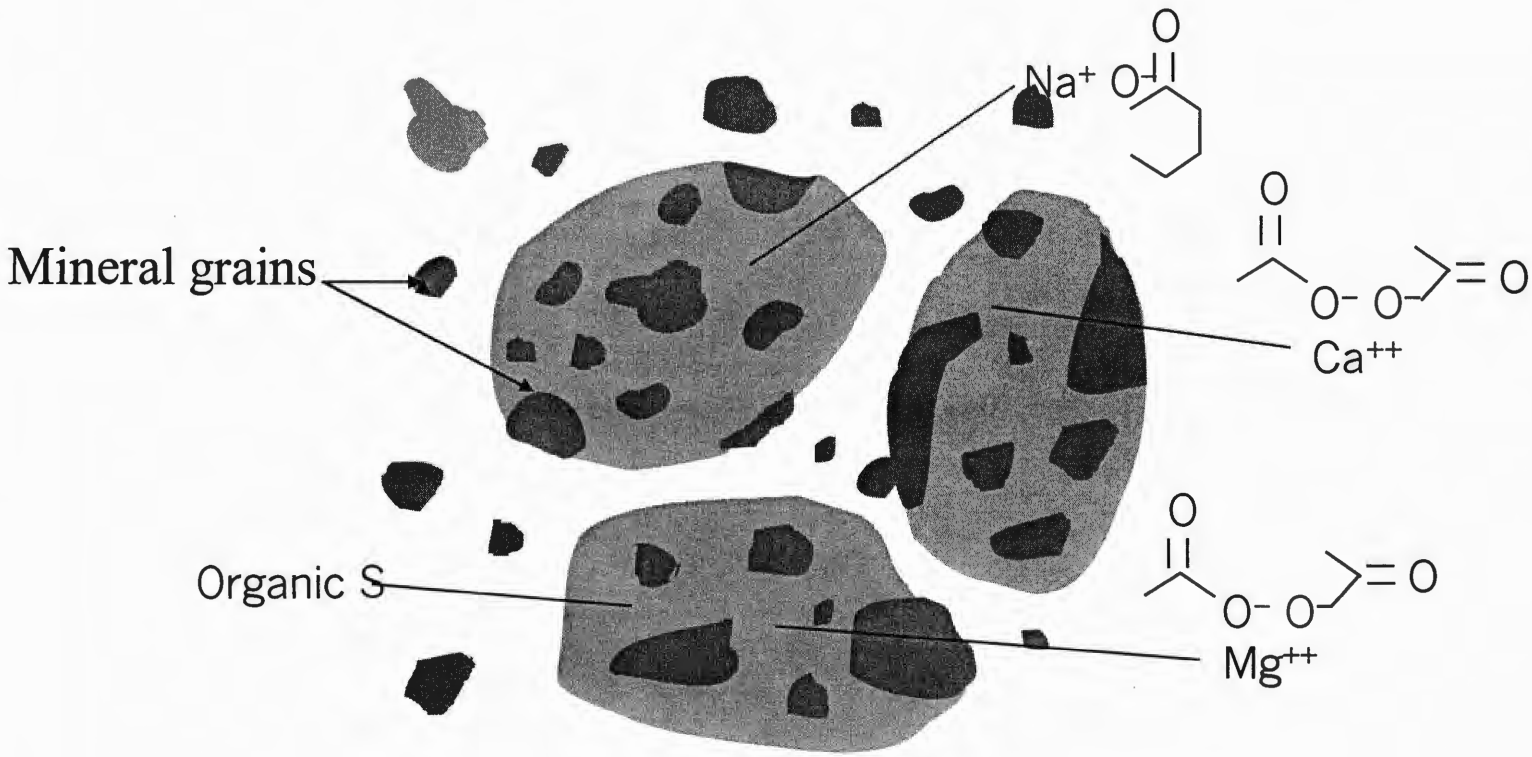
Forms of Inorganic Components in Coal



- Cations as salts of carboxylic acids.
- Organically associated sulfur.
- Coordination complexes Al^{3+} and Fe^{3+}.
- Mineral grains

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Elements Extracted by Ammonium Acetate from 14 Western U.S. Low-Rank Coals

Element	Initial, ppm	Removed by NH_4OAc, %
Na	960–6200	76–100
Mg	980–20,540	17–100
Al	2180–11,480	0–23
Si	2050–33,060	0–12
K	390–1530	2–89
Ca	7500–22,790	39–85
Ti	104–1180	0–5
Fe	1450–11,090	0

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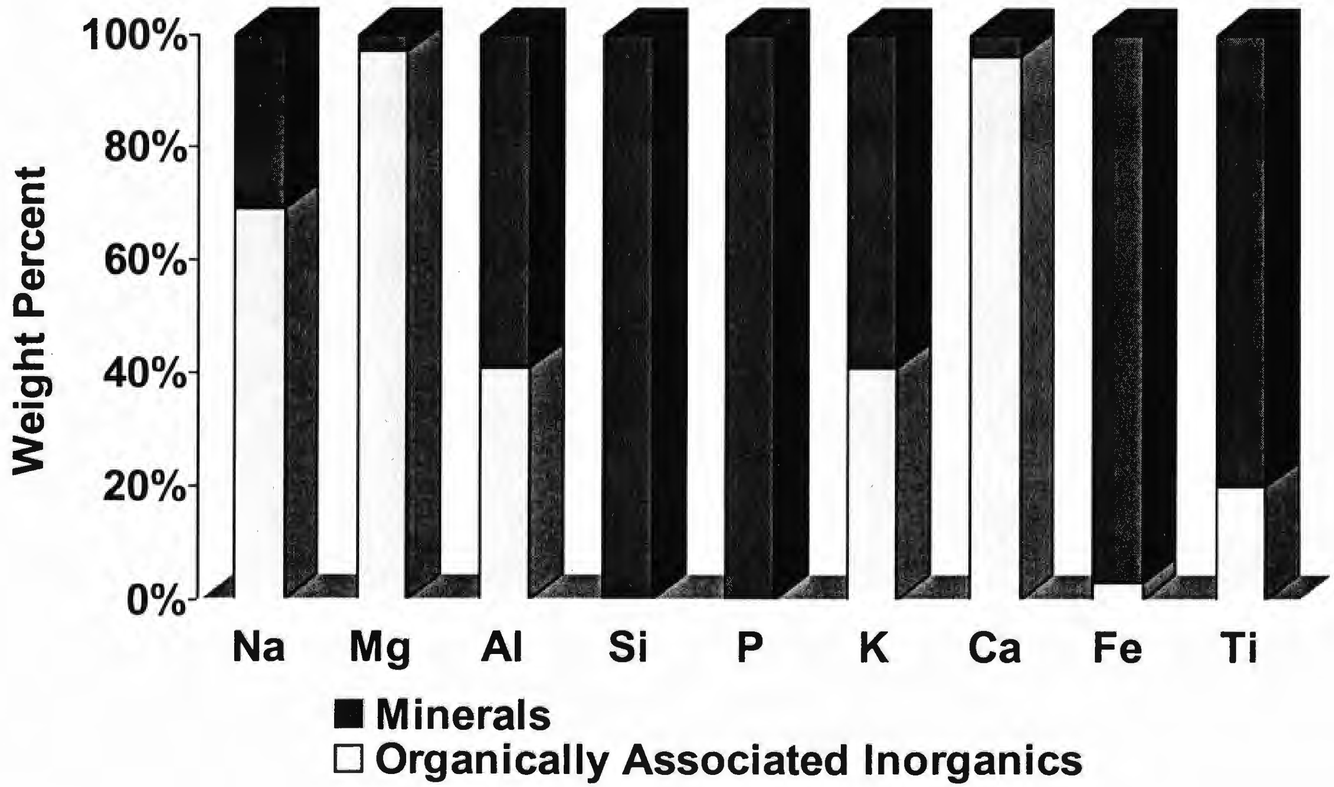
Elements Extracted by HCl and Remaining in the Residues of 14 Western U.S. Low-Rank Coals

Element	Removed by HCl, %	Remaining, %
Na	0–2	0–24
Mg	0–17	0–82
Al	29–81	19–58
Si	2–17	72–97
K	0–30	11–97
Ca	11–29	1–49
Ti	2–57	43–98
Fe	14–73	27–79

Distribution of Inorganic Constituents in Eagle Butte Coal



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Common Minerals Found in Western U.S. Low-Rank Coals

Mineral Name	Formula
Quartz	SiO_2
Kaolinite	$Al_2Si_2O_5(OH)_4$
Illite	Hydrated mica-like composition
Montmorillonite	$(Al,Mg)_8(Si_4O_{10})_3(OH)_{10}\cdot 12H_2O$
Pyrite	FeS_2
Calcite	$CaCO_3$
Dolomite	$CaMg(CO_3)_2$
Gypsum	$CaSO_4\cdot 2H_2O$
Barite	$BaSO_4$
Apatite	$Ca_5(PO_4)_3(F,Cl,OH)$
Hematite	Fe_2O_3
Rutile	TiO_2
Crandallite	$CaAl_3(PO_4)_2(OH)_5\cdot(H2O)$

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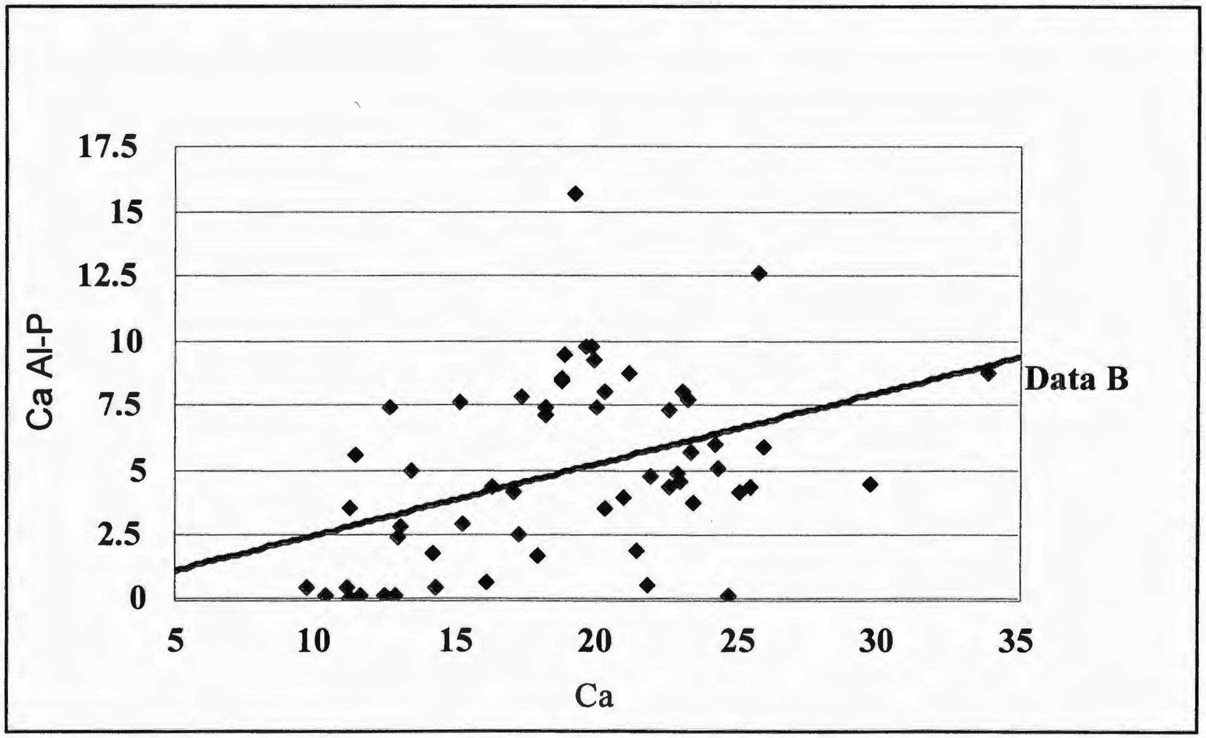
Ca-Al-P Rich Mineral Occurrence vs. Calcium Content

(CCSEM and XRF analysis data for 50 U.S. lignite and PRB coals)



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Background Overview

- Inorganic composition of coal
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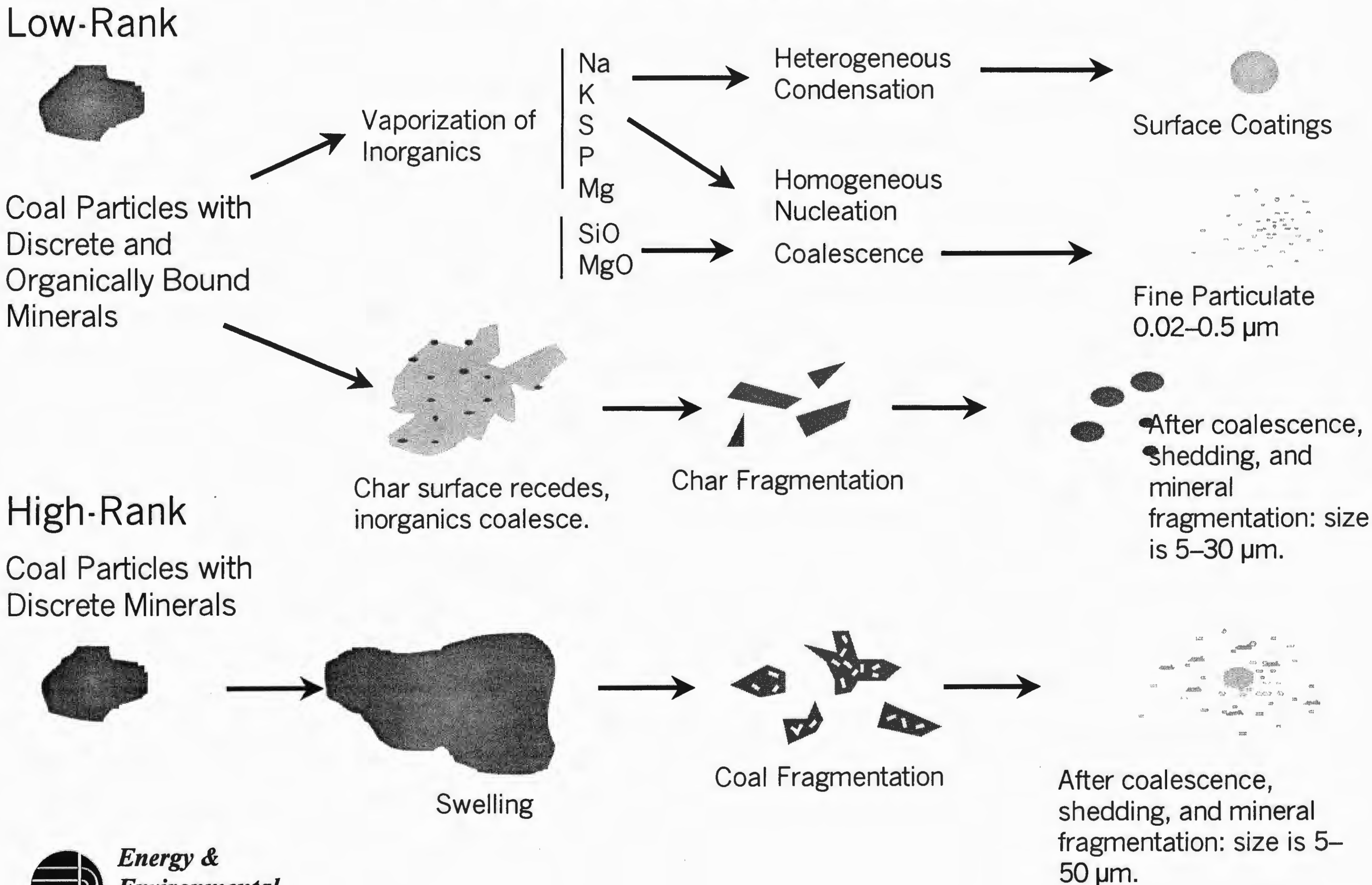
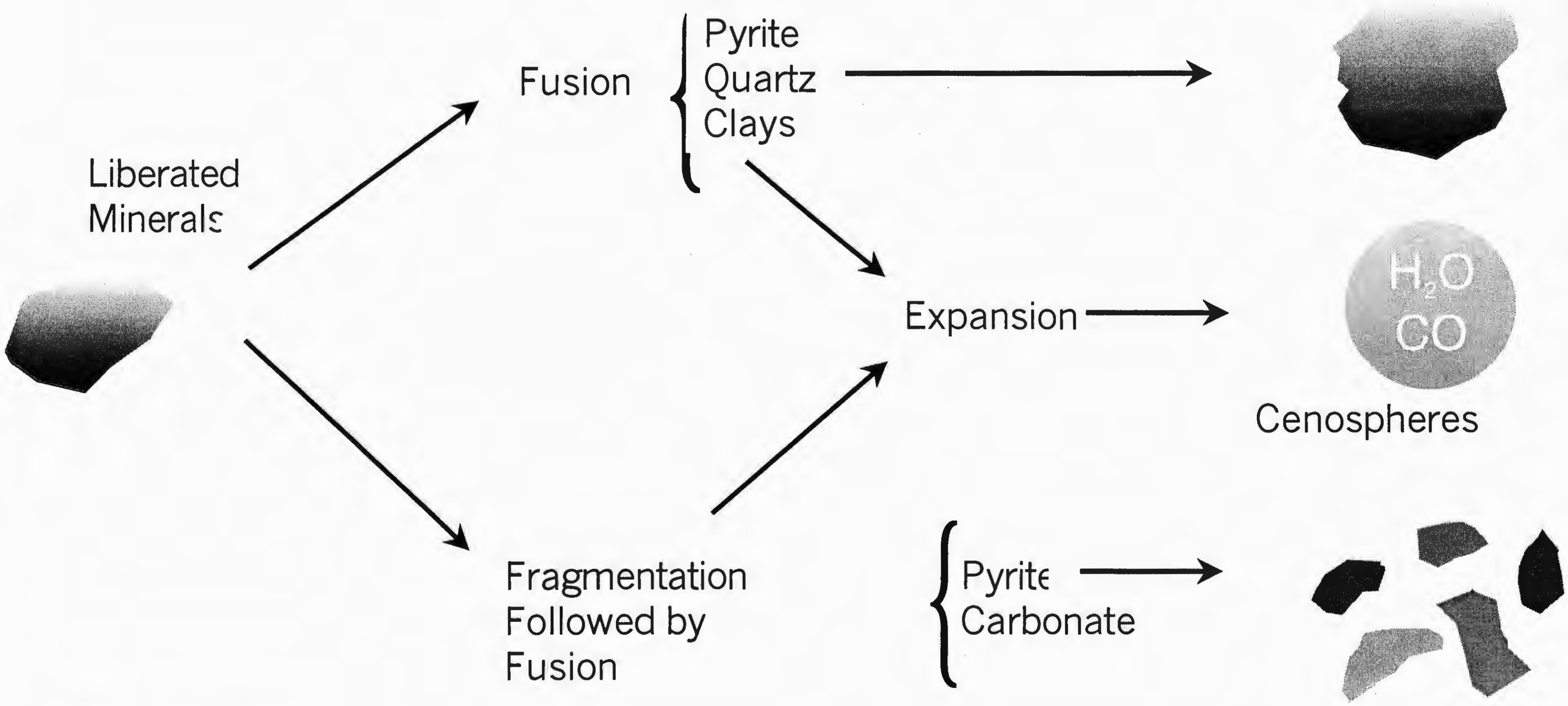
Mechanisms for Fly Ash Formation During Combustion

Coal Particles with Locked Minerals



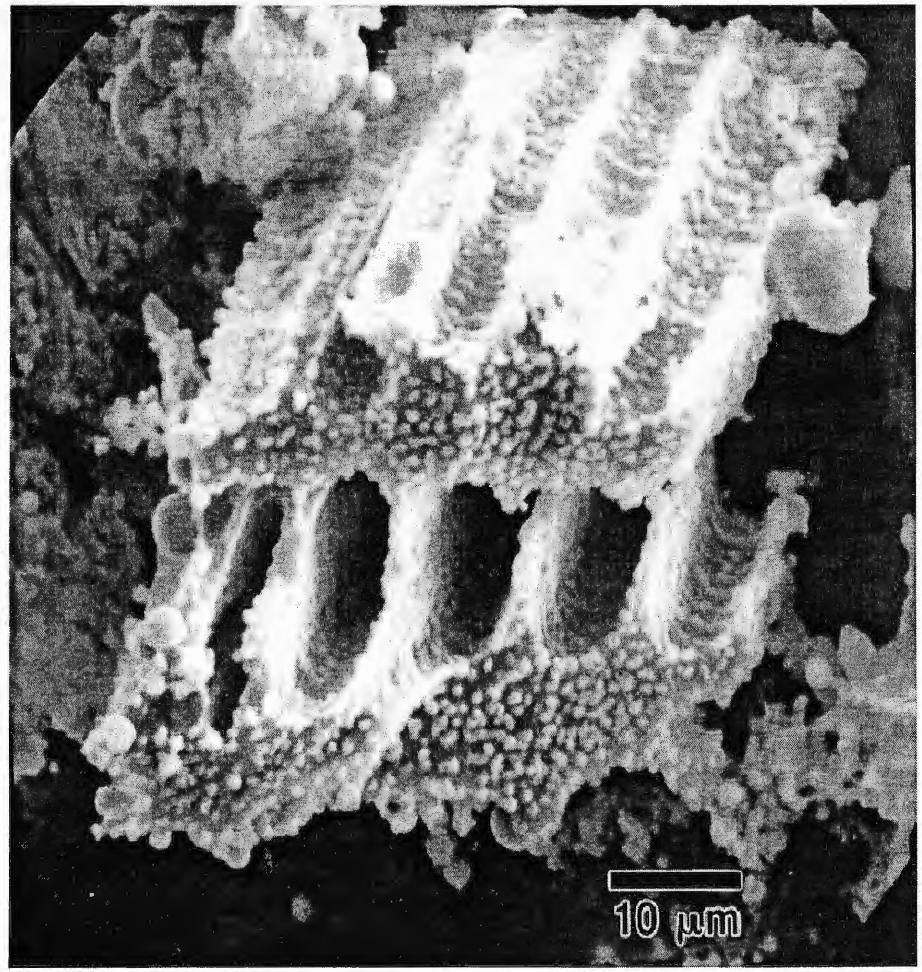
Mechanisms for Fly Ash Formation During Combustion

Liberated Minerals

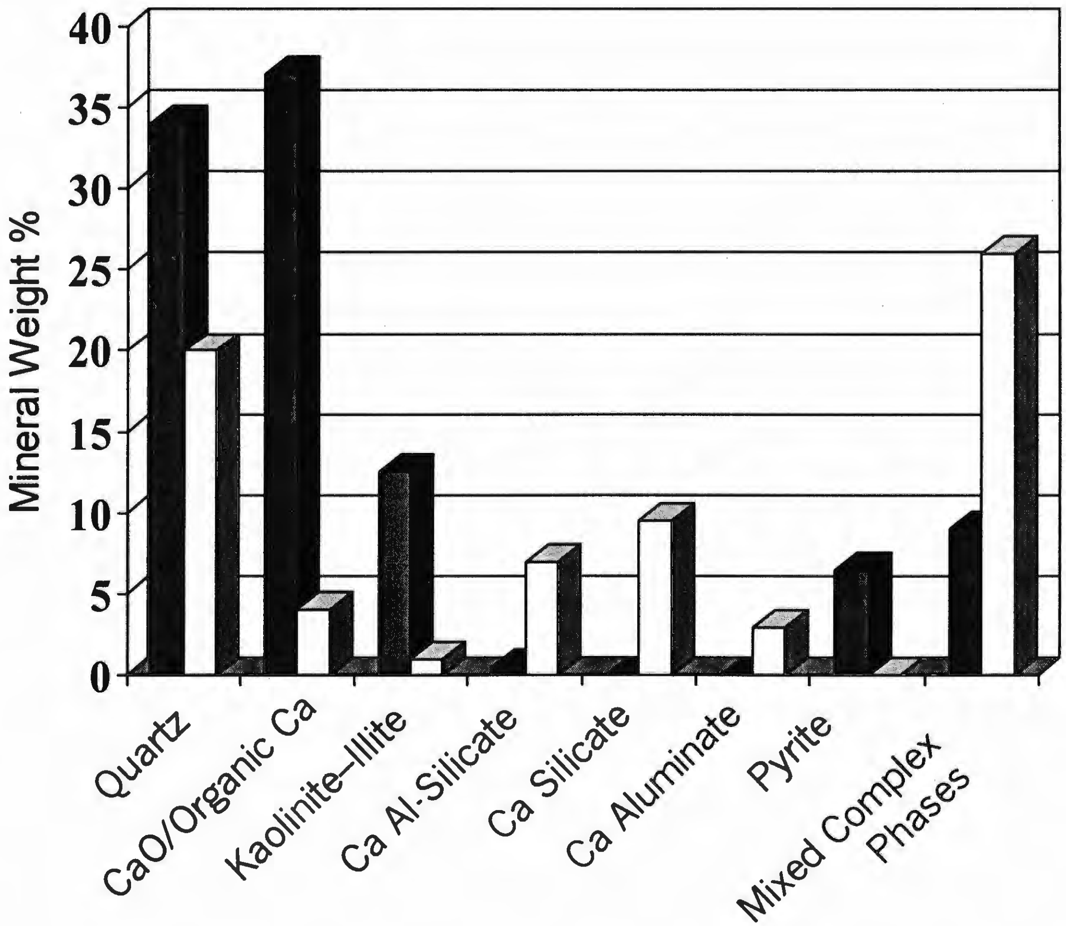


Mineral Formation in Pores

- Eagle Butte coal
- 0.5-sec char
- CaO droplets forming in pores and on surface
- SEI image



Typical Mineral Transformations of Subbituminous Coal Minerals



- Note decrease in quartz, calcium phases, and clays.
- There is a corre-sponding increase in calcium silicates and other amorphous phases.

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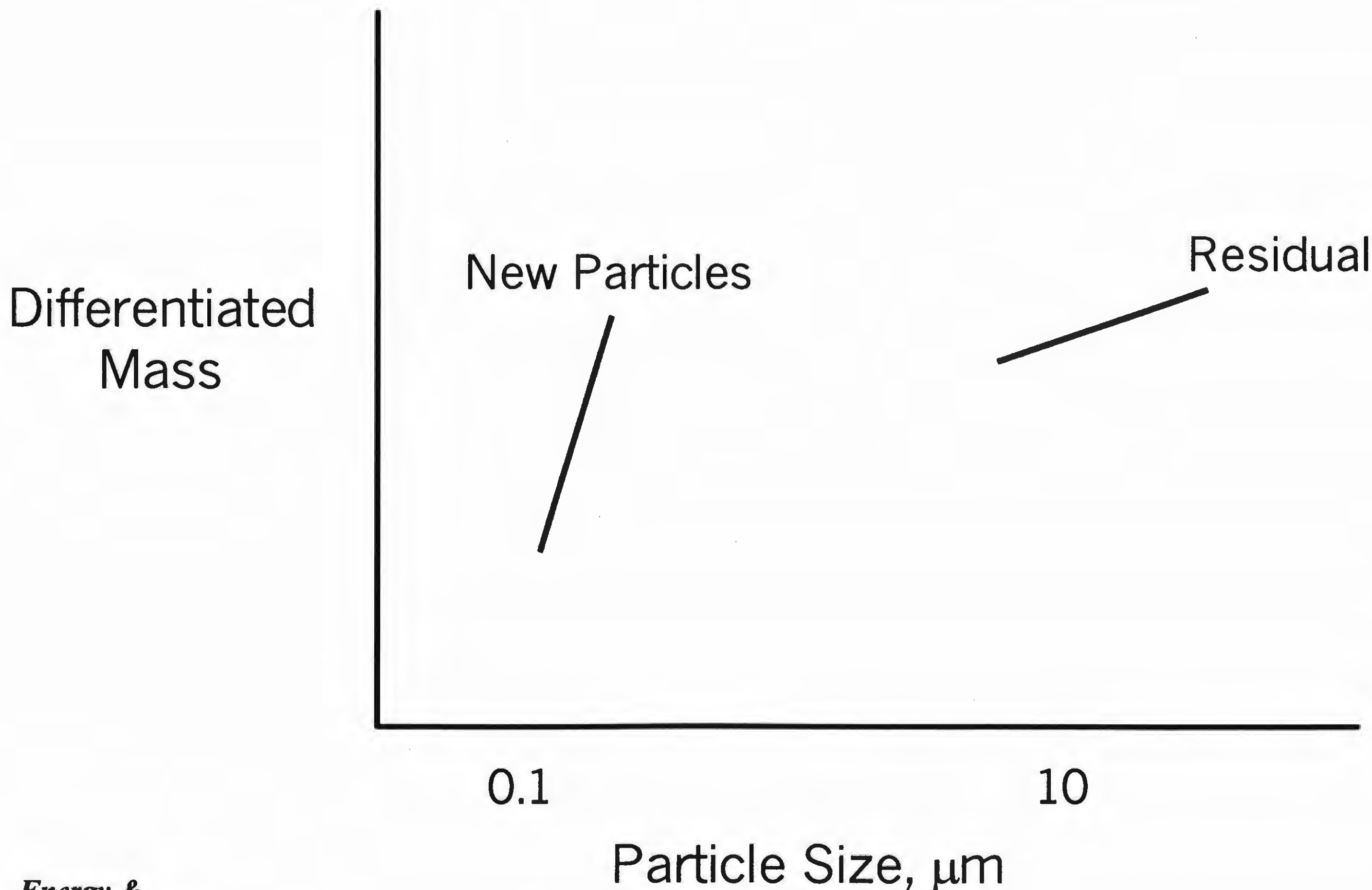
Size Distribution of Fly Ash Produced During Combustion



Background Overview

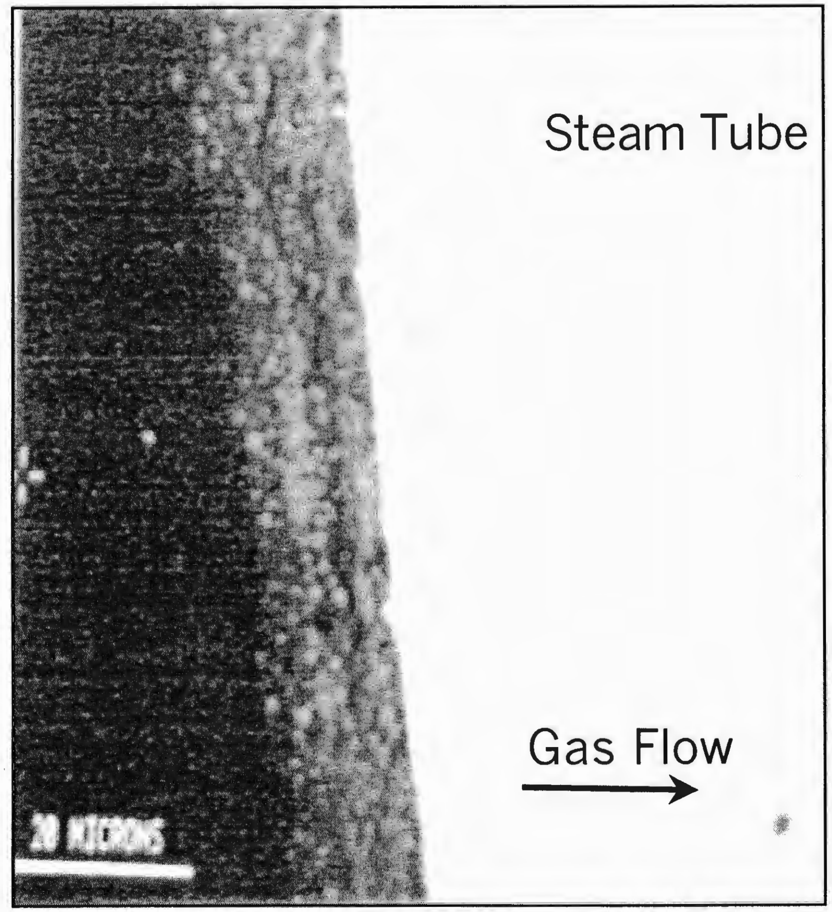
- Inorganic composition of coal
- Ash formation mechanisms
- Transport mechanisms
- Chemical reaction mechanisms
- Modeling of ash behavior

Mechanisms of Ash Transport

- Ash deposition phenomena
  - Formation of deposit layers
  - Effects of particle size
  - Inertial impaction
  - Vapor-phase and small-particle diffusion
  - Thermophoresis/electrophoresis
- Summary of convective pass deposits

Typical Low-Temperature Upstream Deposit

- Note porosity of ash layer
- Particles are small
- Dark matrix is epoxy, gray particles are fly ash
- BSE image



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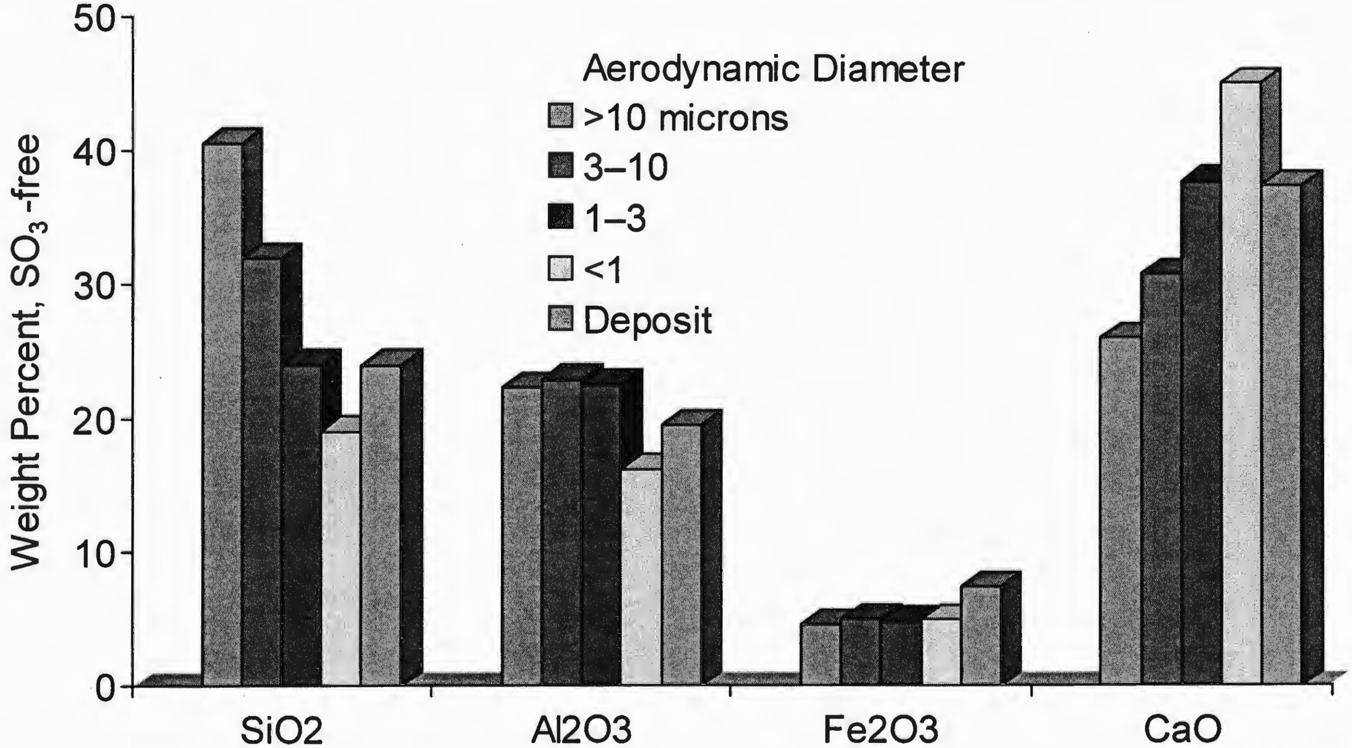
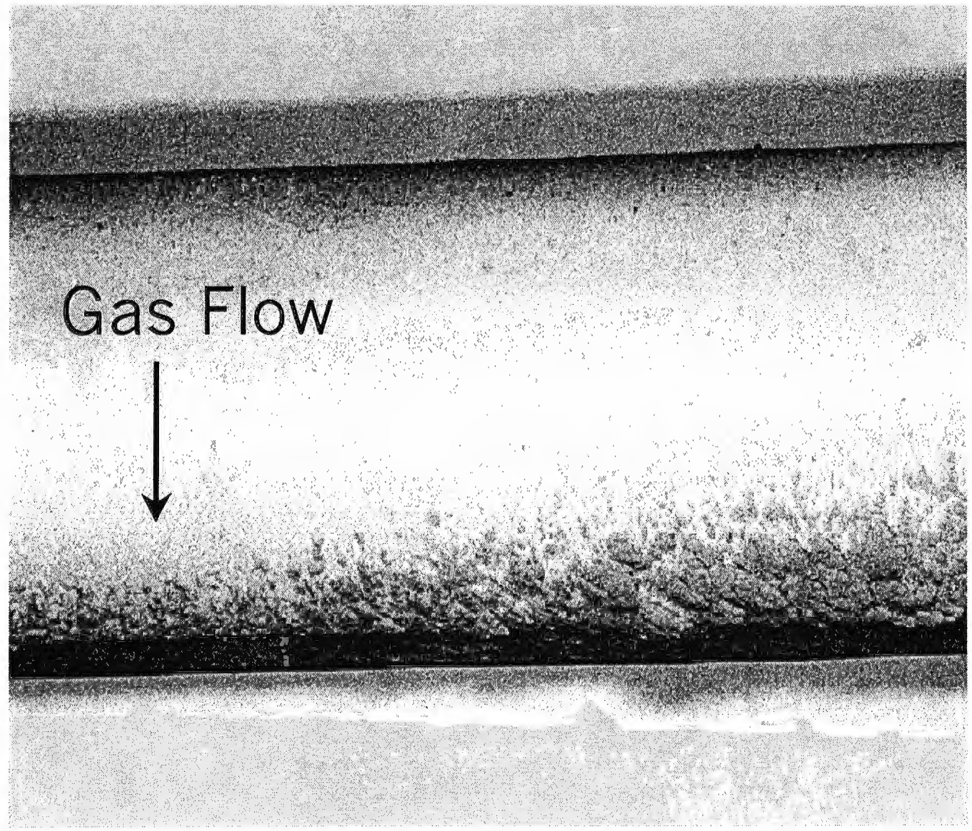
Upstream Enamel Coating

- Wyoming coal ash, 1760°F
- Note chemistry of small part-icles more closely matches deposit



Downstream Deposits

- SWEPCO Welsh Power Station Unit 1 in Pittsburg, Texas
- Test was 8 hours under high load at 500 MW
- Gas flow from top to bottom
- Note downstream deposit



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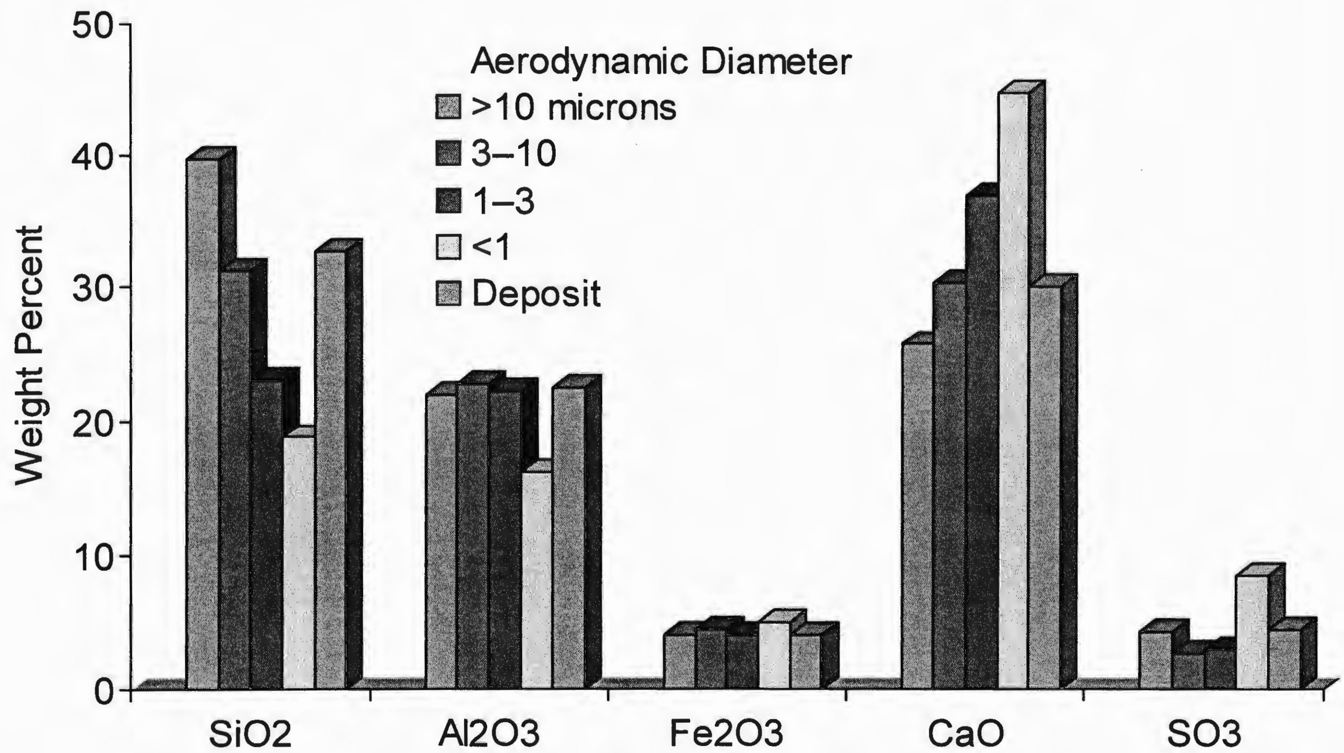
Downstream Powder

- Wyoming coal ash, 1760°F



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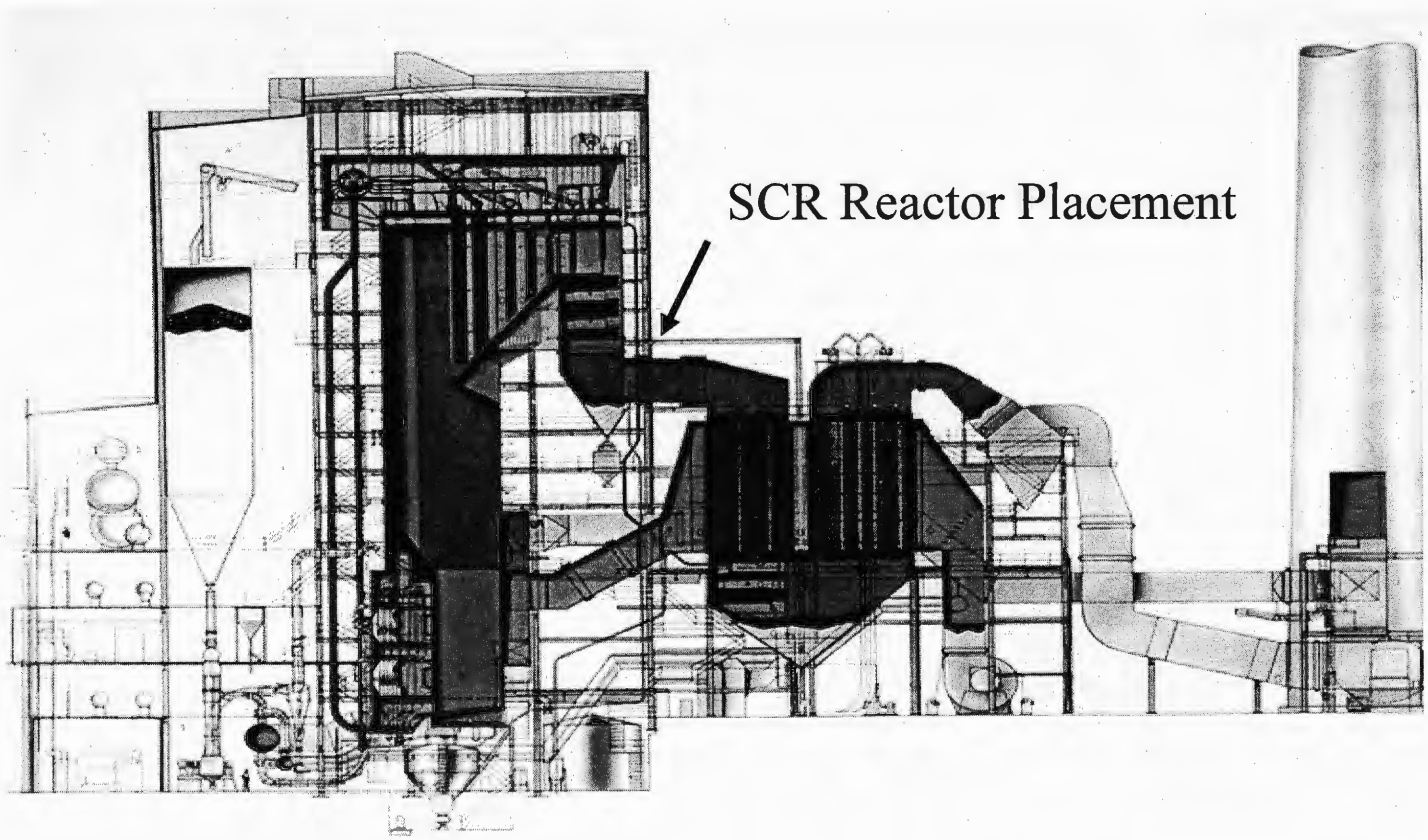
Mechanisms

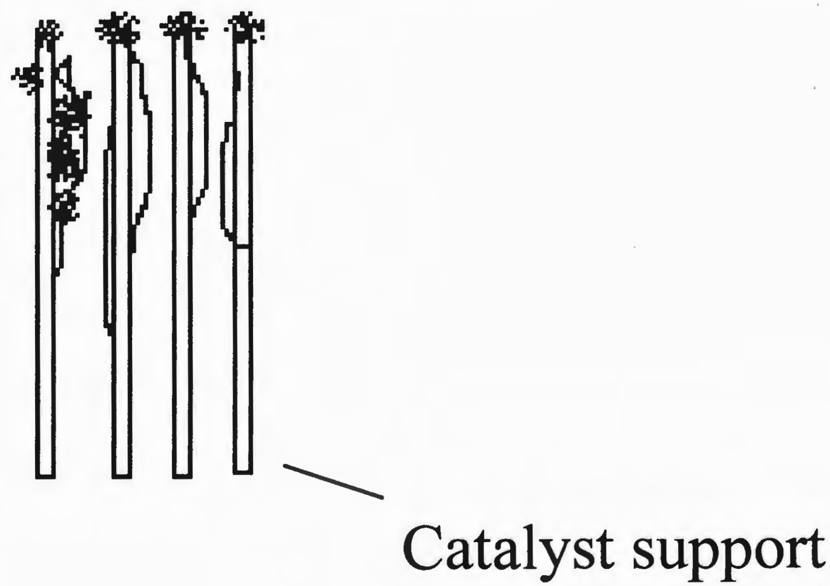
- Large particle mechanisms -- greater than 10 micrometers
  - Inertial impaction -- direct impaction and recirculation eddy impaction
- Small particle transport mechanisms -- particles less than 10 micrometers and vapors
  - Small particle diffusion
  - Vapor phase diffusion

SCR Catalyst



Transport Mechanisms

Inertial impaction and diffusion mechanisms will dominate



Background Overview

- Inorganic composition of coal
- Ash formation mechanisms
- Transport mechanisms
- Chemical reaction mechanisms
- Modeling of ash behavior

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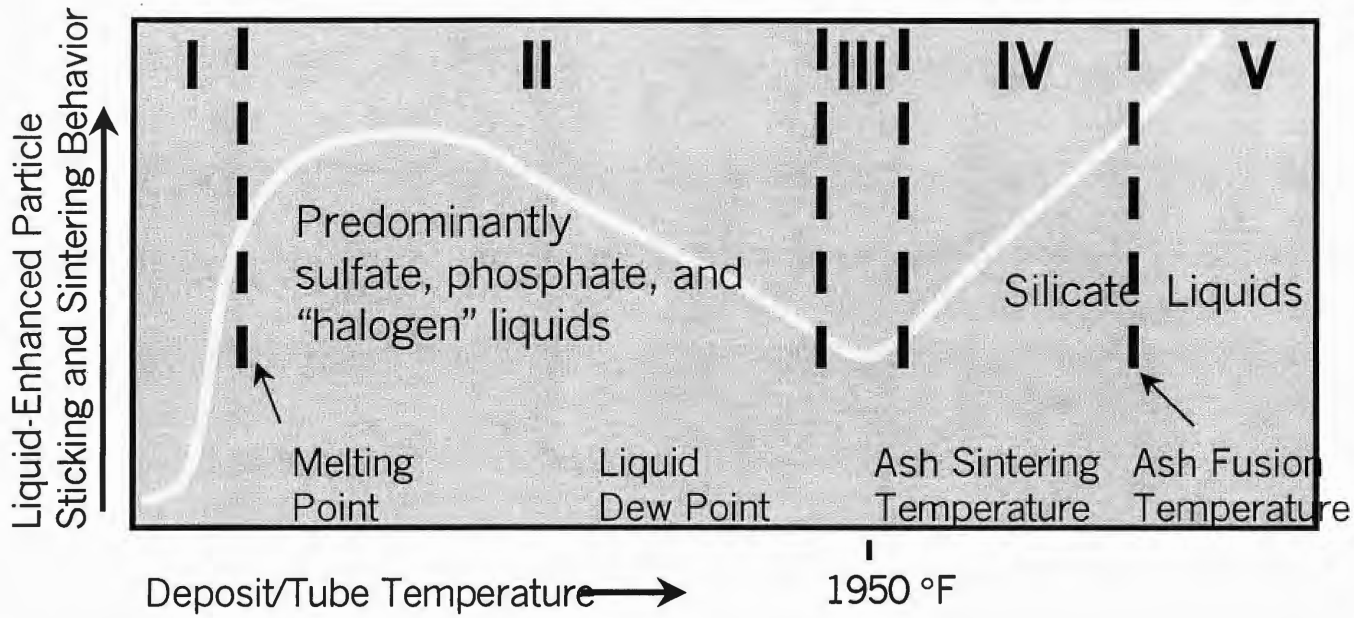
Distribution of Bonding Phases as a Function of Deposit Temperature

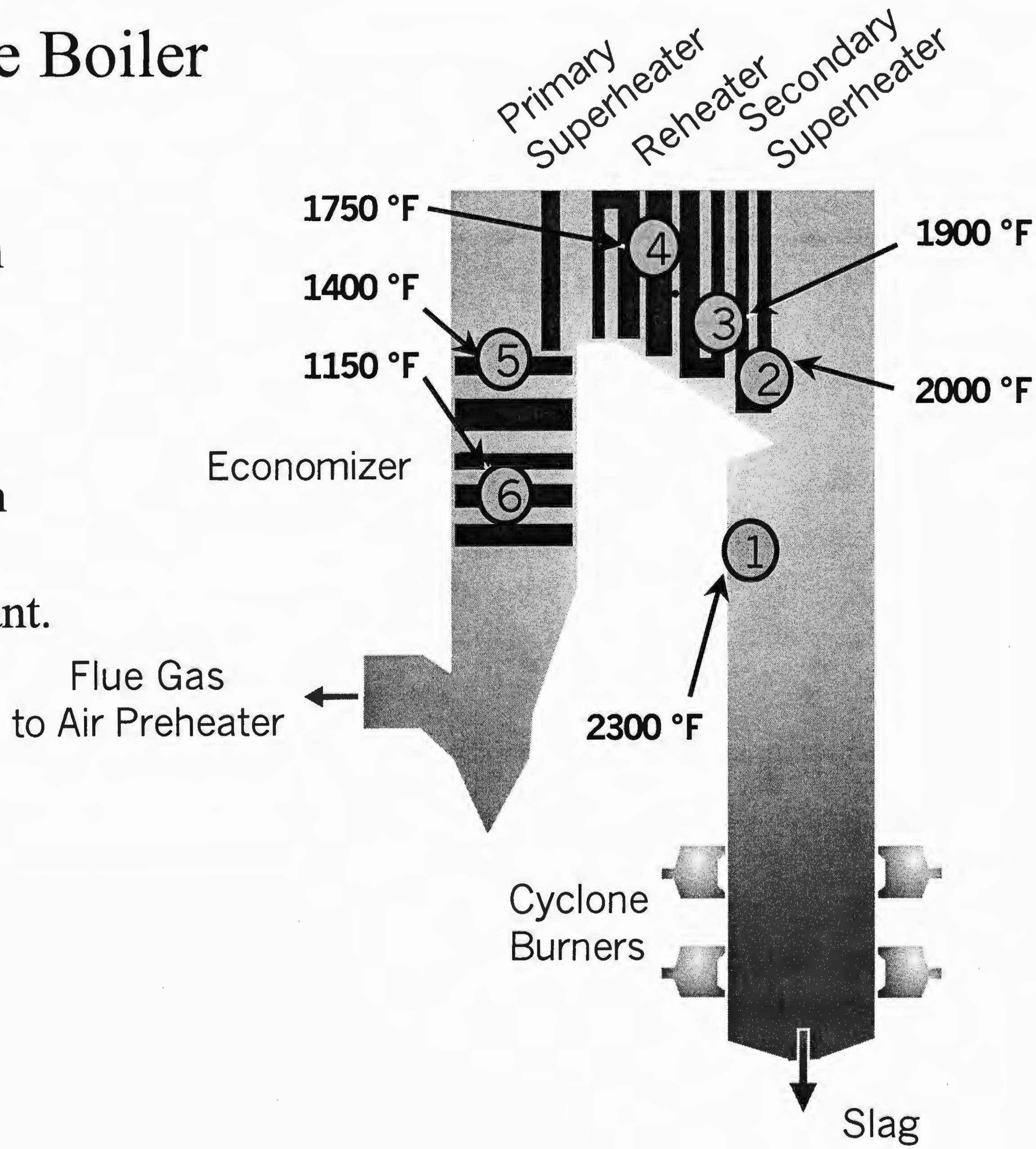


Deposition Regimes:

I. Dry-sticking regime: no glue
II. Vapor or thermophoretically deposited liquid glue
II. Glue produced by heterogeneous chemical reactions at vapor–ash interface
IV Ash particle softening on impact
V. Wet limit (sticking coefficient nearly unity)

Example Boiler

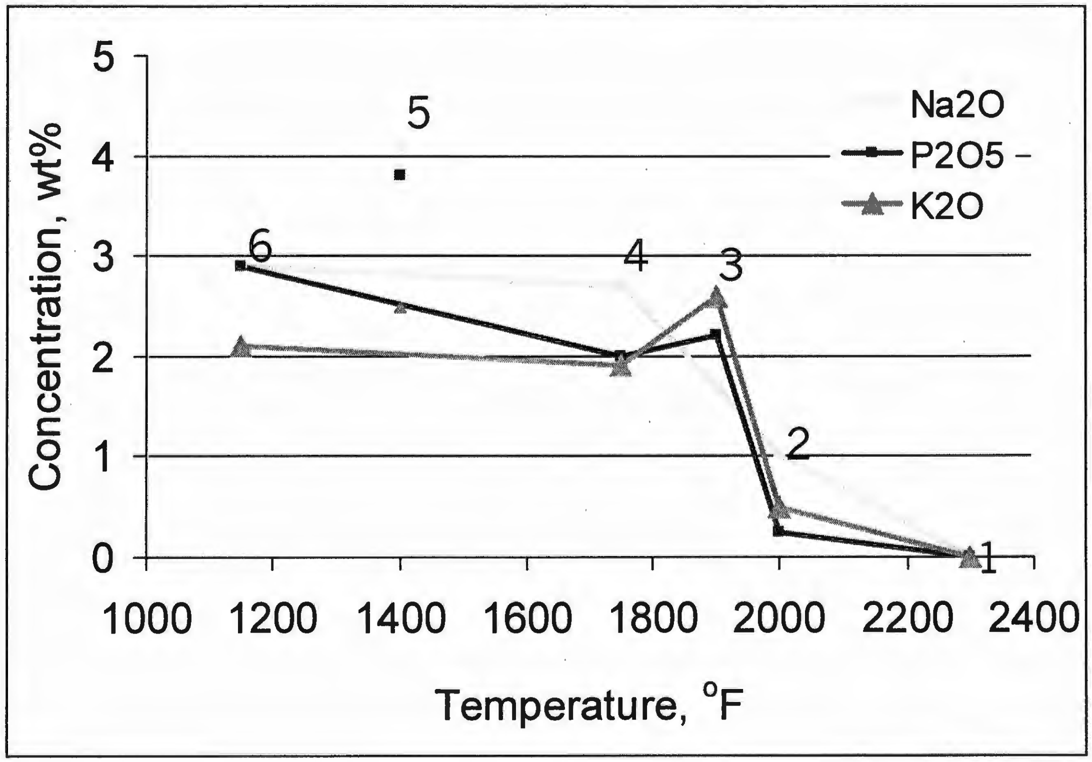
- Sample numbers on diagram refer to points on graphs in following slides.
- Samples were taken off-line at the Schahfer Power Plant.



P, Na, K Concentrations

Schahfer Off-Line Deposits

- Shown is physical vapor deposition below 2000 °F.
- Note increased alkali content as temperatures drop past condensation point.
- Numbers on graph refer to points on boiler diagram.
- Point 5 is an on-line ash sample collected with a probe.



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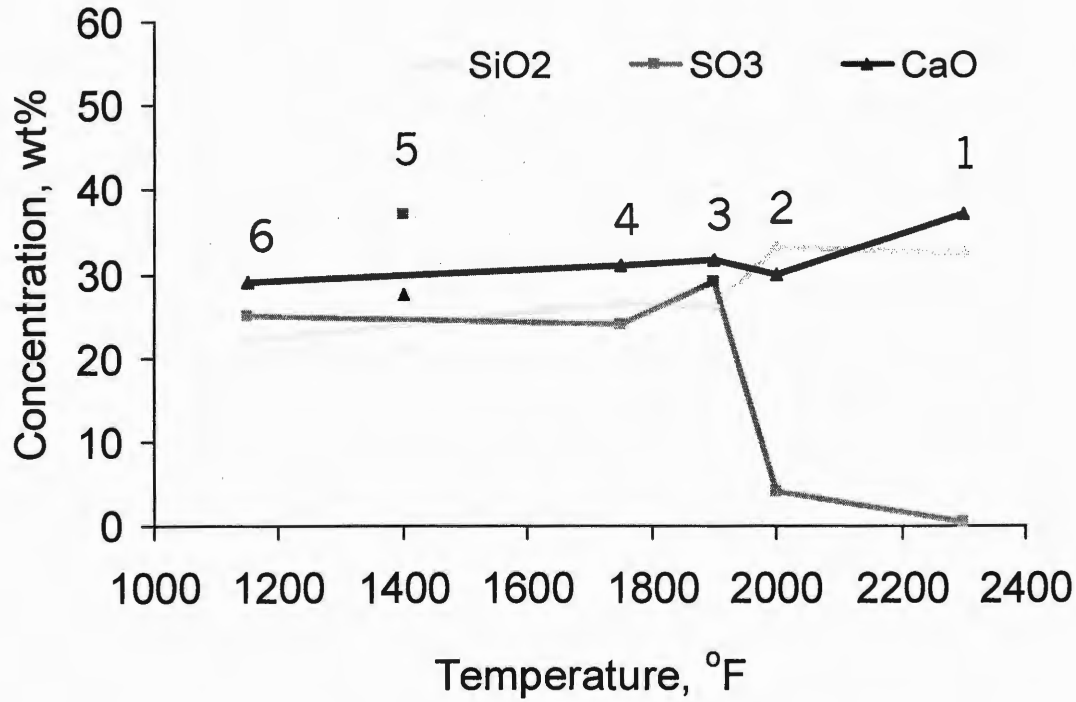
Si, S, Ca Concentrations

Schahfer Off-Line Deposits

- Shown is chemical vapor deposition below 2000°F.
- Note constant Si and Ca content; $CaSO_4$ forming.
- Numbers on graph refer to points on boiler diagram.
- Point 5 is an on-line ash sample collected with a probe.



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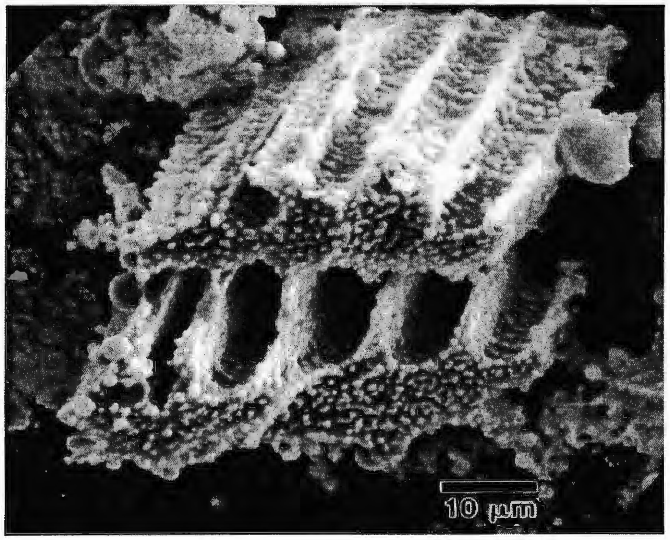
Important Chemical Transformations - I

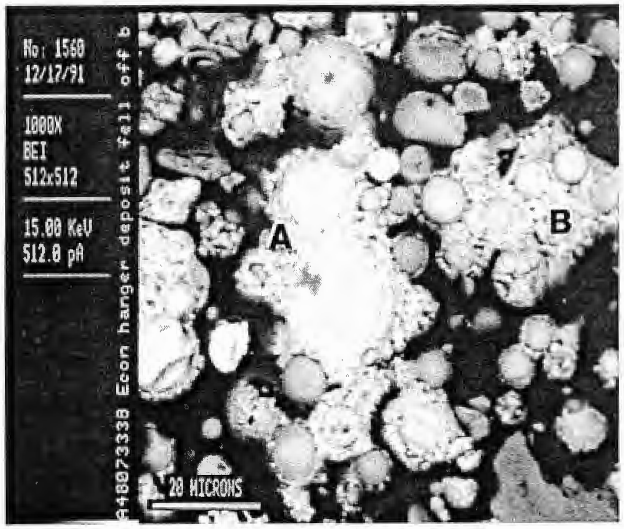
- Inorganic Association in Coal
  - Organically associated Ca



- Location and product
  - flame and boiler
    - < 1 micron particulate of CaO
    - > 1 micron particulate of calcium silicate and calcium aluminosilicate
  - high temp Convective pass
    - CaO and calcium silicate/aluminosilicate particles -- deposit react with deposited particles ....

Important Chemical Transformations - II

- Inorganic Association in Coal
  - Organically associated Ca



- Location and product
  - Low temperature convective pass
    - CaO rich particles react with SO_2/SO_3 to form sulfates
    - CaO reaction with volatile phosphorus containing phases??

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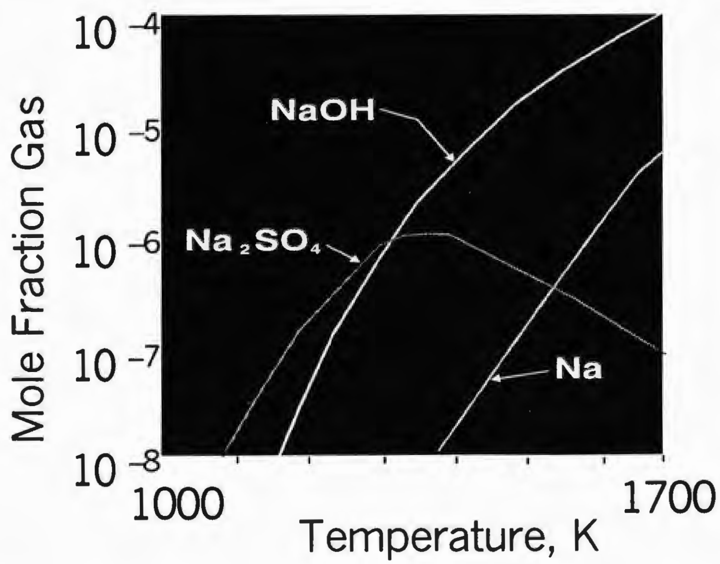
Important Chemical Transformations - III

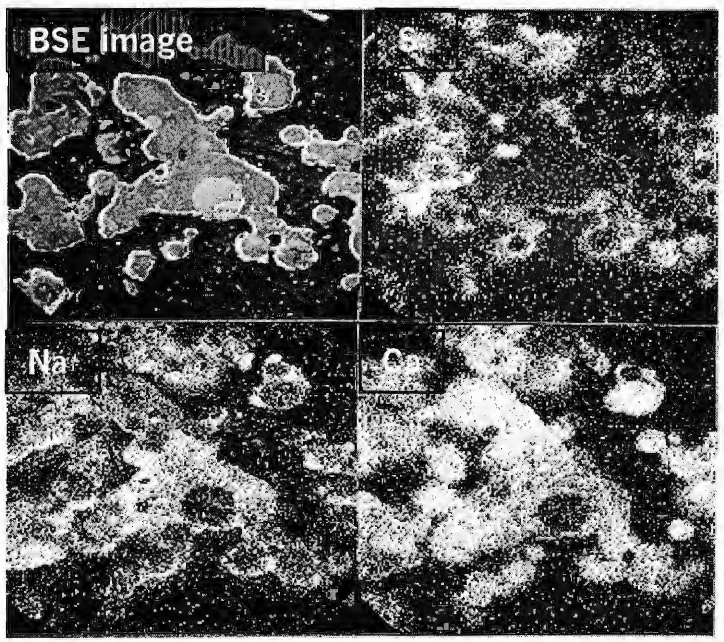
- Inorganic Association in Coal
  - Organically associated Na



- Location and product
  - Flame and boiler
    - vaporize and react with silicates and aluminosilicates
  - High temperature convective pass -- formation of sodium silicate and aluminosilicate liguids

Important Chemical Transformations - IV

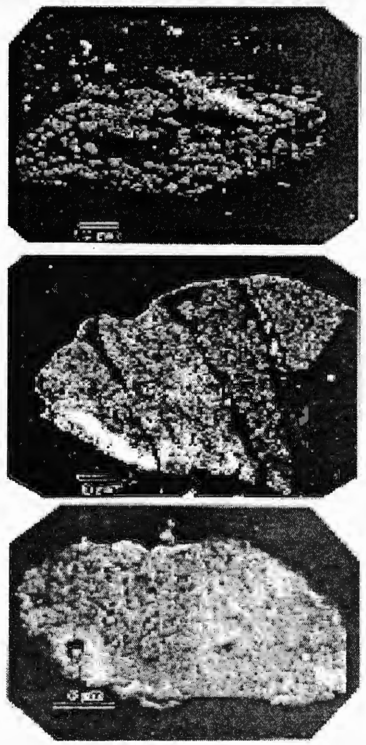
- Inorganic Association in Coal
  - Organic Na



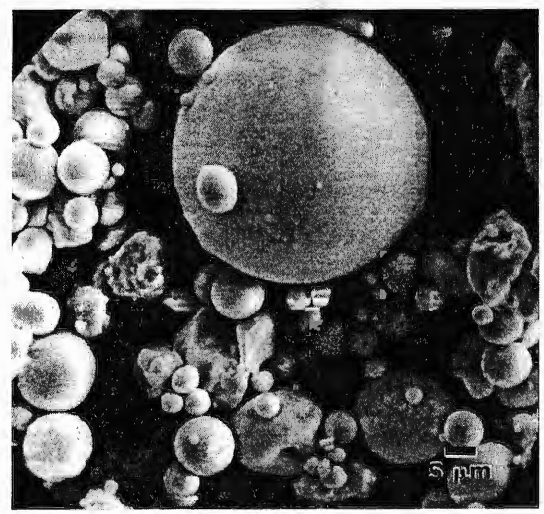
- Location and product
  - Low temperature convective pass -- temperatures below 1800 F

Important Chemical Transformations - V

- Inorganic Association in Coal
  - Clay minerals -- kaolinite, illite, and montmorillonite



- Location and product
  - flame and boiler -- melting, fusion, reaction with Ca, Mg, Na, Fe
  - Liquid phase materials that cause wall slagging



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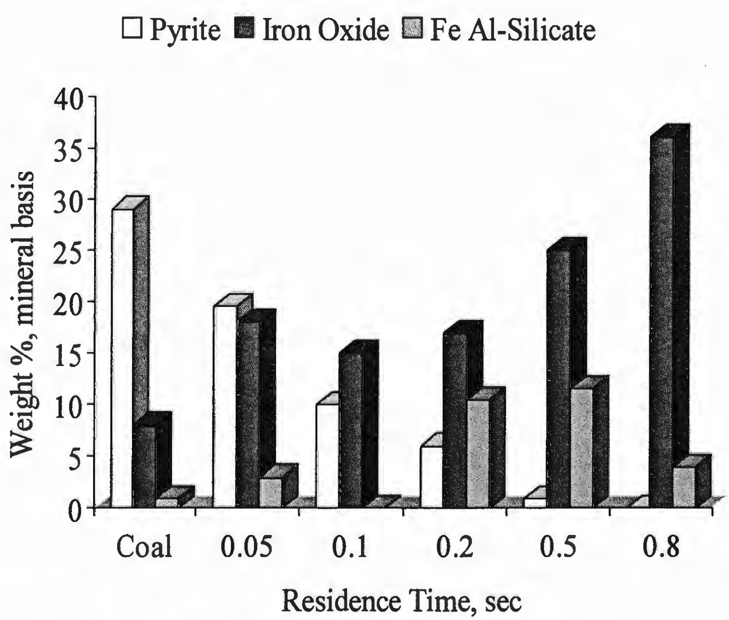
Important Chemical Transformations - VI

- Inorganic Association in Coal
  - Pyrite



- Location and product
  - Flame and boiler
    - Reduced phases--corrosion in low-NOx
    - Formation of low melting point phases that contribute to slagging

Background Overview

- Inorganic composition of coal
- Ash formation mechanisms
- Transport mechanisms
- Chemical reaction mechanisms
- Modeling of ash behavior

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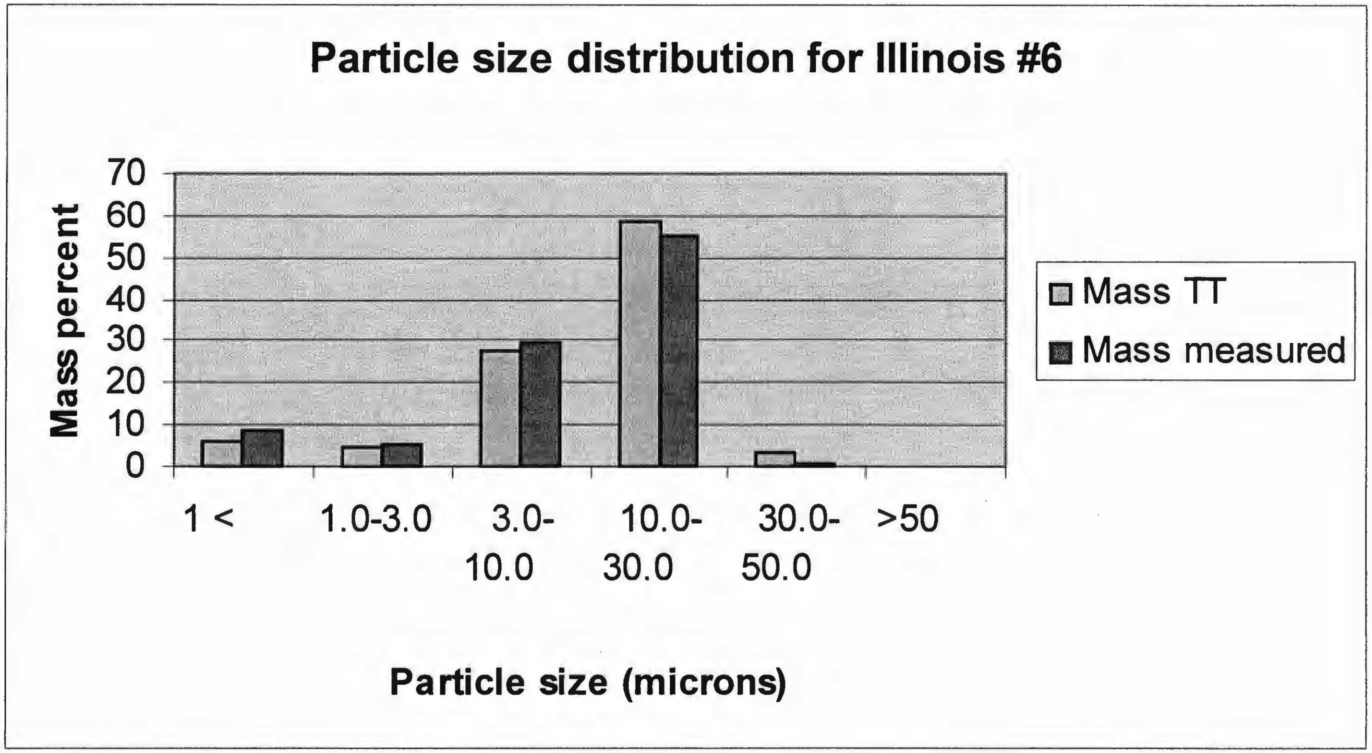
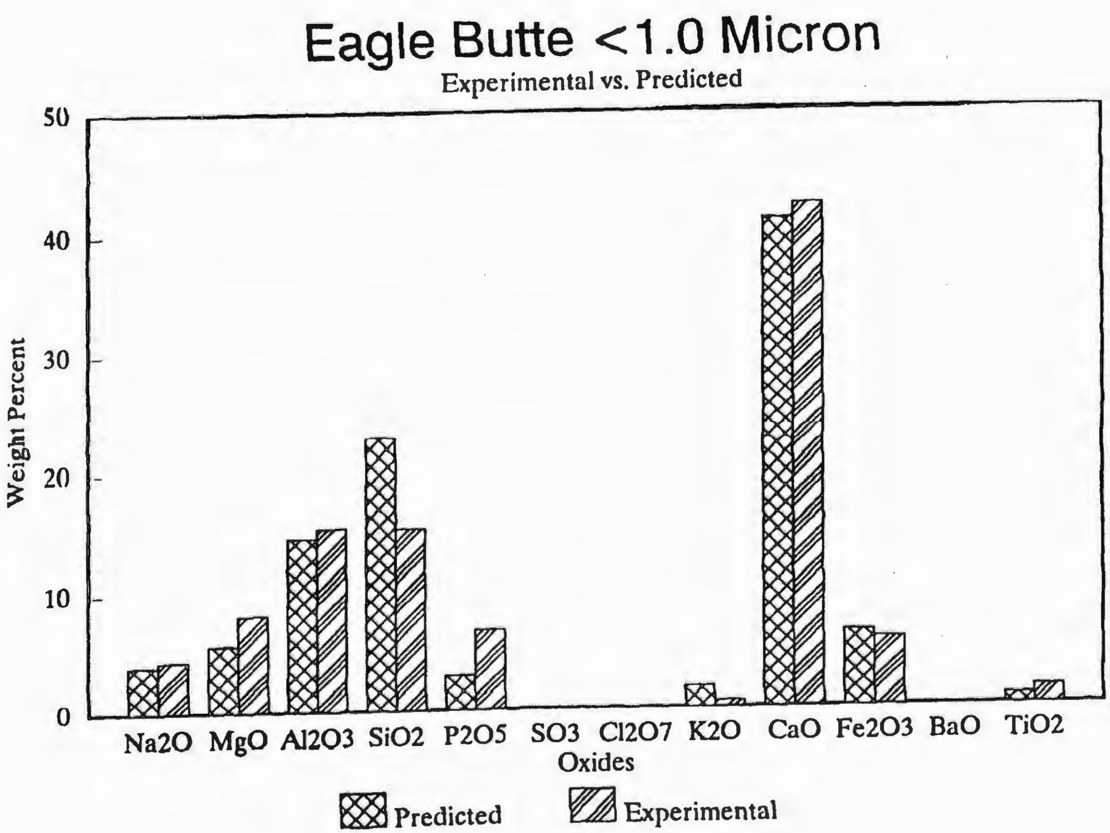
Modeling of Ash Behavior

- Ash Particle Size Composition Distributions
- Thermochemical Equilibrium Modeling -- FACT
  - Vaporization
  - Sulfur phase reactions
  - Phosphorus phase reactions

Example of Atran Prediction



Example of Atran predictions



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Example of Fact Code Predictions

- Prediction of vapor phase species

Bench-Scale Testing

- Working Hypothesis
  - Calcium and other alkaline earth and alkali-rich small particles are deposited that are subsequently reacted with gas phase components causing blinding of catalyst
  - Sulfates and phosphate are responsible for the formation of deposits that blind catalysts
  - Catalyst materials enhance formation of SO_3 enhancing sulfation rates

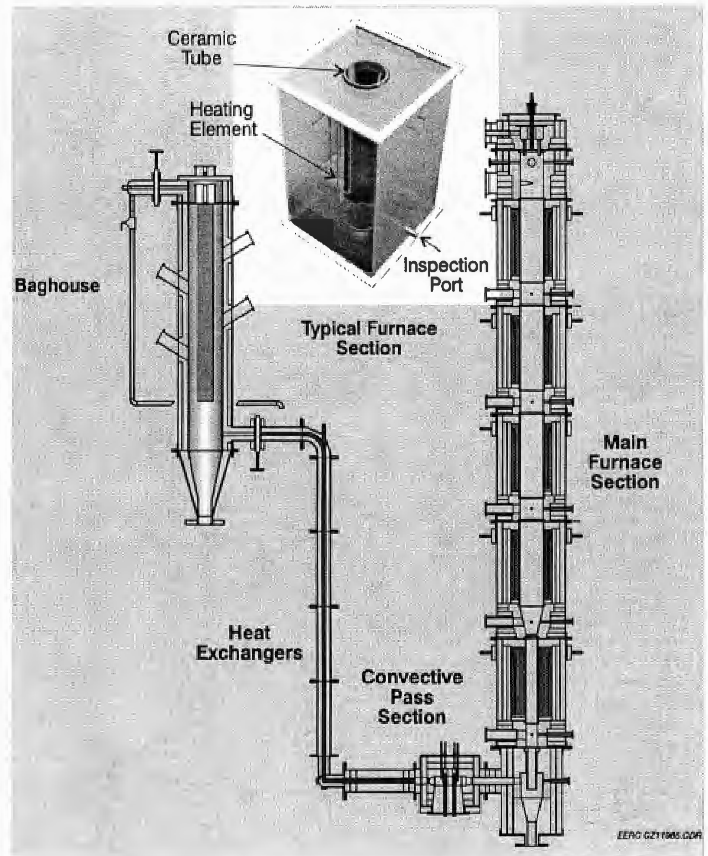
Bench-Scale Testing

- Calcium-rich small particles are deposited that are subsequently reacted with gas phase components causing blinding of catalyst
  - Production of ash from selected coals with and without phosphorus bearing minerals under simulated combustion conditions using small-scale combustion system
  - Collection and characterization of size-fractionated ash to determine distribution of elements as a function of particle size and vapor phase

  -- Information can be used ultimately to assess a coals potential to blind a catalyst

Combustion Testing

- Bench-scale combustion testing using the conversion and environmental process simulator (CEPS)
  - Coal blends
  - Fouling and slagging deposits
  - Multicyclone or impactor ash collection
- 4.4 lb/hr (2 kg/hr) pf and 40,000 Btu/hr
- Preheat air 950°C, main furnace flue gas up to 1600°C, convective section 760°–1200°C, flue gas sampling location 250°C



Ash Characterization -- SEM

- Morphology – pictures and chemical analysis
- Computer controlled scanning electron microscopy – size, composition and abundance
- Bulk composition of size fractions

Bench-Scale Testing

- Sulfates and phosphate are responsible for the formation of deposits that blind catalysts
  - Thermal gravimetric analysis to determine the optimum reaction temperature and reaction rates for small calcium rich ash particles from the combustion testing
    - Gas composition will be a simulated flue gas with SO_2 and gas-phase phosphorus compounds that are passed over a catalyst to produce SO_3

TGA System

- Measures increase or decrease in mass as a function of time, gas composition, and temperature
- TGA system will be equipped with a heated flue gas pretreatment cell containing SCR catalyst material to determine the effect of SO_3 on weight increase

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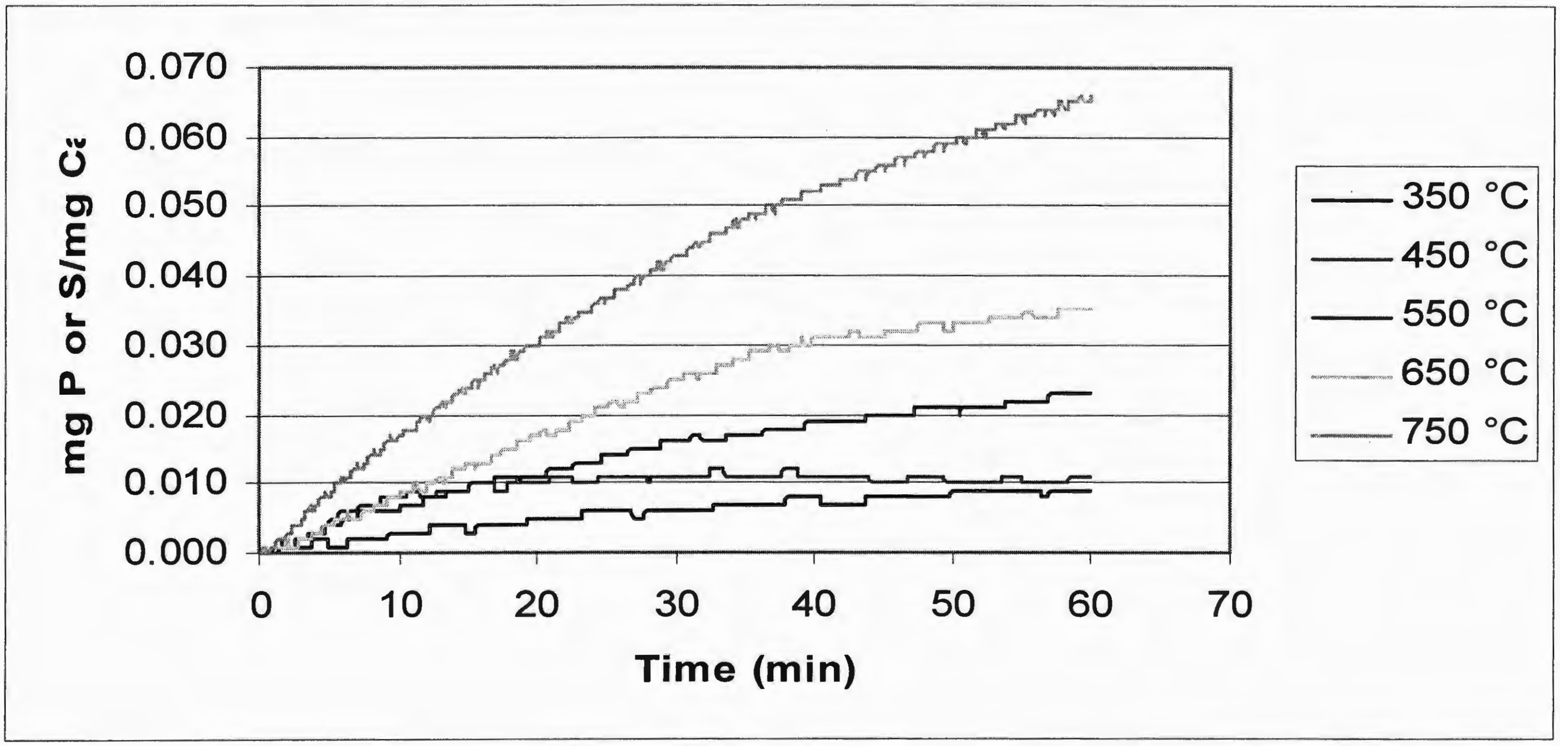
TGA Testing

- Temperature ramps from 400 to 1000 F to determine optimum temperatures containing sulfur dioxide and phosphorus containing species – effects of ammonia
- Isothermal testing to develop reaction rate as a function of temperature
  - This testing will provide key information on the rate of blinding that will occur as a function of temperature and gas composition

Sorption of Vapor Phase Species with CaO- TGA Analysis Example



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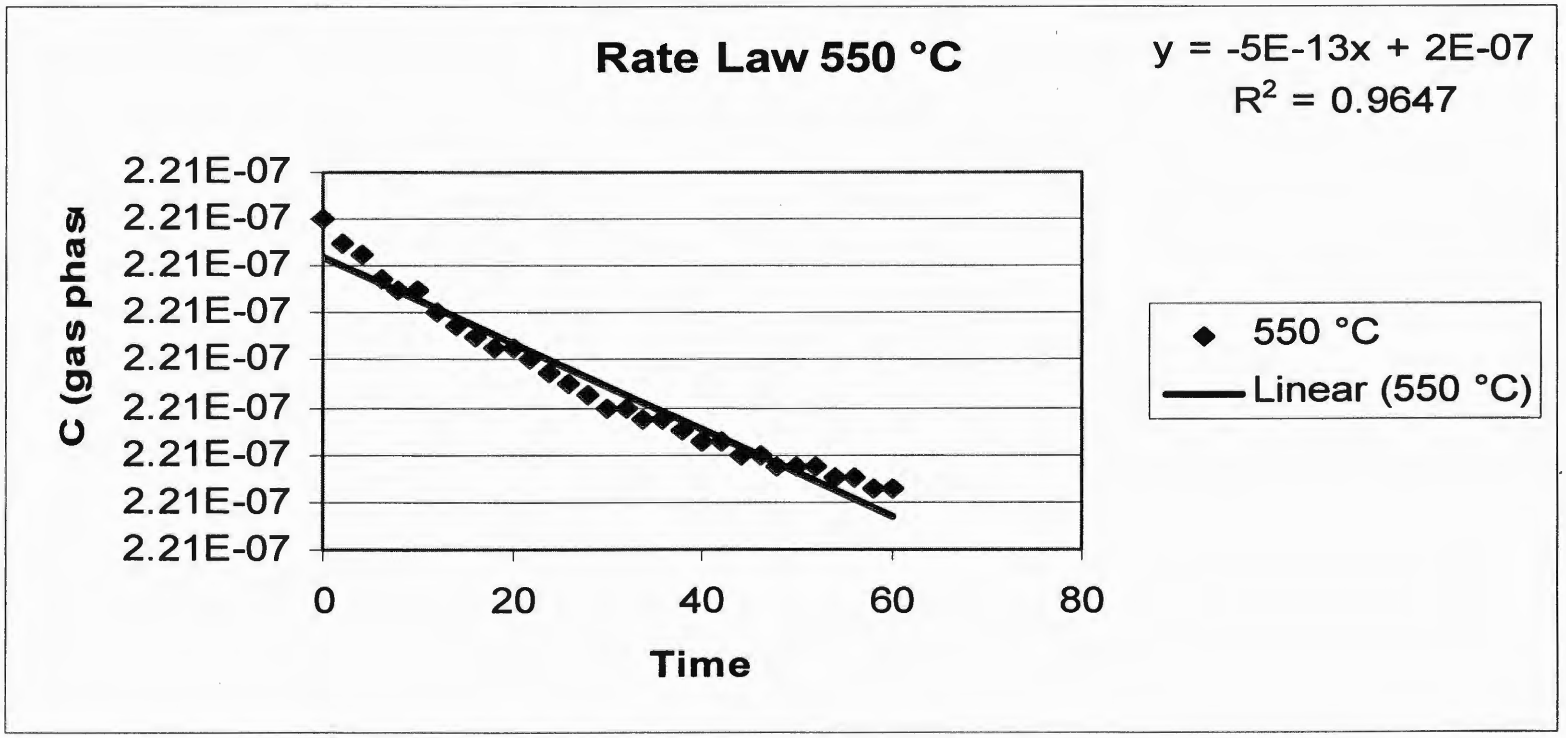
Kinetics-Results



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Characterization of Reaction Products

- SEM morphological analysis
- X-ray diffraction to determine the crystalline phase present

Modeling

- FACT code predictions for sulfate and phosphate phases and compare to measured data – validate the modeling efforts
- Compare Atran prediction

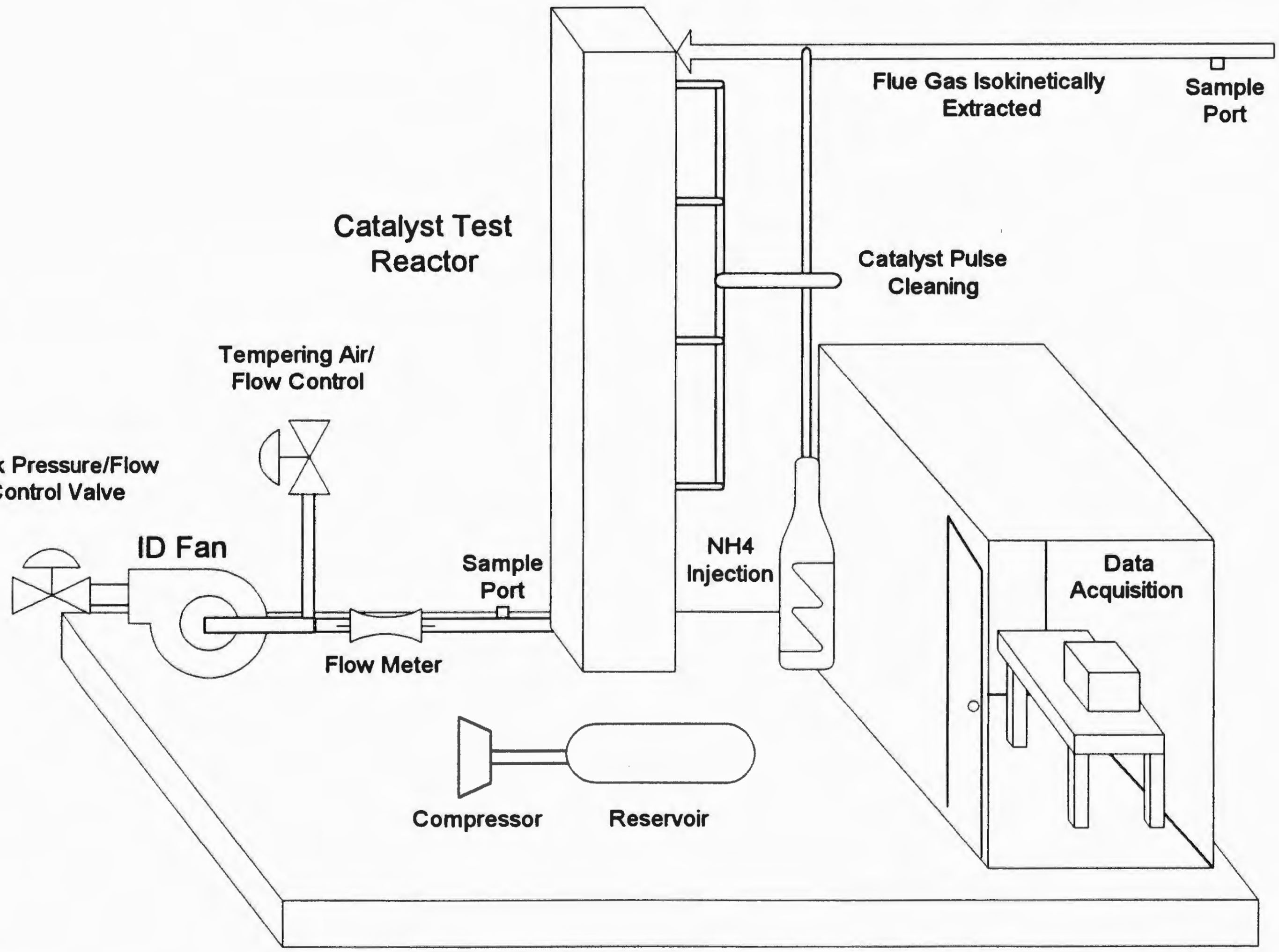
Uses of Bench-Scale Data

- Provide fundamental information on temperatures, gas phases species, and reaction rates that can be used to determine the potential impact on SCR catalyst performance
- Selection of coals to field test
- Critical temperature ranges to conduct the field testing
- Technique to screen coals for impact on SCR performance

SCR Reactor Design

- Skid-Mounted Set-Up
- Catalyst Configuration
- Size and Operating Conditions
- Boiler Access
- Data Acquisition

Conceptual Drawing



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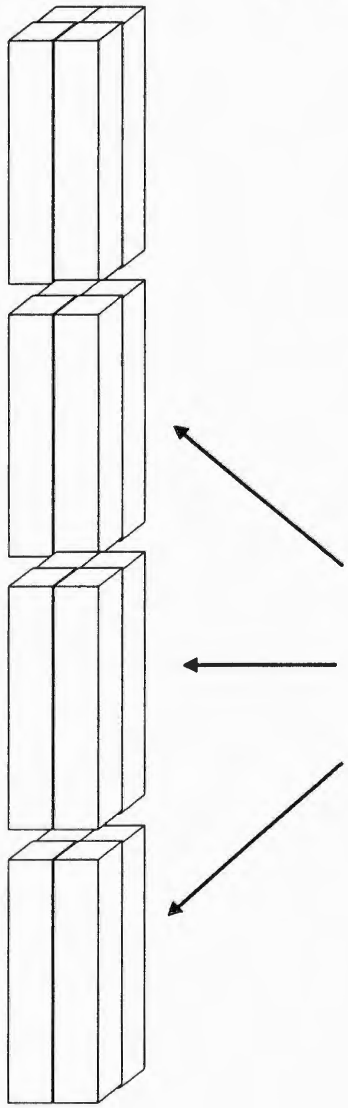
Catalyst Configuration



Flow Conditioner

No Sampling

1 sample removed from each level for analysis at intervals of 1 month, 3 months, and 6 months

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Design Advantages

- Realistic Size and Operating Conditions
- Isokinetic Gas Sampling
- Temperature Control
- Ammonia Injection
- Ease of Sampling
- Fully Instrumented

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Operating Conditions

- Gas Temperature - 600°F
- Gas Flow Rate - 150 acfm
- Ammonia Injection Rate - 1:1 with NOx level
- Tempering Air for Fan ~ 100 - 150 acfm
- Space Velocity ~ 2500 hr^{-1}

Boiler Access

- Need port to accept 3.4” ID nozzle
- Electrical Connections
- Phone Line
- Internet Access
- Optional Utilities
  - Water Hookup and Drain
  - House Air

Data Acquisition

- Computer
- Software: Lab-Tech
- Hardware:
  - Thermocouple Board
  - Analog Input Board
    - Pressure Transducers
    - Gas Analysis
- Internet Access to Data

Equipment List

- Catalyst Material
- Fan(s)
- Flow Meter(s)
- Stainless Piping
- Valves
- Thermocouples/ Pressure Transducers
- Heaters
  - Heat Trace/Reactor
- Insulation
- Computer for Data Acquisition
- Data Acquisition Hardware and Software
- Compressor/Reservoir
  - Catalyst Cleaning
- Gas Analyzer

Discussion

Site Selection

- Lignite-Fired Boiler
  - Assumes a North Dakota utility as one host site.
- PRB-Fired Boiler
  - Open
- Location, Location, Location
  - Boiler Access
  - Availability of Operations/Technical Staff
  - Data Acquisition/Internet Hookup

Site Selection

- May be able to test multiple sites for each coal type
- Suggested sites:
  - ND lignite-fired boiler, year 1, 6 months
  - PRB-fired cyclone boiler, year 1, 6 months
- Possible Additional Sites
  - PRB-fired p.c. boiler, year 2, 6 months
  - Site 4??

Host Site Considerations

- Technical Staff Liason
- Operator Availability
- On-Site Ammonia
- Internet Hookup
  - Availability of data to sponsors
- Boiler Access
  - Port location(s) and size

Discussion

Sampling & Mechanisms

Jason Laumb

Sampling & Determination of Mechanisms

- Sampling Methods
- Analytical Procedures
- Determination of Mechanisms
- Current Hypothesis
- Expected Results

Sampling Methods

- Slip in place for 6 months
- Periodic sampling of catalyst to determine reactivity (1 sample per month)
- Hg sampling (OH method CEM) - taken periodically
  - Ontario Hydro - Hg speciation
- Coal and entrained ash samples taken periodically

Analytical Testing

- Reactivity testing done by catalyst vendor and at EERC
- Entrained ash and catalyst analyzed by SEM, XRD and other techniques
  - SEM - Surface structure and composition
  - XRD- Crystalline phases
- Coal samples to be fully characterized (CCSEM, Prox/Ult., ASTM ash, Trace elements)
  - CCSEM - Mineral associations in the coal
  - Prox/Ult - C, N, H, O, H_2O, Ash

Determination of Mechanisms

- All physical and chemical data will be brought together to determine the severity and cause of catalyst blinding.
- Trace element analysis of catalyst material for As, Sr and Ba. (especially potential As poisoning)
- Solubility testing/cleaning?
  - Catalyst reactivation?

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Current Hypothesis

- Sulfur - Reacts with Ammonia to form small particles of ammonia bisulfate (low temperature, cycling)
- Alkaline Metals - Can react chemically with active sites rendering them inactive. (Water soluble Na & K)
- Earth Metals - React with SO_3 to form sulfate phases which mask the surface. (especially $CaSO_4$)
- Vanadium - Vanadium on surface oxidizes SO_2
- Sintering - Loss of pores due to high temperatures. (Long time period)

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Hypothesis Cont.

- Fly ash plugging - Excess fly ash carryover plugging catalyst pores.
- Arsenic - Vapor phase As penetrates catalyst pores and attaches to active sites.
  - occurs at a rate of 65% over 16,000 hours in dry bottom furnaces (Japanese catalyst vendor)
  - over 400 hours in slag tap furnaces. (German power plant)

Expected Results

- High content of alkaline earth metals, S, and SO_3 will lead to the formation of low-temperature sulfate based deposits.
- As poisoning? - depends on CaO content in the ash
- Deposit buildup can blind/mask the catalyst.
  - Decreased reactivity
  - Increasing Ammonia slip
- Combine results from bench and full scale testing
  - less expensive testing procedure

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CONFERENCE CALL AGENDA

Evaluation of Potential SCR Catalyst Blinding During Coal Combustion

Thursday, September, 7, 2000

Potential Participants

Terry Graumann, Ottertail Power Company
Rene Mangal, Ontario Power Technologies (will be absent)
Dave O'Connor, EPRI
Ken Stuckmeyer, AmerenUE
Edmundo Vasquez, Alliant Energy
Reda Iskandar, Cormetech Inc.
Cliff Porter, North Dakota Industrial Commission, Lignite Energy Council
Thomas Feeley, U.S. DOE NETL
Chris Zygarlicke, EERC
Steve Benson, EERC
Jay Gunderson, EERC
Don Toman, EERC
Jason Laumb, EERC

Action Items

Several action items have resulted from this initial meeting.

- Steve Benson, who made the initial contact Detroit Edison is following up with them. They were at one time very hopeful about being a part of the team and were working on funding approval.
- Chris Z. contacted Tom Watkins and others from AECI and they are evaluating whether or not to join.
- Steve Benson has contacted Keith McFarland or Mark Leifer from Illinois Power/Dynegy.
- Dave O'Connor (EPRI) obtained names for TXU and Central and Southwest for the EERC to contact for joining the project. Jay Gunderson is checking with these contacts.

    - Cliff Clark (214-812-8451) cliff.clark@txu.com)TXU)
    - Tommy Slater (214-777-3617) tslater@CSw.com) Central and Southwest

- EERC sent out the proposal to DOE for JV funding the week of August 7-11, 2000.
- Jay Gunderson has had conference call meetings with various individuals to finalize a design for the SCR test reactor.

- Reda Iskandar (Cormetech) was to look into the possibility of getting catalyst from the New Madrid power plant for analysis.
- Terry Graumann (Ottertail Power Company), Rene Mangal (Ontario Power Technologies), Ken Stuckmeyer (AmerenUE), Edmundo Vasquez (Alliant Energy), and Bill Rogers (Detroit Edison??) need to:
    1. Provide Steve Benson with coals for the bench-scale testing (send 5-10 gallons of each coal).
    2. Obtain permission and check into any hurdles with respect to their candidate boilers having the SCR test chamber set up there sometime in the next 18 months.
    3. Terry has sent coal to the EERC.
- EERC has adjusted the work plan and budget to fit changes needed after discussions with sponsors.

Discussion Items

1. What units should be tested and what coals and in what order?

- We propose three field tests at three different utility boiler units as follows:
    1. Field Test #1: Testing the honeycomb (Cormetech) catalyst and the plates type of catalyst (Siemens ? other?) for six months on PRB coal using two SCR test reactors (#1 and #2)
        - Schedule: 4-10 months
        - Alliant Energy Columbia Energy Station
            - Two 500 MW t-fired units that burn 100% PRB coal.
            - Equipped with many ports, monitors, etc. for testing
        - Ontario Power Nanticoke Station
            - Opposed wall, 500 MW units
            - 50/50 blend of PRB and low S U.S. bituminous
    2. Field Test #2: Testing on a cyclone-fired unit burning PRB coal
        - Schedule: 12-18 months using one SCR test reactor #1
        - AmerenUE, Detroit Edison, Ottertail, Alliant cyclone boilers
        - Honeycomb (Cormetech) catalyst 4 months and plates catalyst 2 months. Note: unless previous tests show we need only one type of catalyst or some other test parameter change.
    3. Field Test #3: Testing on a cyclone-fire lignite boiler
        - Schedule: 5-11 months using one SCR test reactor #2
        - Ottertail Power Coyote Power Station
        - 400MW cyclone boiler burning Beulah lignite

        - Honeycomb (Cormetech) catalyst 4 months and plates catalyst 2 months. Note: unless previous tests show we need only one type of catalyst or some other test parameter change.
- Attached is a listing of units that could be tested.

2. **What coals or blends should be tested at the bench-scale?**

    - Whatever coals are being fired at the host utility test sites (up to 4 coals)
    - 4-6 other coals selected from a pool of suggestions by the project sponsors.
    - Ottertail already sent coal

Sponsors are requested to send 5-10 gallons (buckets) of each coal or blend coal that they want tested and specify the blend ratio if that applies. The EERC will blend coal samples based on sponsor's suggestions. Steve Benson will coordinate which coals get tested.

3. **How can we incorporate data that could be received from the New Madrid plant?**

1) AECI may be interested but they had questions about joining the project. EERC has sent them information on the project, plus has answered some of their questions and has not heard back.

4. **Can we test different catalysts?**

The original plan was to study one type of catalyst in the field and focus on mechanisms. We now will plan for testing two types of catalyst, the honeycomb Cormetech type and the plate-like (Siemens ?) type. We will work with only one vendor such as Cormetech to help design and build the SCR reactors, but then entertain getting catalysts from other vendors to place in the reactor.

5. **SCR Test Reactor Design**

Some issues that were settled in the meeting or since the meeting include:

- A slipstream design will be implemented and made to be able to be dismantled, since a total skid-mount will have accessibility problems in most boilers.
- Individual catalyst sections will be sampled at 1 month, 3 months, and 6 months for full-scale tests.
- Instrumentation will be able to monitor whether NOx control is occurring.

- It will not matter if we use honeycomb or plate catalyst types.
- Ammonia injection will be used.
- Carbon steel and not stainless (as originally planned) will be used, unless for some improbable reason stainless steel would be cheaper.
- An upfront blank SCR flow conditioner section will be used followed by an undetermined number of catalyst sections (but only up to 4) that will be sampled.
- We will attempt to build the reactor to test two catalyst types (honeycomb (Cormetech) and plates (Siemens) catalyst.
- The slipstream design has undergone several redesigns.
    - There will be two one-meter sections, one for flow conditioning and one for catalyst blinding testing.
    - Individual 1.5" square elongate catalyst sections will comprise the SCR test reactor catalyst section which will be 6" in diameter but the overall SCR test reactor shell will be about 9-12" in diameter to allow for wall effects.
    - A pulse sootblowing and cleaning capability will be a part of the reactor.
    - The individual 1.5" elongate sections will be interchangeable.
    - Attempts to speed up the deactivation process experimentally will not be pursued.
    - The SCR test reactor will be allowed to fluctuate slightly with boiler flue gas temperature.
    - In case of boiler shutdown the SCR test unit will be purged with nitrogen.
    - We need input from sponsors on approaching other catalyst vendors (Hitachi, Siemens, KWH) to be involved in testing their catalysts in the test reactor.

Potential Units to Be Tested

AmerenUE – Sioux Plant

The Sioux Unit 2 is the best candidate. It is a 500MW cyclone that burns an 85-15 blend of PRB-Illinois coal. Ken Stuckmeyer did not foresee any problems with including this unit as one of the test sites. Ongoing testing of SCR blinding using a small SCR test reactor is being done in this unit under a different project and this data may be available for comparison. There will be a scheduled outage sometime in September 2000. Onsite ammonia is not a problem.

Ottertail Power – Coyote Station

The Ottertail Power Coyote Station is a 400 MW cyclone boiler that burns 100% lignite from the Beulah mine. Terry Graumann will check into onsite ammonia issues and he will discuss with plant staff the availability of operating staff and time commitments.

Ontario Power Generation – Nanticoke

Ontario Power Generation's Nanticoke Thermal Power Station, situated on Lake Erie near Port Dover, Ontario, Canada, is Ontario Power Generation's largest, and one of the world's largest, coal-fueled plants. Nanticoke plant has eight units that are designed as opposed wall pulverized coal-fired units with a capacity of 4,000 MW from eight Parsons 500 MW turbine generator sets. Nanticoke is looking at burning a 50-50 blend of PRB-bituminous coal.

Nanticoke burns a blend of PRB and low S US. This puts the sulphur content somewhat higher than a pure PRB coal which may represent "worst case scenario" in terms of sulphate and phosphate deposits blinding the catalyst. Also, sulphation rates may be enhanced by V2O5 catalyst material due to higher SO3 in the gas phase. So there may be an advantage to studying the PRB/US blend.

Ontario Power Generation – Lambton Plant

The Ontario Power Generation – Lambton Plant is has a 500 MW t-fired unit. Bringing ammonia on-site is not an issue.

Alliant Energy – Edgewater Plant

The Alliant Energy Edgewater Plant has a 340MW cyclone boiler that burns an 85-13-2 blend of PRB-bituminous coal-tires.

Alliant Energy – Nelson Dewey

The Alliant Energy – Nelson Dewey plant contains a 200 MW cyclone fired boiler that burns a 85-15 blend of PRB-bituminous coal.

The Alliant Energy – Columbia Energy Station

The Alliant Energy Columbia Energy Station has a two 500 MW t-fired units that burn 100% PRB coal. There is no SOFA at the plant.

Detroit Edison – Monroe Power Plant

The Detroit Edison Monroe Power Plant consists of four 750 MW BW boilers equipped with cell burners (slightly similar to wall-fired burners only with much higher heat release rates and NO_x generation). The units burn a mixture of 55-65% PRB and 35-45% mid-sulfur (1.5-2.5%) bituminous coal.

AECI – New Madrid Power Plant

Associated Electric Inc.'s New Madrid Power Plant is comprised of two electric generating units. Unit 1 was constructed in 1972 and Unit 2 was completed in 1977. New Madrid's 600 MW cyclone-fired generating units can each burn about 8000 tons of PRB coal per day. A SCR system that contains Cormetech catalyst has been installed on one of the New Madrid units and has been operating for several hundred hours.

CONFERENCE CALL Agenda

Evaluation of Potential SCR Catalyst Blinding During Coal Combustion

Friday October 20, 2000

1. **Review of Minutes from September 7 Conference Call**
2. **Sponsorship – Review who is planning to participate in the project and status of proposals**
3. **Bench Scale testing – Coals – Ranges of chemical compositions -- identify optimum coal compositions**
4. **SCR Reactor Design – approve and get construction underway**
5. **Discuss select criteria for field testing – three test sites with current level of sponsorship**
   - **Coals/blends fired**
   - **Cyclone/PC fired**
   - **Others**
   - **Update potential unit list**

Potential Units to Be Tested

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SCR CATALYST REACTOR SECTION

The SCR will be an approximately 9.5 inch square by 9 foot long steel housing that will consist of three sections, one flow straightener and two catalyst test sections. Three purge sections will be installed ahead of each of these sections to remove accumulated dust (see Figure 1). Strip heaters will be installed on each catalyst section and the entire housing will be insulated for temperature control. Thermocouple and pressure taps will be located in the purge sections for measurements before and after each section.

Support brackets located on the piping entering and leaving the reactor will enable individual sections of the SCR to be removed.

The first section will be a short length of honeycomb (9 inches square by 6-inch length) used as a flow straightener. The catalyst test sections #1 and #2 will consist of 9-inch square cross-sections, 39" in length. The catalyst sections will consist of an inner 6-inch square section of catalyst used for sampling surrounded by 1.5" of catalyst used for minimizing wall effects (see Figure 2).

The inner 6-inch section will consist of 16 individual 1.5" squares. The additional 1.5 inches of catalyst surrounding the sampling section will be formed by 1.5" by 7.5"pieces if the catalyst can be obtained in 7.5" widths otherwise this outer layer will be formed by 1.5" by 3.75" pieces.

A steel catalyst holder will hold the catalyst pieces together inside the reactor. The catalyst holders will be placed on each end of the catalyst sections. The holder is shown in Figures 3 and 4. The holder consists of an angle iron welded together in a square with bars spanning between two of the flanged sides. One leg of the angle is sandwiched between the reactor shell flanges, and the other holds the catalyst sections tightly together in place. 1/8" bars spaced 1.5" apart will hold the individual square catalyst sections in place. The holder will keep the catalyst away from the reactor shell, prevent flow around the catalyst and allow for easy removal of the catalyst from the reactor.

To remove the catalyst for inspection or catalyst replacement, the catalyst section to be removed will be unbolted and slid out from the reactor. (Support brackets will hold the remaining reactor pieces in place.) Once a catalyst reactor section is removed, the top catalyst holder will be removed and the 1.5" section(s) of interest will be removed by pushing it up from the bottom and out the top. A new section then will be inserted from the top to replace the piece removed.

Operating Conditions:

To achieve an approach velocity of 4.5 m/s (14.76 ft/s), approximately 500 acfm (224 scfm) of flue gas will be extracted from the convective pass of the utility boiler. The extraction will be immediately downstream from the economizer at a temperature in the 700°F range. The total gas flow through the reactor represents a thermal load of approximately 300 kW. A trap will be used upstream of the reactor to eliminate large fly ash agglomerates and deposit fragments that may plug the reactor.

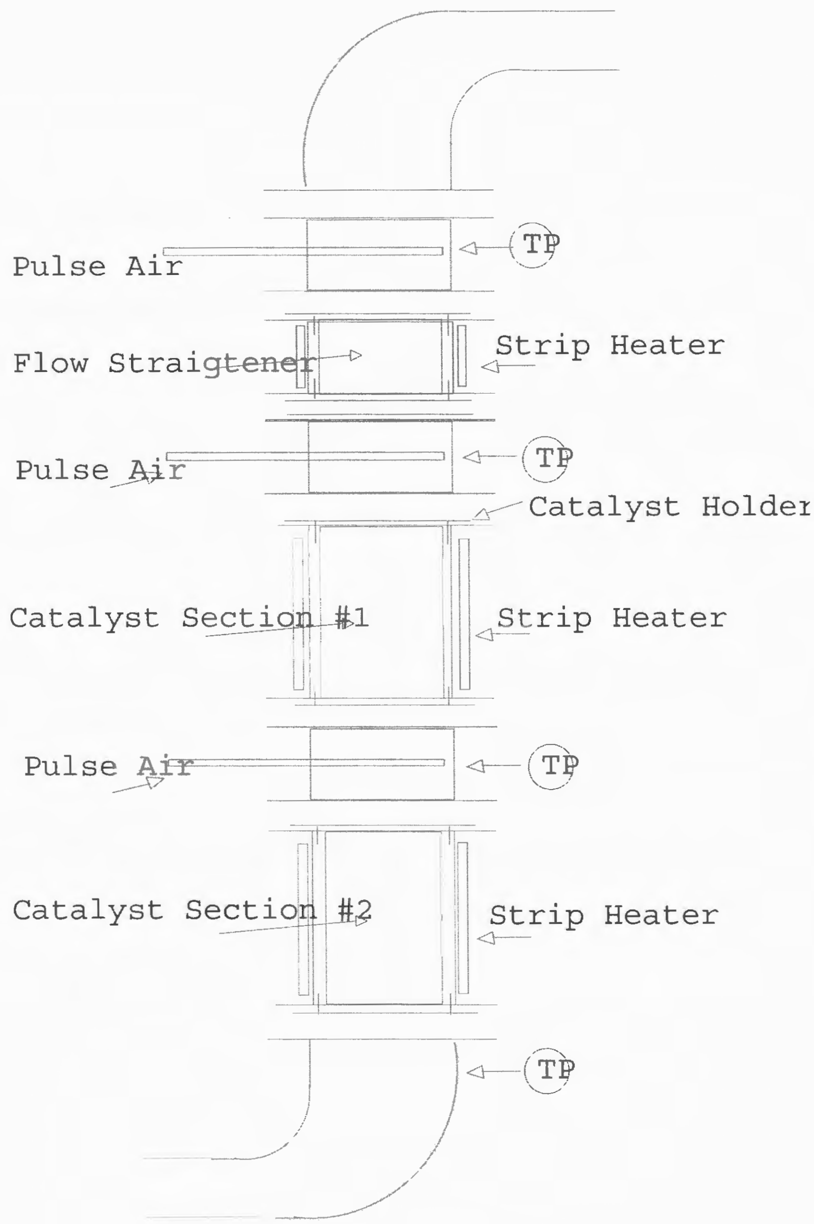
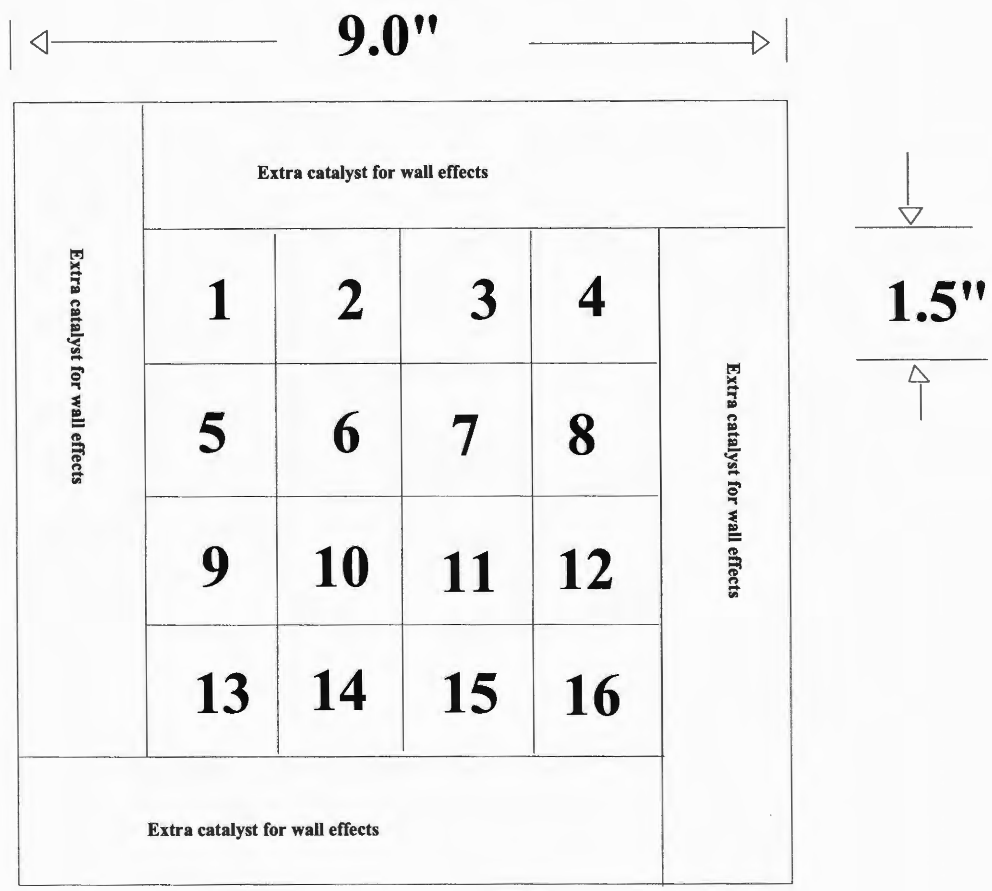


Figure 1. Side View of SCR Reactor.

Figure 2. Cross-Sectional View of Catalyst Test Section



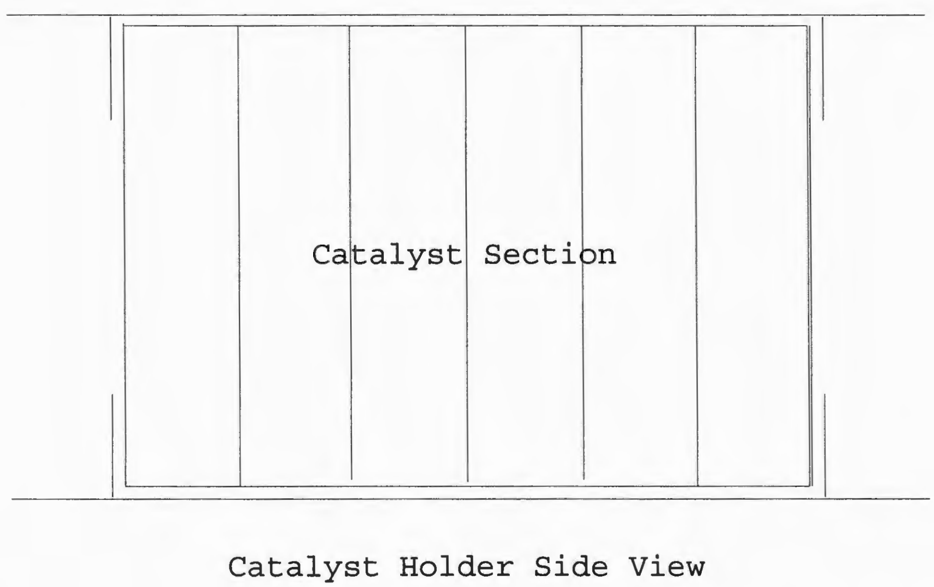


Figure 3. Side View of Catalyst Holder

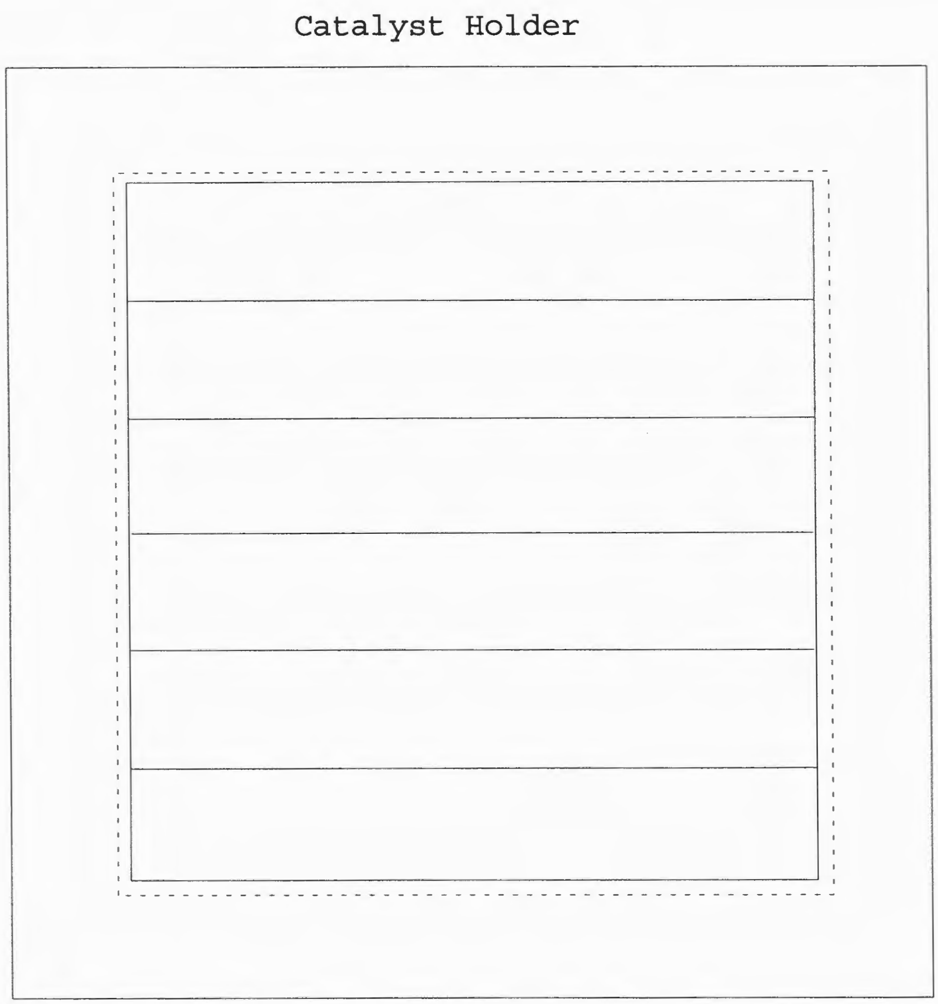
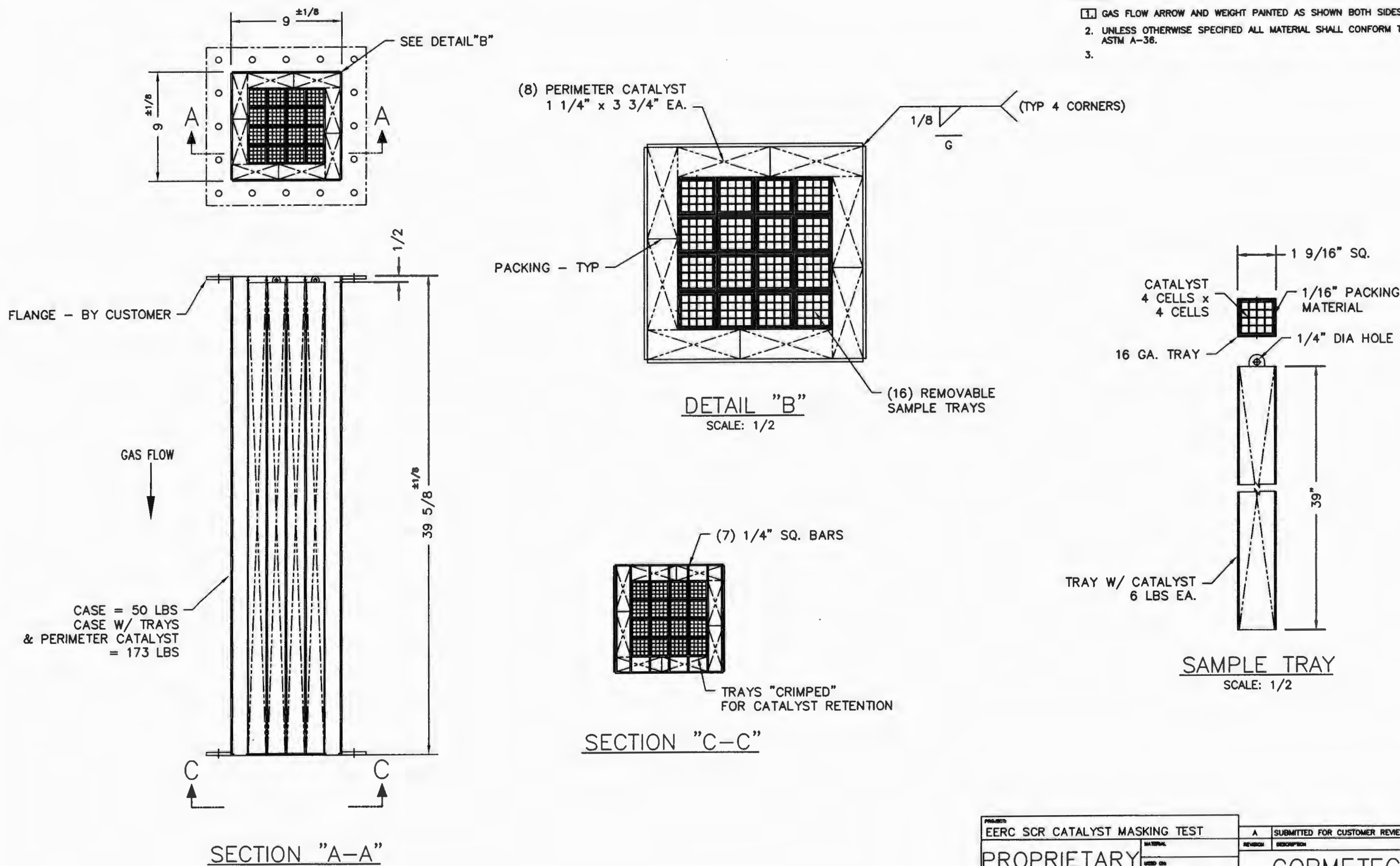


Figure 4. Top View of Catalyst Holder.



NOTES:

1. GAS FLOW ARROW AND WEIGHT PAINTED AS SHOWN BOTH SIDES.
2. UNLESS OTHERWISE SPECIFIED ALL MATERIAL SHALL CONFORM TO ASTM A-36.
3.

PROJECT: EERC SCR CATALYST MASKING TEST		A	SUBMITTED FOR CUSTOMER REVIEW		10/17/00	DB
		REVISION	DESCRIPTION		DATE	INITIALS
PROPRIETARY	MATERIAL	CORMETECH, INC. ENVIRONMENTAL TECHNOLOGIES				
	USED ON 1					
CORMETECH INCORPORATED PROPRIETARY	FINISH	DESIGN CORMETECH	DRAWN BY D BOVAIR	CHECKED BY	DATE 10/16/00	SCALE 1/4
ANY DISSEMINATION OF INFORMATION CONTAINED IN THIS PRINT IS PROHIBITED. ALL PRINTS ARE TO BE RETURNED TO CORMETECH INCORPORATED UPON COMPLETION OF WORK.	TOLERANCES ARE AS FOLLOWS UNLESS OTHERWISE NOTED. FRACTIONAL DIMENSIONS +/-1/8 DECIMAL DIMENSIONS +/- DEGREES +/-	TITLE SCR MODULE			DRAWING NUMBER 0042011	

Clifford Porter

From: Laumb, Jason [JLaumb@undeerc.org]
Sent: Thursday, October 19, 2000 11:42 AM
To: 'tgraumann@otpco.com'; 'cporter@lignite.com'; 'feeley@netl.doe.gov'; 'iskandarrs@cormetech.com'; 'DOCONNOR@epri.com'; 'edmundovasquez@alliant-energy.com'; 'kenneth_b_stuckmeyer@ameren.com'; 'Rene.Mangal@kinectrics.com'; 'blair.seckington@ontariopowergeneration.com'
Cc: Benson, Steven A.; Toman, Donald L.; Gunderson, Jay R.
Subject: SCR Blinding Project Conference Call

SCR disc.doc

> Attached please find a Word document containing a more detailed
> description of the overall SCR reactor. The previous attachment was just
> the catlyst section. I look forward to our call on Friday.
>
> Jason Laumb
> Research Engineer
> Energy and Environmental Research Center
> Tel. (701) 777-5114
>
> <<SCR disc.doc>>
>
>
>
>
>

Clifford Porter

From: Reimer, Patti J. [preimer@undeerc.org]
Sent: Wednesday, October 25, 2000 1:25 PM
To: 'tgraumann@otpco.com'; 'cporter@lignite.com'; 'feeley@netl.doe.gov'; 'prichardsg@cormetech.com'; 'DOCONNOR@epri.com'; 'edmundovasquez@alliant-energy.com'; 'kenneth_b_stuckmeyer@ameren.com'; 'Rene.Mangal@kinectrics.com'; 'blair.seckington@ontariopowergeneration.com'
Cc: Benson, Steven A.; Toman, Donald L.; Gunderson, Jay R.; Laumb, Jason; Zygarlicke, Chris J.
Subject: SCR Blinding Project Conference Call

SCRConfCallnotes1000.doc

Attached below is a copy of the minutes from the conference call which was held October 20. The next conference call is scheduled for Thursday, November 9, at 1:00 CST. Please reply by e-mail whether you are available or not a.s.a.p. so I can make arrangements for the conference call. This time we are going to try a different way to do the conference call that will be more convenient for you. You will get a number to call that will connect you directly into the conference call. Once I get the number set up, I will e-mail you the number to call along with the instructions. This way, if you are not available directly at 1:00 or if you have to call from a different phone number, you are able to.

<<SCRConfCallnotes1000.doc>>

Thank you,
Patti Reimer

Energy & Environmental Research Center
University of North Dakota
PO Box 9018
15 North 23rd Street
Grand Forks, ND 58202-9018
Phone: (701) 777-5070
Fax: (701) 777-5181
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CONFERENCE CALL Agenda

Evaluation of Potential SCR Catalyst Blinding During Coal Combustion

Thursday November 9, 2000

1. **Review of Minutes from October 20 Conference Call**

   Go through specific points in the minutes

2. **Sponsorship – Review who is planning to participate in the project and status of proposals**

   Project is fully funded – Dynegy has agreements at this time and is invited to participate in conference call.
   Hitachi is interested and they are reviewing the project proposal.

3. **Bench Scale testing – Coals – Ranges of chemical compositions -- identify optimum coal compositions**

   Review attached graphs of composition and determine which coal types we want to test.

   Suggested compositions to consider – Range of calcium, sodium, potassium, and phosphorus contents

4. **SCR Reactor Design – approve and get construction underway**

   Approval of sending all design information to Hitachi for review

5. **Discuss select criteria for field testing – three test sites with current level of sponsorship --**

   Develop a questionnaire that would be sent to plants that would describe the reactor and needs and to find out specifics – coals fired, port locations, power availability, ...Is this a good idea?

   - Coals/blends fired
   - Cyclone/PC fired
   - Others
   - Cost
   - Update potential unit list

Next conference call – need to determine time for call.

Potential Units to Be Tested

AmerenUE – Sioux Plant

The Sioux Unit 2 is the best candidate. It is a 500MW cyclone that burns an 85-15 blend of PRB-Illinois coal. Ken Stuckmeyer did not foresee any problems with including this unit as one of the test sites. Ongoing testing of SCR blinding using a small SCR test reactor is being done in this unit under a different project and this data may be available for comparison. There will be a scheduled outage sometime in September 2000. Onsite ammonia is not a problem.

Ottertail Power – Coyote Station

The Ottertail Power Coyote Station is a 400 MW cyclone boiler that burns 100% lignite from the Beulah mine. Terry Graumann will check into onsite ammonia issues and he will discuss with plant staff the availability of operating staff and time commitments.

Ontario Power Generation – Nanticoke

Ontario Power Generation's Nanticoke Thermal Power Station, situated on Lake Erie near Port Dover, Ontario, Canada, is Ontario Power Generation's largest, and one of the world's largest, coal-fueled plants. Nanticoke plant has eight units that are designed as opposed wall pulverized coal-fired units with a capacity of 4,000 MW from eight Parsons 500 MW turbine generator sets. Nanticoke is looking at burning a 50-50 blend of PRB-bituminous coal.

Nanticoke burns a blend of PRB and low S US. This puts the sulphur content somewhat higher than a pure PRB coal which may represent "worst case scenario" in terms of sulphate and phosphate deposits blinding the catalyst. Also, sulphation rates may be enhanced by V_2O_5 catalyst material due to higher SO_3 in the gas phase. So there may be an advantage to studying the PRB/US blend.

Ontario Power Generation – Lambton Plant

The Ontario Power Generation – Lambton Plant is has a 500 MW t-fired unit. Bringing ammonia on-site is not an issue.

Alliant Energy – Edgewater Plant

The Alliant Energy Edgewater Plant has a 340MW cyclone boiler that burns an 85-13-2 blend of PRB-bituminous coal-tires.

Alliant Energy – Nelson Dewey

The Alliant Energy – Nelson Dewey plant contains a 200 MW cyclone fired boiler that burns a 85-15 blend of PRB-bituminous coal.

The Alliant Energy – Columbia Energy Station

The Alliant Energy Columbia Energy Station has a two 500 MW t-fired units that burn 100% PRB coal. There is no SOFA at the plant.

Detroit Edison – Monroe Power Plant

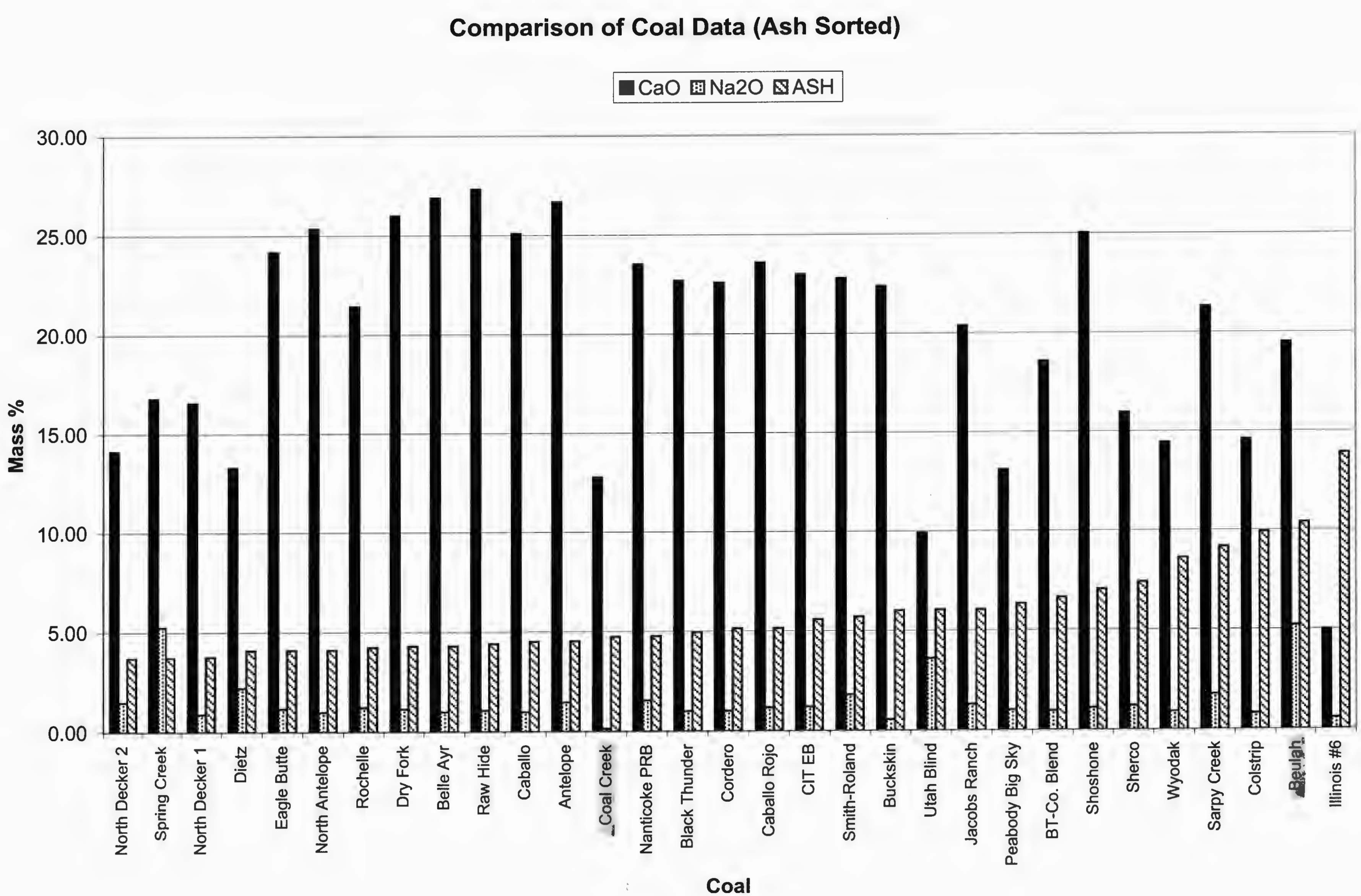
The Detroit Edison Monroe Power Plant consists of four 750 MW BW boilers equipped with cell burners (slightly similar to wall-fired burners only with much higher heat release rates and NO_x generation). The units burn a mixture of 55-65% PRB and 35-45% mid-sulfur (1.5-2.5%) bituminous coal.

AECI – New Madrid Power Plant

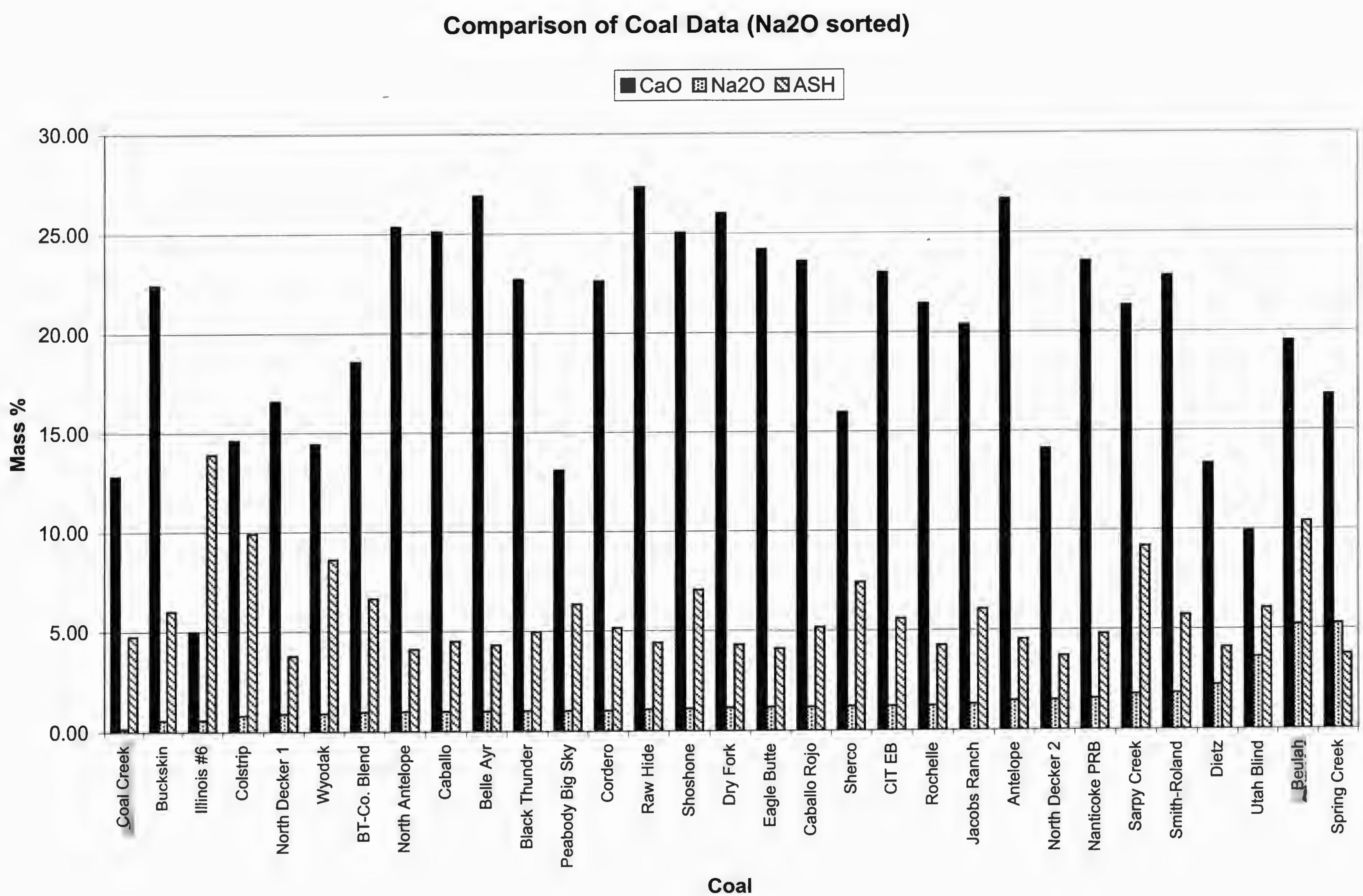
Associated Electric Inc.'s New Madrid Power Plant is comprised of two electric generating units. Unit 1 was constructed in 1972 and Unit 2 was completed in 1977. New Madrid's 600 MW cyclone-fired generating units can each burn about 8000 tons of PRB coal per day. A SCR system that contains Cormetech catalyst has been installed on one of the New Madrid units and has been operating for several hundred hours.

Dynegy – Baldwin Energy Complex

Baldwin Energy Complex consists of 2- 600 (nominal) MW cyclone fired boilers and 1 - 600 MW (nominal) pulverized coal fired boiler. All three boilers burn 100% PRB coal. The cyclone units have SCR's and overfired air installed. The PC unit has T-fired low NOx burners with overfired air.



Comparison of Coal Data (Ash Sorted)
CaO
Na2O
ASH
Mass %
30.00
25.00
20.00
15.00
10.00
5.00
0.00
North Decker 2
Spring Creek
North Decker 1
Dietz
Eagle Butte
North Antelope
Rochelle
Dry Fork
Belle Ayr
Raw Hide
Caballo
Antelope
Coal Creek
Nanticoke PRB
Black Thunder
Cordero
Caballo Rojo
CIT EB
Smith-Roland
Buckskin
Utah Blind
Jacobs Ranch
Peabody Big Sky
BT-Co. Blend
Shoshone
Sherco
Wyodak
Sarpy Creek
Colstrip
Beulah
Illinois #6
Coal



Comparison of Coal Data (Na2O sorted)
CaO
Na2O
ASH
Mass %
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Coal Creek
Buckskin
Illinois #6
Colstrip
North Decker 1
Wyodak
BT-Co. Blend
North Antelope
Caballo
Belle Ayr
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Peabody Big Sky
Cordero
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Shoshone
Dry Fork
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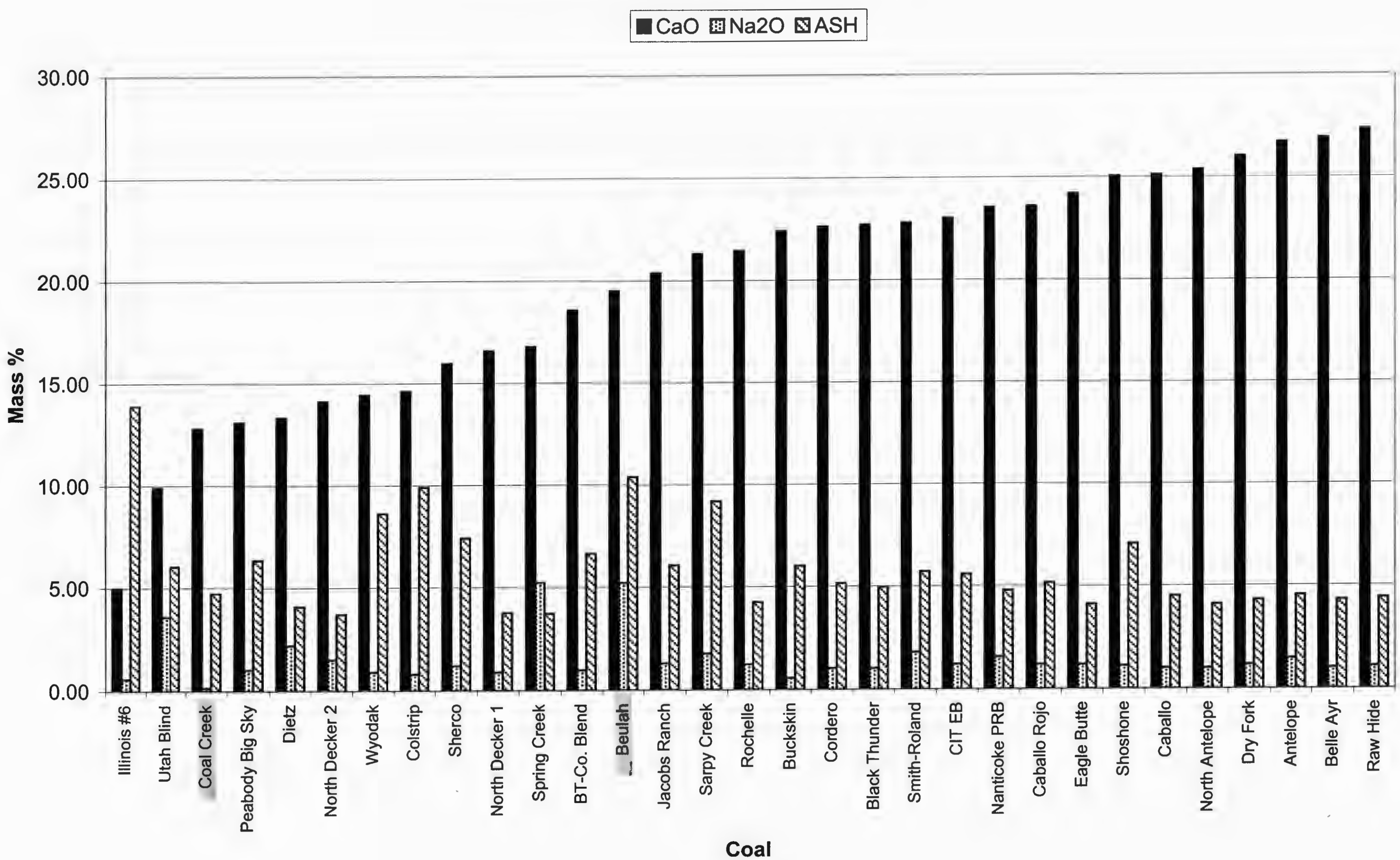
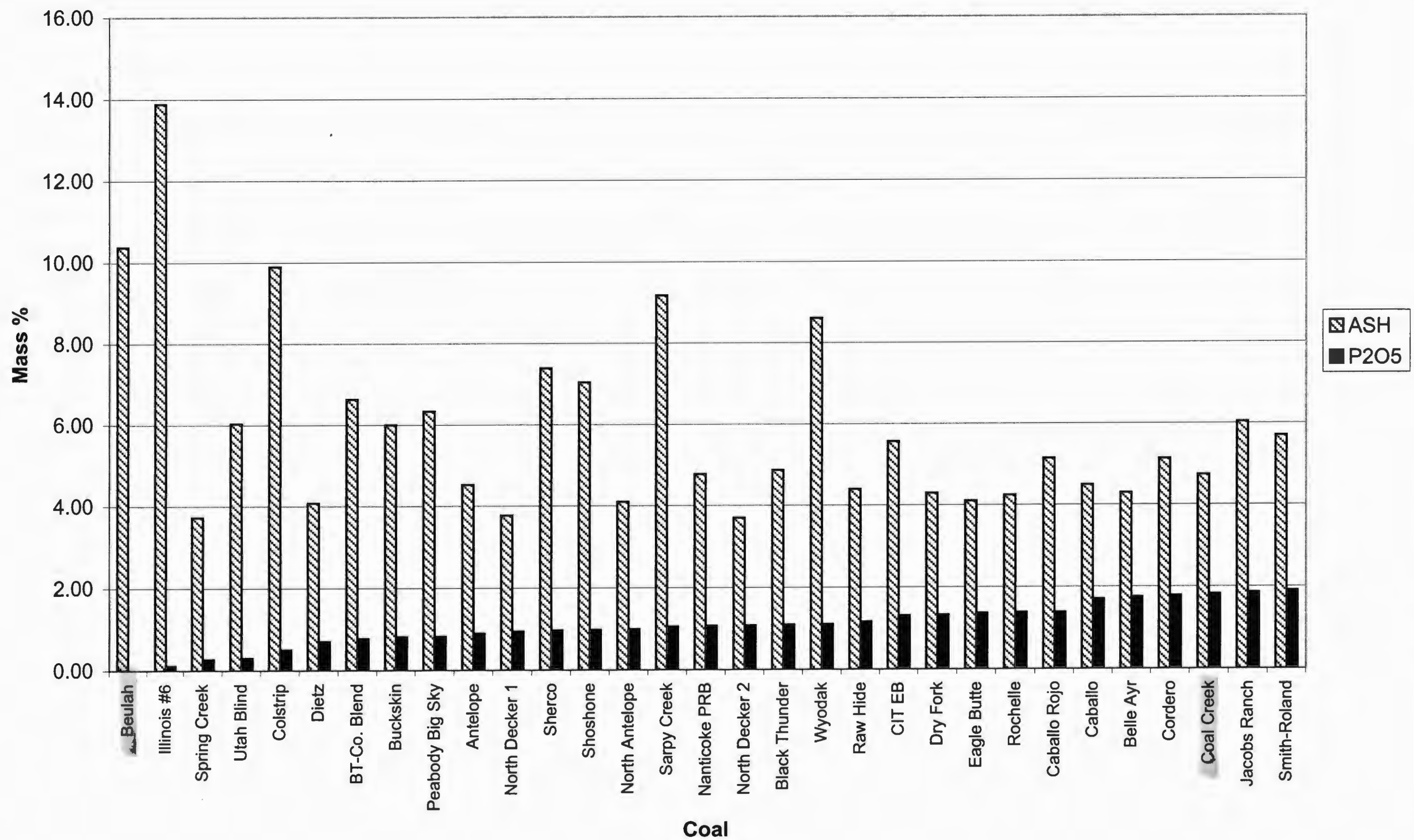
Caballo Rojo
Sherco
CIT EB
Rochelle
Jacobs Ranch
Antelope
North Decker 2
Nanticoke PRB
Sarpy Creek
Smith-Roland
Dietz
Utah Blind
Beulah
Spring Creek
Coal

Comparison of Coal Data (CaO sorted)



Comparison of Coal Data (P2O5 sorted)



Coal	% Ash	SiO2	Al2O3	Fe2O3	TiO2	P2O5	CaO	MgO	Na2O	K2O	SO3	Hydrogen	Carbon	Nitrogen	Sulfur	Oxygen	Ash	HHV
Illinois #6	13.89	41.55	16.51	17.39	0.67	0.11	4.98	0.99	0.57	1.73	15.52	4.94	61.37	1.09	3.93	14.78	13.89	11033.25
Nanticoke PRB	4.78	32.92	16.43	5.33	1.33	1.07	23.53	5.46	1.55	0.34	10.49	3.50	51.33	0.67	0.25	12.14	4.78	8807
Spring Creek	3.73	30.65	18.26	5.47	1.36	0.27	16.78	6.22	5.24	0.27	15.52	6.45	55.69	0.70	0.34	33.10	3.73	9791
Utah Blind	6.03	45.90	16.60	10.00	1.20	0.30	9.90	1.50	3.60	1.20	9.80	5.70	73.50	1.30	0.50	12.97	6.03	11330
Colstrip	9.90	42.30	21.50	5.10	1.40	0.50	14.60	4.30	0.80	0.50	8.90	5.89	53.11	0.80	0.72	29.59	9.90	9176
Dietz	4.08	36.00	20.80	4.90	2.20	0.70	13.30	4.50	2.20	0.30	14.90	6.68	65.89	0.82	0.46	22.08	4.08	9287
BT-Co. Blend	6.63	37.53	19.79	4.59	0.84	0.77	18.56	6.14	0.97	0.58	10.22	6.51	51.83	0.70	0.48	33.85	6.63	9201
Buckskin	6.00	27.50	13.10	6.83	0.87	0.81	22.40	7.15	0.56	0.40	20.40	6.50	50.10	0.70	0.80	35.90	6.00	8814
Peabody Big Sky	6.33	40.02	20.21	1.86	1.00	0.82	13.08	6.26	1.02	0.35	15.39	6.24	54.02	0.75	0.55	32.11	6.33	9439
Antelope	4.53	24.82	13.55	7.52	1.39	0.90	26.68	7.14	1.47	0.17	16.33	6.34	50.46	0.82	0.31	37.52	4.53	8718
North Decker 1	3.77	31.18	17.82	5.30	1.31	0.94	16.57	9.65	0.89	0.46	15.88	6.82	54.80	0.69	0.38	33.52	3.77	9868
Sherco	7.39	33.89	16.53	6.16	0.93	0.97	15.97	6.46	1.20	0.43	17.50	6.20	52.46	0.78	0.61	32.57	7.39	9113
Shoshone	7.04	28.30	13.29	7.06	0.83	0.97	25.04	8.27	1.11	0.79	14.43	5.18	71.75	1.63	0.59	13.79	7.04	12567
North Antelope	4.10	29.13	15.95	6.23	1.11	0.99	25.35	9.85	0.99	0.32	10.07	6.40	51.10	0.80	0.20	37.30	4.10	8990
Sarpy Creek	9.17	45.20	20.70	4.57	1.17	1.05	21.30	3.28	1.76	0.94	15.00	6.24	49.77	0.61	0.64	33.57	9.17	8767
North Decker 2	3.70	32.74	18.00	5.07	0.82	1.07	14.11	8.35	1.49	0.38	17.97	6.50	54.00	0.90	0.40	34.50	3.70	9384
Black Thunder	4.87	30.70	16.87	4.53	1.33	1.09	22.70	6.77	1.02	0.30	14.71	6.77	51.11	0.70	0.38	36.07	4.96	9086
Wyodak	8.61	40.37	22.91	3.21	1.01	1.10	14.43	5.47	0.90	1.11	9.49	6.26	46.91	0.81	0.58	36.83	8.61	8186
Raw Hide	4.40	28.25	14.13	5.26	0.96	1.16	27.33	9.31	1.07	0.25	12.29	6.40	47.90	0.60	0.30	40.40	4.40	8262
CIT EB	5.57	26.30	14.20	7.70	1.10	1.30	23.00	6.10	1.20	0.30	18.80	5.84	54.82	0.63	0.45	32.67	5.57	9220
Dry Fork	4.30	26.99	13.10	5.20	0.66	1.32	26.01	12.38	1.15	0.24	12.96	6.90	46.30	0.80	0.30	41.40	4.30	8232
Eagle Butte	4.10	26.74	13.86	5.40	0.77	1.36	24.19	10.15	1.17	0.23	16.12	6.40	47.80	0.60	0.30	40.80	4.10	8218
Rochelle	4.24	32.15	18.00	5.17	1.28	1.38	21.44	7.18	1.22	0.19	11.95	6.40	51.46	0.66	0.25	37.02	4.24	8830
Caballo Rojo	5.15	27.32	14.84	4.75	1.15	1.38	23.59	5.85	1.18	0.28	19.70	6.44	54.19	0.95	0.40	32.87	5.15	9619
Caballo	4.50	26.70	16.60	5.10	1.10	1.70	25.10	8.00	1.00	0.30	14.40	6.40	48.90	0.70	0.30	39.20	4.50	8508
Belle Ayr	4.30	26.00	16.50	5.07	1.68	1.75	26.89	6.58	1.01	0.34	14.21	6.30	48.50	0.70	0.30	39.90	4.30	8314
Cordero	5.14	26.99	17.90	5.66	1.60	1.78	22.60	5.87	1.02	0.26	16.31	6.58	48.64	0.71	0.32	38.61	5.14	8571
Coal Creek	4.74	35.04	24.01	8.77	1.56	1.82	12.78	4.35	0.15	0.18	11.34	5.99	55.02	0.79	0.33	33.12	4.74	9417
Jacobs Ranch	6.04	26.57	17.56	6.00	0.94	1.85	20.37	6.04	1.30	0.36	19.02	6.33	51.54	0.74	0.57	34.78	6.04	8970
Smith-Roland	5.70	15.60	12.60	5.50	1.30	1.90	22.80	7.90	1.80	0.40	30.10	5.84	54.82	0.63	0.45	32.56	5.70	8700
Beulah	10.38	16.50	13.30	16.60	0.80	0.00	19.50	7.40	5.20	0.20	19.80	5.60	48.47	0.70	1.65	33.17	10.38	8433.00

Clifford Porter

From: Reimer, Patti J. [preimer@undeerc.org]
Sent: Thursday, November 09, 2000 8:03 AM
To: 'tgraumann@otpco.com'; 'cporter@lignite.com'; 'feeley@netl.doe.gov'; 'iskandarrs@cormetech.com'; 'DOCONNOR@epri.com'; 'edmundovasquez@alliant-energy.com'; 'kenneth_b_stuckmeyer@ameren.com'; 'Rene.Mangal@kinectrics.com'; 'blair.seckington@ontariopowergeneration.com'; 'ted_lindenbusch@dynegy.com'; 'mark_liefer@dynegy.com'
Cc: Benson, Steven A.; Toman, Donald L.; Gunderson, Jay R.; Laumb, Jason
Subject: SCR Blinding Project Conference Call Agenda and Coal Data

Sortedcoaldata1.xls SCRConfCall1109.doc

Attached is the agenda and coal data for this afternoon's conference call. If you have any problems with the transmission of these files, contact me by e-mail or call me at (701) 777-5070 and I can fax you copies.

Sincerely,
Patti Reimer

<<Sortedcoaldata1.xls>> <<SCRConfCall1109.doc>>

Clifford Porter

Subject:	SCR Blinding Project
Location:	Conference Call
Start:	Thu 11/9/00 1:00 PM
End:	Thu 11/9/00 3:00 PM
Recurrence:	(none)
Categories:	LRC Contracts, R & D

701-777-4456 Passcode 1445#
Linda 701-777-3206 (Trouble)

Energy & Environmental Research Center
UNIVERSITY OF NORTH DAKOTA
15 North 23rd Street — PO Box 9018 / Grand Forks, ND 58202-9018 / Phone: (701) 777-5000 Fax: 777-5181
Web Site: www.undeerc.org

February 16, 2001

Ms. Karlene Fine
Executive Director
Industrial Commission of North Dakota
10th Floor
600 East Boulevard
Bismarck, ND 58505-0310

Dear Ms. Fine:

Subject: Joint Venture Subtask 31 – Evaluation of Potential SCR Catalyst Blinding During Coal Combustion; Contract FY00-XXXVI-100

Please find enclosed the October 1 – December 31, 2000, Quarterly Technical Progress Report for the subject subtask. This work was performed at the University of North Dakota Energy & Environmental Research Center under the subject contract.

If you have any questions, please call me at (701) 777-5177, fax at (701) 777-5181, or e-mail at sbenson@undeerc.org.

Sincerely,

Steven A. Benson
Senior Research Advisor

SAB/drh

Enclosure

c/enc: Clifford Porter, Lignite Energy Council

SUBTASK 31 – EVALUATION OF POTENTIAL SCR CATALYST BLINDING DURING COAL COMBUSTION
Quarterly Report
October 1 – December 31, 2000

1.0 BENCH-SCALE TESTING

The bench-scale testing portion of the project will determine the rates of formation of sulfate and phosphate at temperatures consistent with placement of selective catalytic reduction (SCR) catalysts in utility boilers. The coals received for testing include Beulah (Otter Tail), Codero (Otter Tail), low-sulfur United States (US) (Kinectrics), Powder River Basin (PRB) (Kinectrics), and low-sulfur US–PRB blend (Kinectrics).

Ash has been produced in the conversion and environmental process simulator (CEPS) for the Beulah, PRB, and low-sulfur US–PRB blend. The ash was aerodynamically classified and will be placed in a thermogravimetric analyzer (TGA) and weight gain measured at selected temperature and flue gas compositions. The TGA analysis is awaiting a catalyst.

2.0 SCR REACTOR DESIGN/CONSTRUCTION

A design for the SCR reactor to test the blinding of SCR catalysts at power plants has been approved by project participants. Recently, the construction activities have centered around procurement of component parts. Suppliers have been identified for pressure transmitters, computers, heating elements, data acquisition, fans, and metal components. Orders have been received or placed for data acquisition, computers, and pressure transmitters. The fan and heating element specifications will be finalized next week, and an order will be placed for these components. The metal will be procured when we have finalized the design of the SCR chamber. Lead time on the fans is approximately 6 to 8 weeks, and the system will be under construction during that time period. The first system is expected to be ready by the end of March or early April.

3.0 SITES FOR FIELD TESTING (three test sites with current level of sponsorship)

Selection criteria for testing catalysts have been discussed at length with sponsors. The primary criteria are the fuel types and boiler types. We plan to test a cyclone firing lignite, a pulverized-coal-fired unit firing a PRB, and a unit firing a blend of PRB and eastern bituminous. A questionnaire was sent to sponsors to provide information for making a decision on the plants to sample. Table 1 summarizes the results.

TABLE 1

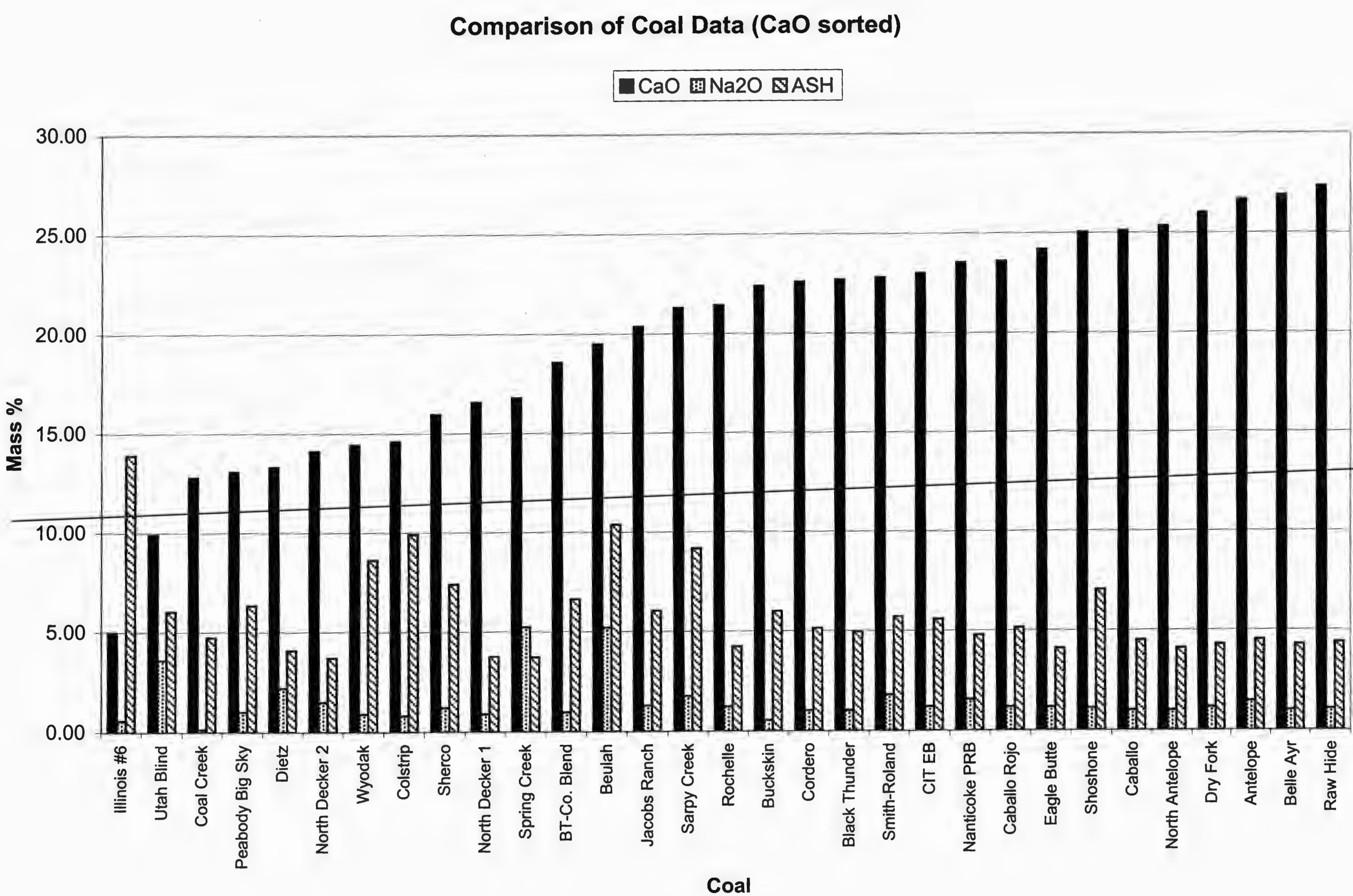
Results of Questionnaire – Units Suggested for Testing

Station	Location	Coal	Other Fuels	Outlet Temp., °F	MWe	Firing Method	Concerns
Nanticoke	Toronto/Niagara Falls area	50% eastern US–50% southern PRB blend	None	650–700	8 × 500	pc–Opposed Wall	Using plant personnel and meeting Canadian codes
Columbia	Portage, WI	PRB coals–Caballo, Black Thunder, Eagle Butte	None	500–850	2 × 540	T-fired	None
Edge Water	Sheboygan, WI	85% Black Thunder, 15% Sufco or Buchanan	Tires	650	340	Cyclone	None
Baldwin	Baldwin, IL	PRB Antelope and Rochelle	2% tires	(Units 1–2) 730–760 (Unit 3) 750–780	3 × 600	Cyclone, Cyclone, pc–T-fired	None
Coyote	Beulah, ND	Beulah lignite	None	780	425	Cyclone	None
Sioux Unit 2	West Alton, MO	85% PRB (Antelope) 15% IL (Rend Lake)	2% tires, 5% petcoke	700–750	500	Cyclone	None

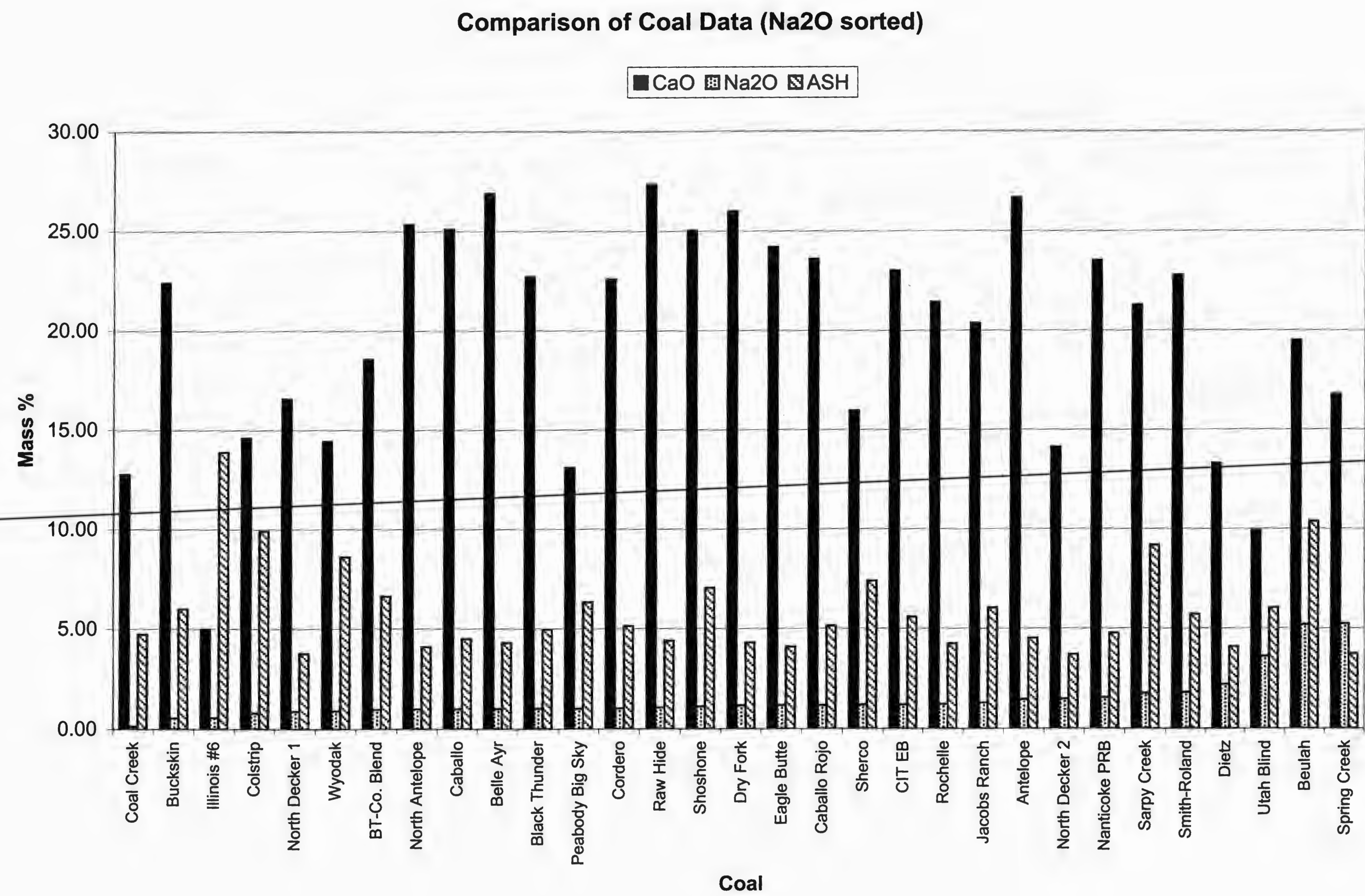
4.0 STATUS ASSESSMENT AND FORECAST

Bench-scale testing of coals using the TGA will be conducted during the next quarter. Construction of the field test units will continue into the next quarter, and the selection of field test sites should be completed during the next quarter.

SC/P



Comparison of Coal Data (CaO sorted)
CaO
Na2O
ASH
Mass %
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Illinois #6
Utah Blind
Coal Creek
Peabody Big Sky
Dietz
North Decker 2
Wyodak
Colstrip
Sherco
North Decker 1
Spring Creek
BT-Co. Blend
Beulah
Jacobs Ranch
Sarpy Creek
Rochelle
Buckskin
Cordero
Black Thunder
Smith-Roland
CIT EB
Nanticoke PRB
Caballo Rojo
Eagle Butte
Shoshone
Caballo
North Antelope
Dry Fork
Antelope
Belle Ayr
Raw Hide
Coal


Comparison of Coal Data (Na2O sorted)
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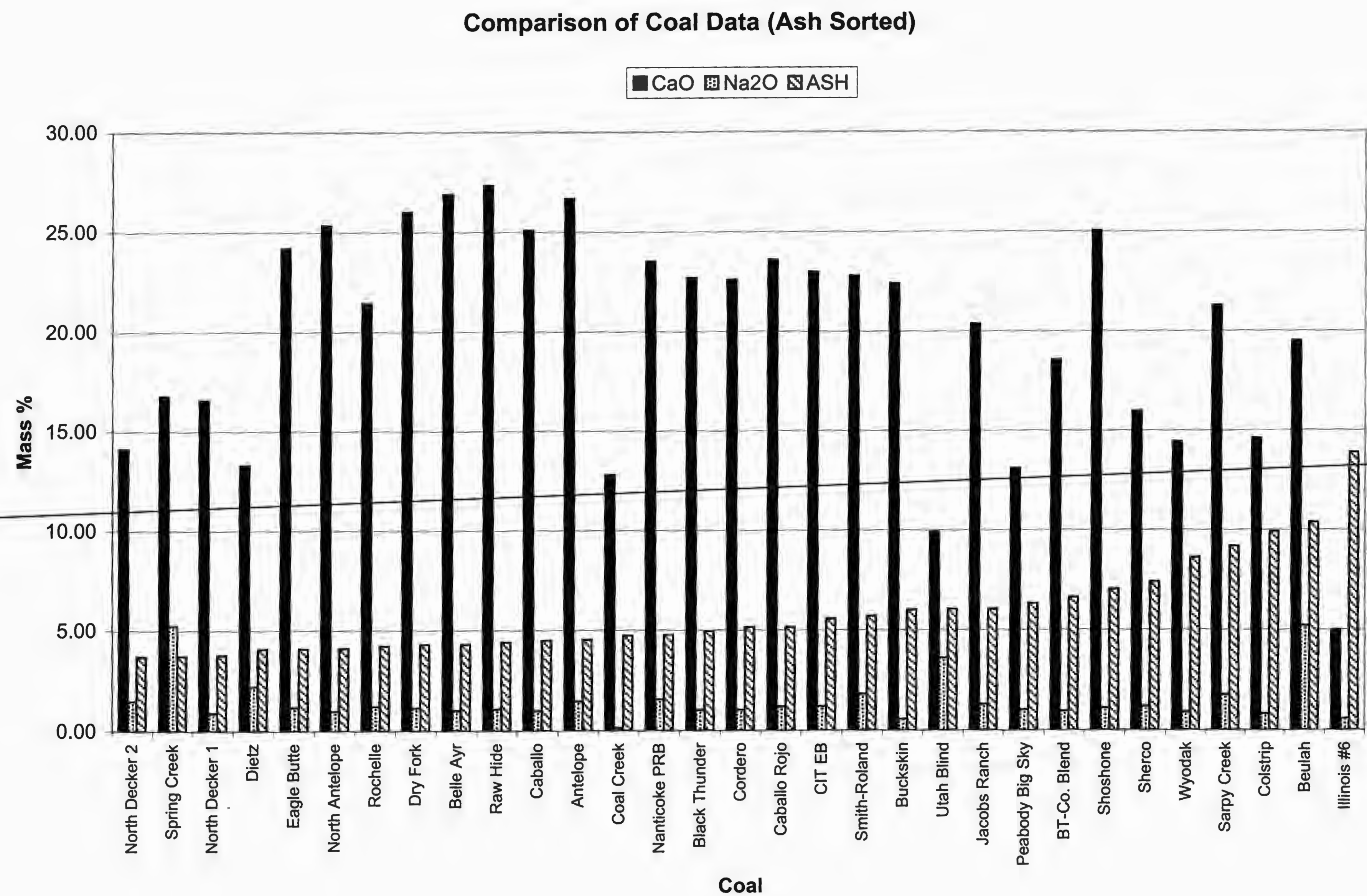

Comparison of Coal Data (Ash Sorted)
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North Decker 2
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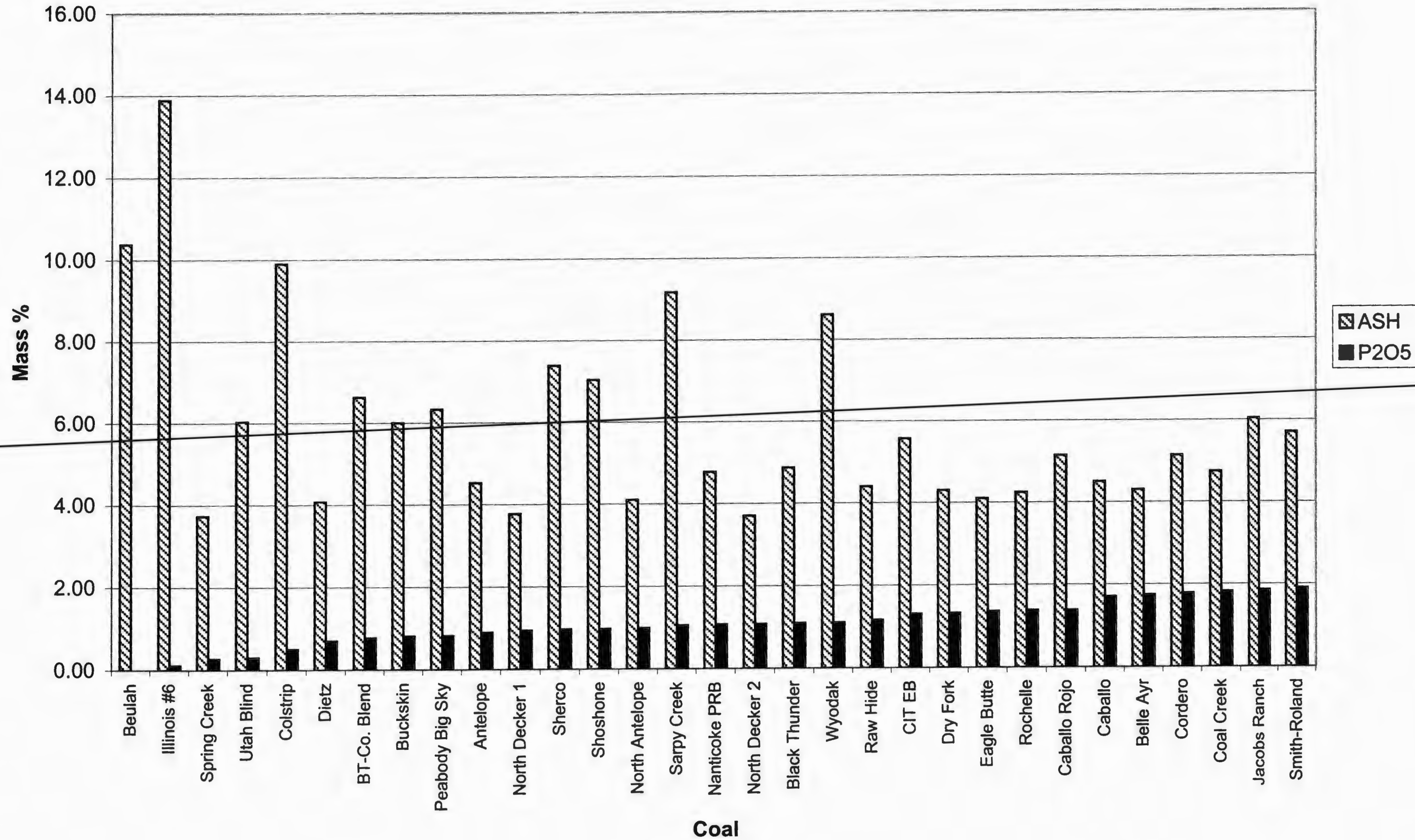
Buckskin
Utah Blind
Jacobs Ranch
Peabody Big Sky
BT-Co. Blend
Shoshone
Sherco
Wyodak
Sarpy Creek
Colstrip
Beulah
Illinois #6
Coal

Comparison of Coal Data (P2O5 sorted)



Coal	% Ash	SiO2	Al2O3	Fe2O3	TiO2	P2O5	CaO	MgO	Na2O	K2O	SO3	Hydrogen	Carbon	Nitrogen	Sulfur	Oxygen	Ash	HHV
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Spring Creek	3.73	30.65	18.26	5.47	1.36	0.27	16.78	6.22	5.24	0.27	15.52	6.45	55.69	0.70	0.34	33.10	3.73	9791
Utah Blind	6.03	45.90	16.60	10.00	1.20	0.30	9.90	1.50	3.60	1.20	9.80	5.70	73.50	1.30	0.50	12.97	6.03	11330
Colstrip	9.90	42.30	21.50	5.10	1.40	0.50	14.60	4.30	0.80	0.50	8.90	5.89	53.11	0.80	0.72	29.59	9.90	9176
Dietz	4.08	36.00	20.80	4.90	2.20	0.70	13.30	4.50	2.20	0.30	14.90	6.68	65.89	0.82	0.46	22.08	4.08	9287
BT-Co. Blend	6.63	37.53	19.79	4.59	0.84	0.77	18.56	6.14	0.97	0.58	10.22	6.51	51.83	0.70	0.48	33.85	6.63	9201
Buckskin	6.00	27.50	13.10	6.83	0.87	0.81	22.40	7.15	0.56	0.40	20.40	6.50	50.10	0.70	0.80	35.90	6.00	8814
Peabody Big Sky	6.33	40.02	20.21	1.86	1.00	0.82	13.08	6.26	1.02	0.35	15.39	6.24	54.02	0.75	0.55	32.11	6.33	9439
Antelope	4.53	24.82	13.55	7.52	1.39	0.90	26.68	7.14	1.47	0.17	16.33	6.34	50.46	0.82	0.31	37.52	4.53	8718
North Decker 1	3.77	31.18	17.82	5.30	1.31	0.94	16.57	9.65	0.89	0.46	15.88	6.82	54.80	0.69	0.38	33.52	3.77	9868
Sherco	7.39	33.89	16.53	6.16	0.93	0.97	15.97	6.46	1.20	0.43	17.50	6.20	52.46	0.78	0.61	32.57	7.39	9113
Shoshone	7.04	28.30	13.29	7.06	0.83	0.97	25.04	8.27	1.11	0.79	14.43	5.18	71.75	1.63	0.59	13.79	7.04	12567
North Antelope	4.10	29.13	15.95	6.23	1.11	0.99	25.35	9.85	0.99	0.32	10.07	6.40	51.10	0.80	0.20	37.30	4.10	8990
Sarpy Creek	9.17	45.20	20.70	4.57	1.17	1.05	21.30	3.28	1.76	0.94	15.00	6.24	49.77	0.61	0.64	33.57	9.17	8767
North Decker 2	3.70	32.74	18.00	5.07	0.82	1.07	14.11	8.35	1.49	0.38	17.97	6.50	54.00	0.90	0.40	34.50	3.70	9384
Black Thunder	4.87	30.70	16.87	4.53	1.33	1.09	22.70	6.77	1.02	0.30	14.71	6.77	51.11	0.70	0.38	36.07	4.96	9086
Wyodak	8.61	40.37	22.91	3.21	1.01	1.10	14.43	5.47	0.90	1.11	9.49	6.26	46.91	0.81	0.58	36.83	8.61	8186
Raw Hide	4.40	28.25	14.13	5.26	0.96	1.16	27.33	9.31	1.07	0.25	12.29	6.40	47.90	0.60	0.30	40.40	4.40	8262
CIT EB	5.57	26.30	14.20	7.70	1.10	1.30	23.00	6.10	1.20	0.30	18.80	5.84	54.82	0.63	0.45	32.67	5.57	9220
Dry Fork	4.30	26.99	13.10	5.20	0.66	1.32	26.01	12.38	1.15	0.24	12.96	6.90	46.30	0.80	0.30	41.40	4.30	8232
Eagle Butte	4.10	26.74	13.86	5.40	0.77	1.36	24.19	10.15	1.17	0.23	16.12	6.40	47.80	0.60	0.30	40.80	4.10	8218
Rochelle	4.24	32.15	18.00	5.17	1.28	1.38	21.44	7.18	1.22	0.19	11.95	6.40	51.46	0.66	0.25	37.02	4.24	8830
Caballo Rojo	5.15	27.32	14.84	4.75	1.15	1.38	23.59	5.85	1.18	0.28	19.70	6.44	54.19	0.95	0.40	32.87	5.15	9619
Caballo	4.50	26.70	16.60	5.10	1.10	1.70	25.10	8.00	1.00	0.30	14.40	6.40	48.90	0.70	0.30	39.20	4.50	8508
Belle Ayr	4.30	26.00	16.50	5.07	1.68	1.75	26.89	6.58	1.01	0.34	14.21	6.30	48.50	0.70	0.30	39.90	4.30	8314
Cordero	5.14	26.99	17.90	5.66	1.60	1.78	22.60	5.87	1.02	0.26	16.31	6.58	48.64	0.71	0.32	38.61	5.14	8571
Coal Creek	4.74	35.04	24.01	8.77	1.56	1.82	12.78	4.35	0.15	0.18	11.34	5.99	55.02	0.79	0.33	33.12	4.74	9417
Jacobs Ranch	6.04	26.57	17.56	6.00	0.94	1.85	20.37	6.04	1.30	0.36	19.02	6.33	51.54	0.74	0.57	34.78	6.04	8970
Smith-Roland	5.70	15.60	12.60	5.50	1.30	1.90	22.80	7.90	1.80	0.40	30.10	5.84	54.82	0.63	0.45	32.56	5.70	8700
Beulah	10.38	16.50	13.30	16.60	0.80	0.00	19.50	7.40	5.20	0.20	19.80	5.60	48.47	0.70	1.65	33.17	10.38	8433.00

CONFERENCE CALL Agenda

Evaluation of Potential SCR Catalyst Blinding During Coal Combustion

Friday January 12, 2001

1. **Review of Minutes from November Conference Call**

   Go through specific points in the minutes that need clarification and updating.

2. **Sponsorship/Confidentiality**

   Confidentiality agreements with all parties took some time. The agreement with NDIC is currently in the process of being approved by the Industrial commission. We are waiting on Cormetech – Sheryl Landis and Jill Zola of EERC grants and contracts will joint us early in the conference call to answer any questions that may come up.
   Hitachi is interested in participating and is reviewing confidentiality documents.
   Contacted Siemens and we are waiting for a reply.
   Invite Hitachi to participate in next conference call??

3. **Bench Scale testing – Coals – Ranges of chemical compositions -- identify optimum coal compositions**

   Coals Received: Beulah (OtterTail), Codero (Otter Tail), Low sulfur US (Kinectrics), PRB (Kinectrics), Low sulfur US/PRB blend (Kinectrics).

   Produced ash from: Beulah, PRB, low sulfur US/PRB blend, PRB

   TGA analysis: Awaiting catalyst

4. **SCR Reactor Design/Construction – approve and get construction underway**

   Construction activities have centered around procurement of component parts. We have identified suppliers for pressure transmitters, computers, heating elements, data acquisition, fans, and metal components. Orders have been received or placed for data acquisition, computers, and pressure transmitters. The fan and heating element specifications will be finalized next week and an order will be placed for these components. The metal will be procured when we have finalized the design of the SCR chamber. Lead time on the fans is approximately 6 to 8 weeks, and the system will be under construction during that time period. The first system is expected to be ready by the end of March or early April.

5. **Discuss select criteria for field testing – three test sites with current level of sponsorship --**

   - Coals/blends fired
   - Cyclone/PC fired
   - Others

Clifford Porter

From: Reimer, Patti J. [preimer@undeerc.org]
Sent: Thursday, January 11, 2001 10:21 AM
To: 'tgraumann@otpco.com'; 'cporter@lignite.com'; 'pritchardsg@cormetech.com'; 'DOCONNOR@epri.com'; 'edmundovasquez@alliant-energy.com'; 'kenneth_b_stuckmeyer@ameren.com'; 'Rene.Mangal@kinectrics.com'; 'blair.seckington@ontariopowergeneration.com'; 'ted_lindenbusch@dynegy.com'; 'mark_liefer@dynegy.com'; 'patton@netl.doe.gov'
Cc: Benson, Steven A.; Toman, Donald L.; Gunderson, Jay R.; Laumb, Jason; Zygarlicke, Chris J.
Subject: SCR Blinding Project Conference Call Agenda

SCRConfCall0112agenda.doc

Attached is the agenda for tomorrow afternoon's conference call. Steve has not received all of the plant questionnaires at this time and he will update the information if he receives it this afternoon or tomorrow morning. If there are any items you would like to add to the agenda, please let me know and I will get it added. If you have any problems with the transmission of this file or need the number to call in for the conference call, contact me by e-mail or call me at (701) 777-5070.

Sincerely,
Patti Reimer

<<SCRConfCall0112agenda.doc>>

V2O5 catalyst material due to higher SO3 in the gas phase. So there may be an advantage to studying the PRB/US blend.

Ontario Power Generation – Lambton Plant

The Ontario Power Generation – Lambton Plant is has a 500 MW t-fired unit. Bringing ammonia on-site is not an issue.

Alliant Energy – Edgewater Plant

The Alliant Energy Edgewater Plant has a 340MW cyclone boiler that burns an 85-13-2 blend of PRB-bituminous coal-tires.

Alliant Energy – Nelson Dewey

The Alliant Energy – Nelson Dewey plant contains a 200 MW cyclone fired boiler that burns a 85-15 blend of PRB-bituminous coal.

The Alliant Energy – Columbia Energy Station

The Alliant Energy Columbia Energy Station has a two 500 MW t-fired units that burn 100% PRB coal. There is no SOFA at the plant.

Detroit Edison – Monroe Power Plant

The Detroit Edison Monroe Power Plant consists of four 750 MW BW boilers equipped with cell burners (slightly similar to wall-fired burners only with much higher heat release rates and NO_x generation). The units burn a mixture of 55-65% PRB and 35-45% mid-sulfur (1.5-2.5%) bituminous coal.

AECI – New Madrid Power Plant

Associated Electric Inc.'s New Madrid Power Plant is comprised of two electric generating units. Unit 1 was constructed in 1972 and Unit 2 was completed in 1977. New Madrid's 600 MW cyclone-fired generating units can each burn about 8000 tons of PRB coal per day. A SCR system that contains Cormetech catalyst has been installed on one of the New Madrid units and has been operating for several hundred hours.

Dynegy – Baldwin Energy Complex

Baldwin Energy Complex consists of 2- 600 (nominal) MW cyclone fired boilers and 1 - 600 MW (nominal) pulverized coal fired boiler. All three boilers burn 100% PRB coal. The cyclone units have SCR's and overfired air installed. The PC unit has T-fired low NOx burners with overfired air.

- Cost

Results of Questionnaire – Units suggested for testing (Questionnaires received as of 1/11/01 at 10:00CST)

Station	Coal	Other Fuels	Outlet Temp	MWE	Firing Method	Concerns
Nanticoke	50 % Eastern LSUS/ 50% Southern PRB Blend	NONE	650 to 700 °F	8 X 500	PC - Opposed Wall	Concerns about using plant personnel and Canadian codes.
Baldwin	PRB Antelope and Rochelle	2 % tires	(Units 1 & 2) 730 to 760 °F (Unit 3) 750 to 780 °F	3 X 600	Cyclone, Cyclone, PC – T-fired	NONE
Coyote	Beulah Lignite	NONE	780 °F	425	Cyclone	NONE
Sioux Unit 2	85% PRB (Antelope) 15% Illinois (Rend Lake)	2% tires, 5% Pet Coke	700 to 750 °F	500	Cyclone	NONE

Potential Units to Be Tested

AmerenUE – Sioux Plant

The Sioux Unit 2 is the best candidate. It is a 500MW cyclone that burns an 85-15 blend of PRB-Illinois coal. Ken Stuckmeyer did not foresee any problems with including this unit as one of the test sites. Ongoing testing of SCR blinding using a small SCR test reactor is being done in this unit under a different project and this data may be available for comparison. There will be a scheduled outage sometime in September 2000. Onsite ammonia is not a problem.

Ottertail Power – Coyote Station

The Ottertail Power Coyote Station is a 400 MW cyclone boiler that burns 100% lignite from the Beulah mine. Terry Graumann will check into onsite ammonia issues and he will discuss with plant staff the availability of operating staff and time commitments.

Ontario Power Generation – Nanticoke

Ontario Power Generation's Nanticoke Thermal Power Station, situated on Lake Erie near Port Dover, Ontario, Canada, is Ontario Power Generation's largest, and one of the world's largest, coal-fueled plants. Nanticoke plant has eight units that are designed as opposed wall pulverized coal-fired units with a capacity of 4,000 MW from eight Parsons 500 MW turbine generator sets. Nanticoke is looking at burning a 50-50 blend of PRB-bituminous coal.

Nanticoke burns a blend of PRB and low S US. This puts the sulphur content somewhat higher than a pure PRB coal which may represent "worst case scenario" in terms of sulphate and phosphate deposits blinding the catalyst. Also, sulphation rates may be enhanced by

INDUSTRIAL COMMISSION OF NORTH DAKOTA

John Hoeven Governor	Wayne Stenehjem Attorney General	Roger Johnson Commissioner of Agriculture

Memorandum

TO: Karen Gutenkunst

FR: Karlene Fine
Executive Director and Secretary

DT: March 14, 2001

RE: GRANT PAYMENT

Please have a check(s) prepared in the following amount to the entity(s) listed below as per their contract.

UND - EERC $75,000
ATTN: GRANTS & CONTRACTS OFFICE
FY00-XXXIV-94 LIGNITE TESTING IN ADVANCED HIGH-TEMP HIGH-PRESS
PO BOX 9018
GRAND FORKS, ND 58202-9018 (Second Payment)

UND - EERC $43,750
ATTN: GRANTS & CONTRACTS OFFICE
FY00-XXXVI-100 EVLUATION POTENTIAL SCR CATALYST BLINDING
PO BOX 9018
GRAND FORKS, ND 58202-9018 (First and Second Payments)

LIGNITE ENERGY COUNCIL $35,000
ATTN: JOHN DWYER
FY01-XXXVII-104 LIGNITE VISION 21 PROJECT PHASE II TRANSMISSION
PO BOX 2277
BISMARCK, ND 58502-2277 (Final Payment)

Please pay from the 1999-2001 biennium. If you have any questions, please call. Please forward the check(s) to the appropriate person(s) and make a copy for my files.

Thanks. KF

Karlene K. Fine, Executive Director and Secretary
State Capitol, 10th Floor - 600 E Boulevard Ave Dept 405 - Bismarck, ND 58505-0840
E-Mail: kfine@state.nd.us
Phone: (701) 328-3722 FAX: (701) 328-2820
"Your Gateway to North Dakota": discovernd.com

INDUSTRIAL COMMISSION OF NORTH DAKOTA

LIGNITE RESEARCH, DEVELOPMENT AND MARKETING PROGRAM

Governor,
John Hoeven
Attorney General,
Wayne Stenehjem
Commissioner of Agriculture,
Roger Johnson

MEMORANDUM

March 13, 2001

TO: Karlene Fine, Executive Director and Secretary
North Dakota Industrial Commission

FROM: Clifford R. Porter, Director CRP
Lignite Research, Development and Marketing Program

SUBJECT: FY00-XXXVI-100: "Evaluation of Potential SCR Catalyst Blinding During Coal Combustion"; Contractor: Energy & Environmental Research Center; Recommendation for Payment of $22,500 for First Quarterly Report (10/1/00 – 12/31/00).

I have reviewed the first quarterly report (October 1, 2000 – December 31, 2000) from the contractor (Energy & Environmental Research Center) regarding Contract No. FY00-XXXVI-100 for the project titled "Evaluation of Potential SCR Catalyst Blinding During Coal Combustion".

The first quarterly report is adequate to determine that the contractor has complied with the statement of work.

The contractor has met the terms of contract FY00-XXXVI-100 required for receiving the $22,500 payment for the first quarterly report. I recommend payment of the $22,500.

CRP/vg: 24.S.30.A

LIGNITE RESEARCH COUNCIL
John Dwyer, Chairman
Clifford Porter, Director & Technical Advisor
P.O. Box 2277
Bismarck, N.D. 58502
(701) 258-7117 (701) 258-2755 Fax

INDUSTRIAL COMMISSION OF NORTH DAKOTA
Karlene Fine
Executive Director
600 East Boulevard, State Capitol
Bismarck, N.D. 58505
(701) 328-3722 (701) 328-2820 Fax

INDUSTRIAL COMMISSION OF NORTH DAKOTA

John Hoeven Governor	Wayne Stenehjem Attorney General	Roger Johnson Commissioner of Agriculture

Memorandum

TO: Karen Gutenkunst

FR: Karlene Fine
Executive Director and Secretary

DT: March 14, 2001

RE: GRANT PAYMENT

Please have a check(s) prepared in the following amount to the entity(s) listed below as per their contract.

UND - EERC $75,000
ATTN: GRANTS & CONTRACTS OFFICE
FY00-XXXIV-94 LIGNITE TESTING IN ADVANCED HIGH-TEMP HIGH-PRESS
PO BOX 9018
GRAND FORKS, ND 58202-9018 (Second Payment)

UND - EERC $43,750
ATTN: GRANTS & CONTRACTS OFFICE
FY00-XXXVI-100 EVLUATION POTENTIAL SCR CATALYST BLINDING
PO BOX 9018
GRAND FORKS, ND 58202-9018 (First and Second Payments)

LIGNITE ENERGY COUNCIL $35,000
ATTN: JOHN DWYER
FY01-XXXVII-104 LIGNITE VISION 21 PROJECT PHASE II TRANSMISSION
PO BOX 2277
BISMARCK, ND 58502-2277 (Final Payment)

Please pay from the 1999-2001 biennium. If you have any questions, please call. Please forward the check(s) to the appropriate person(s) and make a copy for my files.

Thanks. KF

Karlene K. Fine, Executive Director and Secretary
State Capitol, 10th Floor - 600 E Boulevard Ave Dept 405 - Bismarck, ND 58505-0840
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INDUSTRIAL COMMISSION OF NORTH DAKOTA

LIGNITE RESEARCH, DEVELOPMENT AND MARKETING PROGRAM

Governor,
John Hoeven
Attorney General,
Wayne Stenehjem
Commissioner of Agriculture,
Roger Johnson

MEMORANDUM

March 13, 2001

TO: Karlene Fine, Executive Director and Secretary
North Dakota Industrial Commission

FROM: Clifford R. Porter, Director CRP
Lignite Research, Development and Marketing Program

SUBJECT: FY00-XXXVI-100: "Evaluation of Potential SCR Catalyst Blinding During Coal Combustion"; Contractor: Energy & Environmental Research Center; Recommendation for Payment of $22,500 for First Quarterly Report (10/1/00 – 12/31/00).

I have reviewed the first quarterly report (October 1, 2000 – December 31, 2000) from the contractor (Energy & Environmental Research Center) regarding Contract No. FY00-XXXVI-100 for the project titled "Evaluation of Potential SCR Catalyst Blinding During Coal Combustion".

The first quarterly report is adequate to determine that the contractor has complied with the statement of work.

The contractor has met the terms of contract FY00-XXXVI-100 required for receiving the $22,500 payment for the first quarterly report. I recommend payment of the $22,500.

CRP/vg: 24.S.30.A

LIGNITE RESEARCH COUNCIL
John Dwyer, Chairman
Clifford Porter, Director & Technical Advisor
P.O. Box 2277
Bismarck, N.D. 58502
(701) 258-7117 (701) 258-2755 Fax

INDUSTRIAL COMMISSION OF NORTH DAKOTA
Karlene Fine
Executive Director
600 East Boulevard, State Capitol
Bismarck, N.D. 58505
(701) 328-3722 (701) 328-2820 Fax

INDUSTRIAL COMMISSION OF NORTH DAKOTA

John Hoeven
Governor

Wayne Stenehjem
Attorney General

Roger Johnson
Commissioner of Agriculture

Memorandum

TO: Karen Gutenkunst

FR: Karlene Fine
Executive Director and Secretary

DT: June 7, 2001

RE: GRANT PAYMENT

Please have a check(s) prepared in the following amount to the entity(s) listed below as per their contract.

BASIN ELECTRIC POWER COOP $20,000
ATTN: CURT MELLAND
FY99-XXXIII-92 TRI VARIABLE SPPED FLUID DRIVES INDUCED DRAFT
1717 EAST INTERSTATE AVENUE
BISMARCK, ND 58501-0564 (Final Payment)

UND - EERC $22,500
ATTN: GRANTS & CONTRACTS OFFICE
FY00-XXXVI-100 EVLUATION POTENTIAL SCR CATALYST BLINDING
PO BOX 9018
GRAND FORKS, ND 58202-9018 (Third Payment)

Please pay from the 1999-2001 biennium. If you have any questions, please call. Please forward the check(s) to the appropriate person(s) and make a copy for my files.

Thanks. KF

Karlene K. Fine, Executive Director and Secretary
State Capitol, 10th Floor - 600 E Boulevard Ave Dept 405 - Bismarck, ND 58505-0840
E-Mail: kfine@state.nd.us
Phone: (701) 328-3722 FAX: (701) 328-2820
"Your Gateway to North Dakota": discovernd.com

INDUSTRIAL COMMISSION OF NORTH DAKOTA

LIGNITE RESEARCH, DEVELOPMENT AND MARKETING PROGRAM

MEMORANDUM

June 6, 2001

TO: Karlene Fine, Executive Director and Secretary
North Dakota Industrial Commission

FROM: Clifford R. Porter, Director CRP
Lignite Research, Development and Marketing Program

SUBJECT: FY00-XXXVI-100: "Evaluation of Potential SCR Catalyst Blinding During Coal Combustion"; Contractor: Energy & Environmental Research Center; Recommendation for Payment of $22,500 for Second of Seven Quarterly Reports (1/1/01 – 3/31/01).

I have reviewed the second quarterly report (January 1, 2001 – March 31, 2001) from the contractor (Energy & Environmental Research Center) regarding Contract No. FY00-XXXVI-100 for the project titled "Evaluation of Potential SCR Catalyst Blinding During Coal Combustion".

This second of seven quarterly reports is adequate to determine that the contractor has complied with the statement of work.

The contractor has met the terms of contract FY00-XXXVI-100 required for receiving the $22,500 payment for the second quarterly report. I recommend payment of the $22,500.

CRP/vg: 24.S.30.A

LIGNITE RESEARCH COUNCIL
John Dwyer, Chairman
Clifford Porter, Director & Technical Advisor
P.O. Box 2277
Bismarck, N.D. 58502
(701) 258-7117 (701) 258-2755 Fax

INDUSTRIAL COMMISSION OF NORTH DAKOTA
Karlene Fine
Executive Director
600 East Boulevard, State Capitol
Bismarck, N.D. 58505
(701) 328-3722 (701) 328-2820 Fax

100

Energy & Environmental Research Center

UNIVERSITY OF NORTH DAKOTA

15 North 23rd Street — PO Box 9018 / Grand Forks, ND 58202-9018 / Phone: (701) 777-5000 Fax: 777-5181
Web Site: www.undeerc.org

May 11, 2001

Ms. Susan Maley
U.S. Department of Energy
National Energy Technology Laboratory
PO Box 10940, MS 922-273C
Pittsburgh, PA 15236-0940

Dear Ms. Maley:

Subject: Joint Venture Subtask 31 – Evaluation of Potential SCR Catalyst Blinding During Coal Combustion; Contract DE-FC26-98FT40321

Please find enclosed the January 1 – March 31, 2001, Quarterly Technical Progress Report for the subject subtask. This work was performed at the University of North Dakota Energy & Environmental Research Center under the subject contract.

If you have any questions, please call me at (701) 777-5177, fax at (701) 777-5181, or e-mail at sbenson@undeerc.org.

Sincerely,

Steven A. Benson
Senior Research Manager

SAB/drh

Enclosure

S — does this generate a payment

c/enc: Edmundo Vasquez, Alliant Energy
Kenneth Stuckmeyer, AmerenUE
Mark Liefer, Dynegy/Midwest Generation
Blair Seckington, Ontario Power Generation, Inc.
Terry Graumann, Otter Tail Power Company
Karlene Fine, Industrial Commission of North Dakota
Clifford Porter, Lignite Energy Council

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(09-92)
Replaces EIA-459F
All Other Editions Are Obsolete

OMB Control No.
1910-0400

U.S. DEPARTMENT OF ENERGY
FEDERAL ASSISTANCE PROGRAM/PROJECT STATUS REPORT

1. Program/Project Identification No.	2. Program/Project Title	3. Reporting Period
DE-FC26-98FT40321	JV Task 31 – Evaluation of Potential SCR Catalyst Blinding During Coal Combustion	1-1-01 through 3-31-01

4. Name and Address
Energy & Environmental Research Center
University of North Dakota
PO Box 9018, Grand Forks, ND 58202-9018

5. Program/Project Start Date
4-15-98

6. Completion Date
3-31-03

7. Approach Changes

■ None

8. Performance Variances, Accomplishments, or Problems

Bench-Scale Testing

Ash has been produced for coals submitted to the Energy & Environmental Research Center (EERC) using the conversion and environmental process simulator (CEPS). The CEPS is a small-scale combustion system used to produce fly ash under closely controlled conditions. The following coals have been combusted using the CEPS, and the fly ash produced has been aerodynamically classified: Beulah (Otter Tail), Codero (Otter Tail), low-sulfur U.S. Nanticoke (bituminous Kinectrics), Powder River Basin (PRB) (Kinectrics), low-sulfur US (Nanticoke)–PRB blend (Kinectrics), Antelope–Rend Lake blend (AmerenUE), and North Antelope (Dynegy). The smaller size fraction of ash (less than 10 micrometers) was obtained for thermal gravimetric analysis (TGA). The compositions of selected coal ashes are listed in Table 1.

Combustion ash has been produced from Beulah, PRB, low-sulfur US–PRB blend, Antelope, and Antelope–Rend Lake Blend in the CEPS.

TGA Analysis

The working hypothesis for the TGA portion of the bench-scale testing is that the less than 5-micrometer size fraction of ash produced from PRB coals reacts wi vapor-phase sulfur dioxide and/or phosphorus compounds resulting in particle-to-particle bonding that has the potential to lead to the formation of deposits in the temperature range where selective catalytic reduction (SCR) catalysts are used. The TGA testing is focused on determining the reactivity of the less than 5-micrometer ash produced from selected PRB coals and blends to sulfur dioxide and gas-phase phosphorus species as a function of temperature. We also want determine the effect of ammonia and catalyst on the rates of reaction of the ash with sulfur dioxide and gas- phase phosphorus species. In order to determine the effect of the catalyst, we need small samples of the catalyst for our TGA testing. Our aim is to determine the effect the presence of catalyst has on the reactivity o the ash and not on the catalyst reactivity.

Baseline analysis without catalyst — PRB, low-sulfur US–PRB blend, Beulah
Awaiting catalyst – catalyst samples from Hitachi arrived, and tests will be conducted with the catalyst.

☐ None

Continued . . .

9. Open Items

■ None

10. Status Assessment and Forecast

Next meeting will be at the EERC on May 23 beginning about 8:30 a.m. We plan to finish by 3:00 p.m. so that participants can catch the late afternoon flight. We anticipate that the reactor construction will be completed prior to the meeting, and field testing will begin in June or July. We will continue bench-scale testing.

■ No Deviation from Plan is Expected

11. Description of Attachments

Performance Variances, Accomplishments, or Problems (continued)
☐ None

12. Signature of Recipient and Date	13. Signature of U.S. Department of Energy (DOE) Reviewing Representative and Date
[signature] 5/11/01	

8. Performance Variances, Accomplishments, or Problems (continued)

TABLE 1

Composition of Coal Ashes Used in Bench-Scale Testing

	Nanticoke 100% PRB		Nanticoke 52%PRB–48%LSUS		Beulah	
Oxides, wt%	(a)	(b)	(a)	(b)	(a)	(b)
SiO_2	27.9	32.0	43.4	48.4	31.5	39.7
Al_2O_3	17.7	20.3	26.7	29.7	14.2	17.9
Fe_2O_3	6.2	7.1	4.8	5.3	7.3	9.2
TiO_2	1.5	1.8	1.6	1.8	0.8	1.0
P_2O_5	1.0	1.2	0.4	0.4	0.2	0.2
CaO	24.8	28.5	8.5	9.4	15.8	19.9
MgO	6.6	7.6	2.6	2.9	5.8	7.3
Na_2O	1.0	1.2	0.7	0.7	3.1	3.9
K_2O	0.4	0.5	1.2	1.3	0.8	1.0
SO_3	12.9	—	10.2	—	20.6	—

(a) Oxide concentrations normalized to a closure of 100%.
(b) Oxide concentrations renormalized to a SO_3-free basis.

Updated data from the TGA analysis conducted with sulfur dioxide in a simulated flue gas atmosphere is shown in Figures 1 and 2 for Beulah and Nanticoke PRB, respectively. Figure 3 shows the weight gain for the Nanticoke low-sulfur US–PRB blend. The weight gain was plotted on a mg/mg ash versus time for the selected temperatures. The results indicate that sulfation rates increase with increasing temperatures and the PRB appears to have higher sulfation rates than the Beulah. The results from the Nanticoke low-sulfur US–PRB blend indicate very high sulfation at 800°F.

Ash tested in the TGA has been submitted for scanning electron microscopy analysis. According to this analysis, vapor-phase phosphorus is being generated and deposited on the surfaces of particles in those coals that have the phosphorus-containing compounds, such as the coals from Nanticoke. The other sample (Beulah) did show evidence of forming sulfur species. In all samples, the sulfur and phosphorus levels varied from 1% to 2 %. These data will be more completely evaluated when catalyst samples are received.

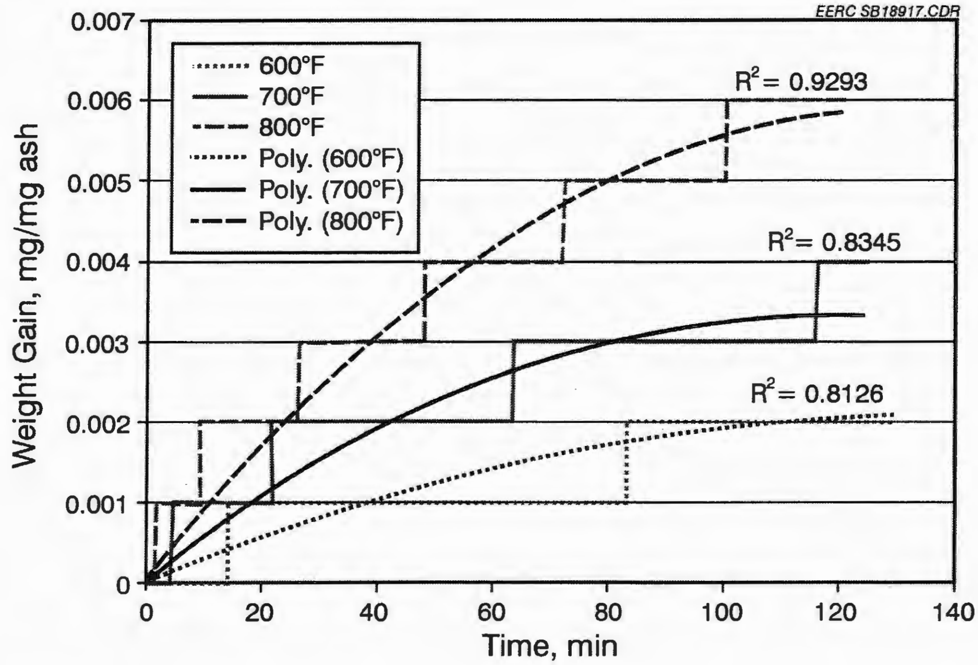

Figure 1. Weight gain curves for Beulah lignite ash (less than 3 microns).

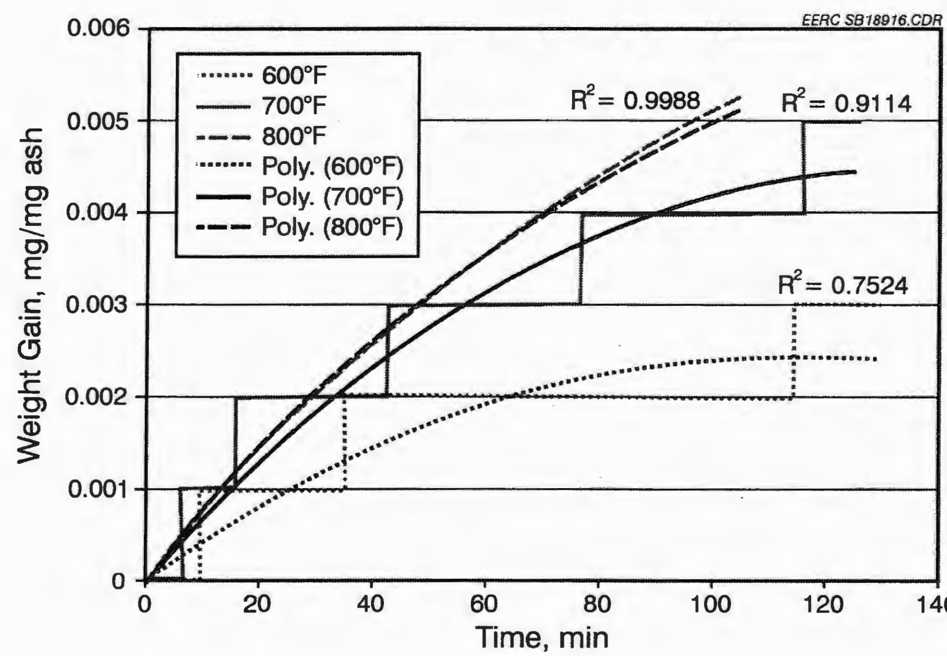

Figure 2. Weight gain curves for Nanticoke PRB (less than 3 microns).

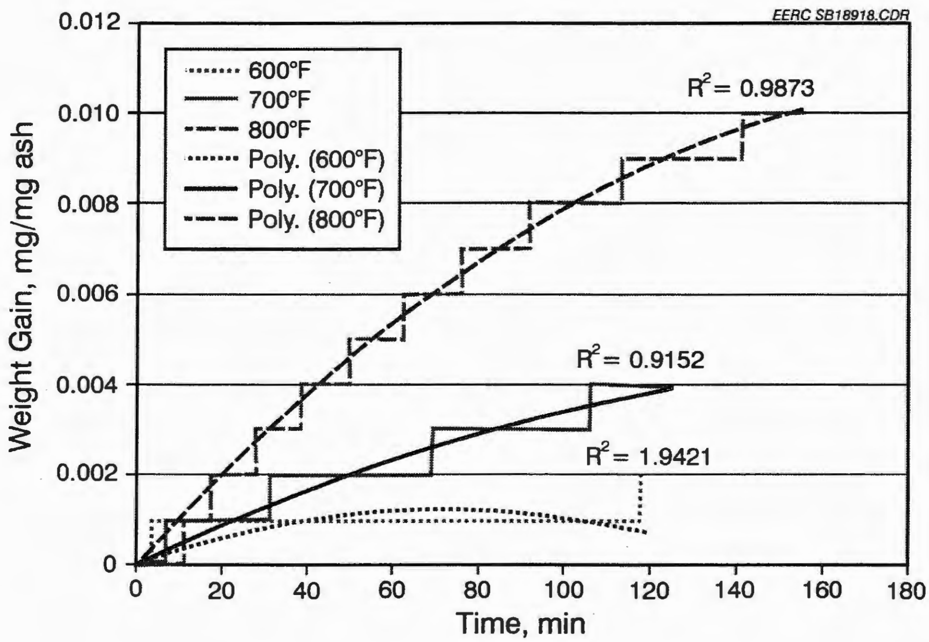

Figure 3. Weight gain for Nanticoke U.S. Bit–PRB blend.

SCR Reactor Design/Construction – Status of Construction Activities

Nearly all of the components for the SCR reactor have been designed and ordered. The final design for the reactor is awaiting approval from Hitachi and input from Haldor Topsoe. Once that is finalized, the construction of the reactor vessel will be completed.

Discussions with Hitachi have yielded a simple design that will accommodate all of the sampling we need. The reactor design essentially has remained the same except for the number of sections. The number of sections has been reduced from two to one and will be up to 675 mm (26.5 inches) in length. This is a standard size that Hitachi makes and will make the construction easier. Construction on the catalyst section of the reactor could begin as early as the end of this week if personnel are available.

Construction is under way for the control system and piping. All of the flanges have been welded that can be welded. Ammonia regulator/flowmeter is on order. The computer control system is being programmed and debugged. The enclosure for the control systems has been built, and mounting of the data acquisition boards, magnehelic, thermocouple panel, transmitters, air conditioning, breaker panel, etc, will begin next week. The insulation and heating system has been ordered.

Field Testing

Field test sites have been identified. Site visits have been conducted to Coyote and Baldwin. We hope to have the reactors available for installation at power plants by the middle of May. The site visit to Baldwin yielded useful descriptions of its unit. A sample port is being installed, and we hope to get our sampling nozzle installed before the outage is over. We need to schedule a visit to Columbia.

TABLE 2

Field Test Locations

Station	Location	Coal	Other Fuels	Outlet Temp	MW_E	Firing Method
Columbia	Portage, WI	PRB Coals – Caballo, Black Thunder, Eagle Butte	None	500° to 850°F	2 × 540	T-fired
Baldwin	Baldwin, IL	PRB Antelope and Rochelle	2% tires	(Units 1 and 2) 730° to 760°F (Unit 3) 750° to 780°F	3 × 600	Cyclone, Cyclone, PC – T-fired
Coyote	Beulah, ND	Beulah lignite	None	780°F	425	Cyclone

CONFERENCE CALL Meeting Minutes

Evaluation of Potential SCR Catalyst Blinding During Coal Combustion

Wednesday March 21, 2001

1. Review of Minutes from November Conference Call

Go through specific points in the minutes that need clarification and updating.

Discussion: No clarification needed

2. Sponsorship/Confidentiality

Sponsorship:

We are still awaiting the contract from EPRI (Intellectual property issue – being reviewed by legal council).

Discussion. Dave indicated we should have the contract shortly.

Detroit Edison emailed me last week inquiring about the project and they are considering funding the project. Hopefully we will hear soon. If we get additional sponsorship we may be able to test an additional plant such as a plant that fires blends of PRB subbituminous and high sulfur bituminous coals.

Confidentiality
We have signed confidentiality agreements from:
Hitachi
Otter Tail Power
EPRI
AmerenUE
Karlene Fine hopes to get out this week the approval to us from the Industrial Commission.
We don't have signed agreements from:
Cormetech
Dynegy
Alliant (however, I've left a message to communicate with their attorney)
Ontario Power

Additional Particpants:

Discussion: Dave O'Connor provided the name of another catalyst vendor, Haldor Topsoe, who may be interested in participating. EERC will contact them.

3. Bench Scale testing – Status

Ash has been produced for coals submitted to EERC using the conversion and environmental process simulator (CEPS). The CEPS is a small scale combustion system that is used to produce fly ash under closely controlled conditions. The following coals have been combusted using the CEPS and the fly ash produced has been aerodynamically classified. The smaller size fraction of ash (less than 10 micrometers) was obtained for thermal gravimetric analysis. The coals received for testing include:

Beulah (OtterTail), Codero (Otter Tail), Low sulfur US (Kinectrics), PRB (Kinectrics), Low sulfur US/PRB blend (Kinectrics), Antelope/Rend Lake blend (AmerenUE), and North Antelope (Dynegy). The compositions of selected coal ashes are listed in Table 1.

Combustion ash has been produced from Beulah, PRB, low sulfur US/PRB blend, Antelope, and Antelope/Rend Lake Blend in the CEPS.

Table 1. Composition of Coal Ashes used in Bench Scale Testing.

	Nanticoke 100% PRB		Nanticoke 52%PRB/48%LSUS		Beulah	
Oxides, wt%	(a)	(b)	(a)	(b)	(a)	(b)
SiO2	27.9	32.0	43.4	48.4	31.5	39.7
Al2O3	17.7	20.3	26.7	29.7	14.2	17.9
Fe2O3	6.2	7.1	4.8	5.3	7.3	9.2
TiO2	1.5	1.8	1.6	1.8	0.8	1.0
P2O5	1.0	1.2	0.4	0.4	0.2	0.2
CaO	24.8	28.5	8.5	9.4	15.8	19.9
MgO	6.6	7.6	2.6	2.9	5.8	7.3
Na2O	1.0	1.2	0.7	0.7	3.1	3.9
K2O	0.4	0.5	1.2	1.3	0.8	1.0
SO3	12.9	----	10.2	----	20.6	----
Total						

(a) Oxide concentrations normalized to a closure of 100%.
(b) Oxide concentrations renormalized to a SO3-free basis

TGA analysis:

Baseline analysis without catalyst -- PRB, low sulfur US/PRB blend, Beulah
Awaiting catalyst –

Data from the TGA analysis conducted with sulfur dioxide in a simulated flue gas atmosphere is shown in Figures 1 and 2 for Beulah and Nanticoke PRB, respectively. Figure 3 shows the weight gain for the Nanticoke low sulfur US/PRB blend. The results indicate that sulfation rates increase with increasing temperatures and the PRB appears to have higher sulfation rates than the Beulah. The results from the Nanticoke low sulfur US/PRB blend indicate very high sulfation at 800 F.

Discussion: Need to get catalyst for bench-scale testing.

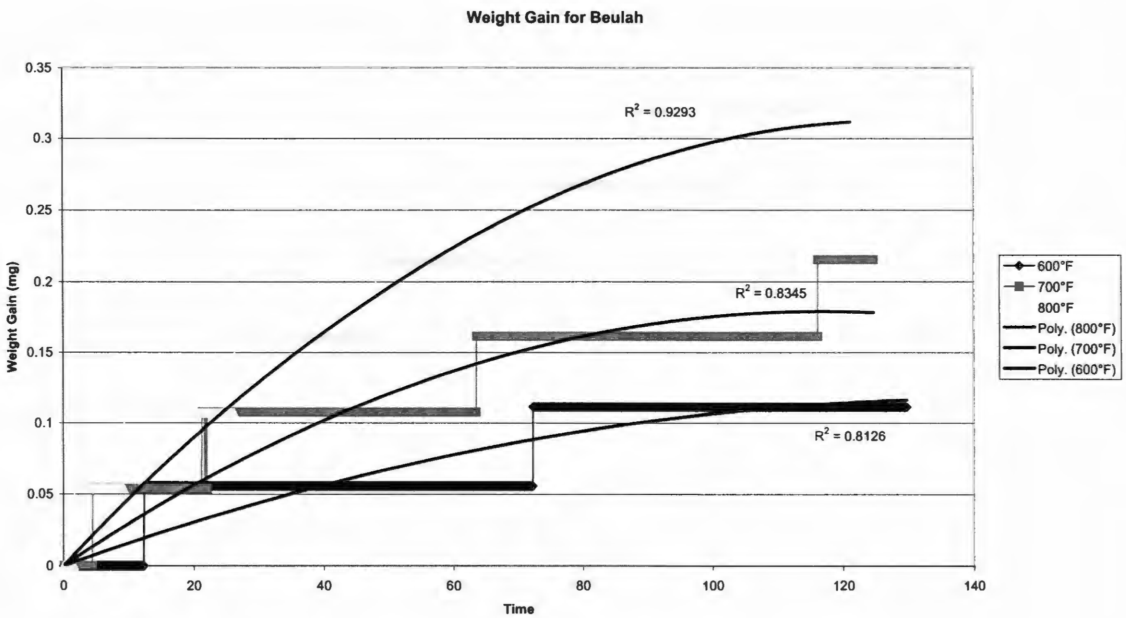

Figure 1. Weight gain curves for Beulah lignite ash (less than 3 micron)

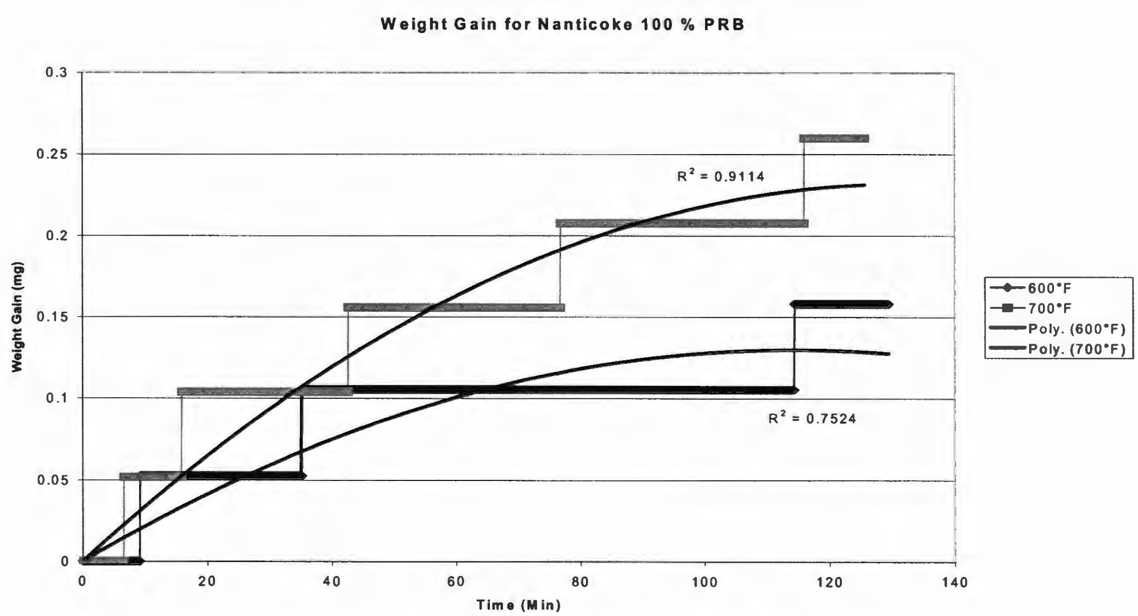

Figure 2. Weight gain curves for Naticoke PRB (less than 3 microns).

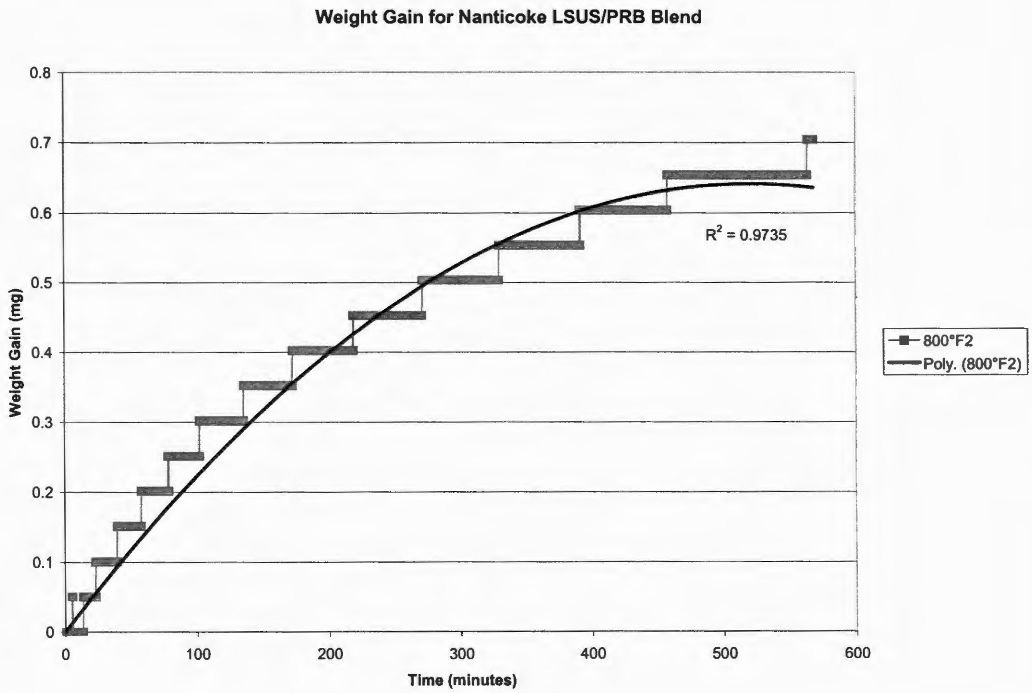

Figure 3. Weight gain for Naticoke US Bit/PRB blend.

4. SCR Reactor Design/Construction – Status of Construction Activities

Nearly all of the components for the SCR reactor have been designed and ordered. The final design for the reactor is awaiting final approval by Hitachi. Once that is finalized the construction of the reactor vessel will be completed. Construction is underway for the control system and piping. All the flanges have been welded that can be welded. Ammonia regulator/flow meter on order. The computer control system is being programmed and debugged. The enclosure for the control systems have been built and mounting of the data acquisition boards, magnehelic, thermocouple panel, transmitters, air conditioning, breaker panel, etc will begin next week. The insulation and heating system has been ordered.

Discussion: Don Toman discussed the status of the reactors and the need to finalize the design of the vessel to house the catalysts. This is the only part of the design and construction phase currently on hold. Design awaiting final approval by Catalyst vendors.

5. Field Testing

Field test sites have been identified and a site visit has been conducted to Coyote and a visit to Baldwin the end of this week. We hope to have the reactors available for installation at power plants by the middle of May.

Discussion: Don Toman discussed the pipe and electrical requirements for the Baldwin Plant and Don visited the site the end of last week after the conference call.

Table 2. Field test locations

Station	Location	Coal	Other Fuels	Outlet Temp	MWE	Firing Method
Colombia	Portage, WI	PRB Coals - Caballo, Black Thunder, Eagle Butte	NONE	500 to 850 °F	2 X 540	T-Fired
Baldwin	Baldwin, IL	PRB Antelope and Rochelle	2 % tires, plastic, and dirt with coal tar	(Units 1 & 2) 730 to 760 °F (Unit 3) 750 to 780 °F	3 X 600	Cyclone, Cyclone, PC – T-fired
Coyote	Beulah, ND	Beulah Lignite	NONE	780 °F	425	Cyclone

6. Conference Call/Meetings

Organizing conference calls is becoming increasingly difficult. We suggest the following as a way to discuss project directions and status. EERC will prepare monthly statements of project status, accomplishments, and issues to be resolved on EERC's website on a page that is only accessible by SCR Blinding Project participants. The page will be linked to a Net Forum program that will allow you to post questions or comments regarding progress and make suggestions and comments. We will make the reports available on the 15 of each month or as issues come up with up to a week to respond to issues raised. This would provide the opportunity for project participants to review project status and directions at times most convenient for them. At the end of the week EERC will compile the discussion/comments and email the responses to all SCR participants and make them available on the website. We will also make available the most recent results of the project on the website. We also understand that it is necessary to have conference calls and to have on-site visits to discuss project status.
Decisions:

- What do you think about the website idea?
- Check your calendar we would like to schedule a meeting at EERC in mid May to see the reactors. Nice time of the year in North Dakota – snow is usually gone.
- Conference call – should we try to continue?

Discussion: We decided to continue the conference calls and hopefully we will have good participation. The next call is set up for April 18 at 1:00pm. We also plan to have a meeting at EERC on either May 22 or 23. Patti will be contacting everyone.
Regarding the website idea – We will give it a try and provide information including reports and conference call meeting minutes.

Clifford Porter

From:	Reimer, Patti J. [preimer@undeerc.org]
Sent:	Wednesday, March 28, 2001 4:01 PM
To:	'tgraumann@otpco.com'; 'cporter@lignite.com'; 'pritchardsg@cormetech.com'; 'DOCONNOR@epri.com'; 'edmundovasquez@alliant-energy.com'; 'kenneth_b_stuckmeyer@ameren.com'; 'byron_veech@illinoispower.com'; 'mark_liefer@dynegy.com'; 'Rene.Mangal@kinectrics.com'; 'blair.seckington@ontariopowergeneration.com'; 'walter.nischt@hal.hitachi.com'; 'Susan.Maley@netl.doe.gov'; 'patton@netl.doe.gov'; 'ziaul_karim@dynegy.com'; 'fgh@topsoe.com'
Cc:	Benson, Steven A.; Laumb, Jason; Zygarlicke, Chris J.; Toman, Donald L.; Gunderson, Jay R.; Landis, Sheryl
Subject:	SCR Blinding Project Conference Call Minutes

ConfCallMinutes-0321.doc

Attached below are the minutes from the last conference call which was held on March 21. The next conference call is scheduled for April 18, at 1:00 p.m. CST. Let me know if you will not be participating in the conference call.

Thank you
Patti

<<ConfCallMinutes-0321.doc>>

Energy & Environmental Research Center
UNIVERSITY OF NORTH DAKOTA
15 North 23rd Street — PO Box 9018 / Grand Forks, ND 58202-9018 / Phone: (701) 777-5000 Fax: 777-5181
Web Site: www.undeerc.org

100

June 5, 2001

Mr. Clifford Porter
Lignite Research Council
PO Box 2277
Bismarck, ND 58502

Dear Mr. Porter:

Enclosed please find a copy of the handouts from the SCR Blinding Project Review meeting which was held at the Energy & Environmental Research Center (EERC) on May 23. You will be e-mailed a copy of the minutes from the meeting at a later date.

Sincerely,

Patti J. Reimer

Patti J. Reimer
Administrative Assistant
Administrative Resources

PJR

Enclosures

c: Steve Benson, EERC

Energy &
Environmental
Research
Center

Evaluation of Potential SCR Catalyst Blinding During Coal Combustion

Project Review Meeting
May 23, 2001

Energy & Environmental Research Center
Grand Forks, North Dakota

Energy & Environmental Research Center

Evaluation of Potential SCR Catalyst Blinding During Coal Combustion

Project Review Meeting
Energy & Environmental Research Center
Grand Forks, North Dakota
Wednesday, May 23, 2001

Agenda

Evaluation of Potential SCR Catalyst Blinding During Coal Combustion
Project Review Meeting, Grand Forks, ND, May 23, 2001

8:30 a.m.	Welcome and Introductions	Gerry Groenewold Tom Erickson Steve Benson
9:00 a.m.	Project Overview and Status	Steve Benson
9:30 a.m.	Task 1 – Identification of Test Coals and Utility Host Sites	Steve Benson
9:45 a.m.	Break	
10:00 a.m.	Task 2 – Bench-Scale Testing and Screening	Jason Laumb Don McCollor
11:00 a.m.	Task 3 – Design of Slipstream Unit	Jay Gunderson Don Toman
11:30 a.m.	Task 3 – Software and Control Systems	Bob Jensen
12:00 noon	Lunch at EERC *[2nd Floor Lunchroom]*	
1:00 p.m.	Task 3 – Tour of the Slipstream System and Demonstration	Jason Laumb Jay Gunderson Don Toman
2:00 p.m.	Project Schedule	Steve Benson
2:30 p.m.	Evaluation of SCR Catalyst Blinding for Biomass–Coal Cofiring	Chris Zygarlicke
3:15 p.m.	Adjourn	

Project Participants

- Electric utilities
  - Kinectrics/Ontario Power Generation
  - Otter Tail Power Company
  - Alliant Energy
  - AmerenUE
  - Dynegy
- EPRI
- North Dakota Industrial Commission
- U.S. Department of Energy National Energy Technology Laboratory
- Catalyst Vendors: Hitachi, Haldor Topsøe, Cormetech

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Objectives

- Determine potential for low-rank coal ash to cause blinding of selective catalytic reduction (SCR) catalysts
- Determine mechanisms of SCR blinding
- *Determine the degree of elemental mercury conversion across SCR catalyst material – discuss keeping this task.*

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Background

- EPA
  - Phase II (Year 2000) NO_x Emissions Rule for Coal Boilers
  - EPA rule (1998) to lower new source performance standards for NO_x
  - Required that states develop state implementation plans (SIPs) for reducing nitrogen oxide (NO_x) emissions. These plans must be developed by 22 states and the District of Columbia between now and September 1999
- SCR considered a "best demonstrated system" for NO_x control
- NO_x reduction costs estimated at ~$1100/ton removal or $40–$90/kWh
- Potential rules for mercury: 2000 – regulatory determination; 2004 – final rule; 2007 – mercury compliance

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Justification

- SCR may be the only option for many utilities, especially those with cyclone-fired boilers, and there may be problems with SCR for low-rank coals.
- Utilities, SCR vendors, and regulating agencies need sound scientific information on SCR performance for low-rank coals.
  - Recent utility boiler tests show rapid deactivation of catalyst material in relatively short times.
  - Knowledge of blinding mechanisms is critical.
- Potential to challenge EPA or other state rulings (i.e., SCR may not be "best" system for control because of blinding or poisoning issues).
- SCR may convert mercury to a form more likely to be captured

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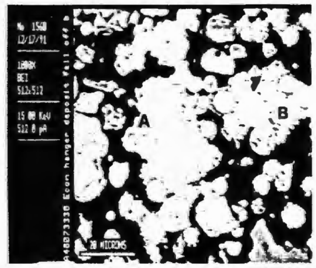
Issues Involving Low-Rank Coals and SCR

- Research by Germans, Cormetech, EPRI, and other utilities showed that physical blinding is caused by alkali sulfates (Na, K, Ca).
- Recent Siemens work (ASME Joint Power Conf.) describes small calcium sulfate crystals/particles blocking catalyst pores with 50% catalyst deactivation after 3000 hours for PRB coal.
- Tradeoff between lessening arsenic poisoning (> Ca) and lessening calcium-sulfate blinding (<reactive Ca)



SEM micrograph showing Ca-Na-rich fly ash sulfating with time at low temperatures.

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Issues Involving Low-Rank Coals and SCR (Continued)

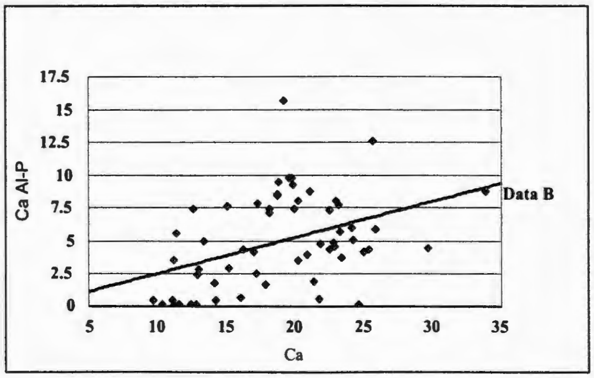
Fine particulate deposits at low temperature (full-scale boiler)

Ca-sulfate-rich deposit, particles <3μm | Steel deposition probe

- Fine-particle production more prevalent with North Dakota lignite and Powder River Basin-type lower-rank coals compared to bituminous coals.
- PRB and lignites produce large concentrations of reactive Ca (for sulfation).
- Catalytic activity of metals in SCR may enhance deposition (sulfation).
- Certain phosphate compounds are stable in SCR regime.

Ca-Al-P-Rich Mineral Occurrence vs. Calcium Content

(CCSEM and XRF analysis data for 50 U.S. lignite and PRB coals)



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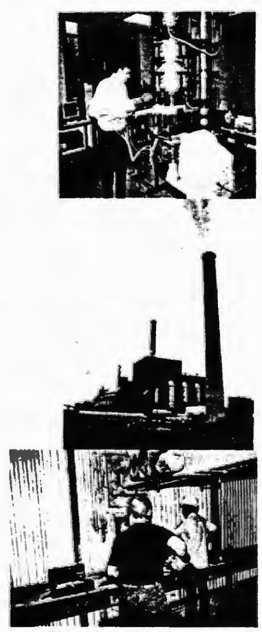
Project Work Plan

- Task 1 – Identification of Test Coals, Utility Host Sites, and Final Work Plan
- Task 2 – Bench-Scale Testing and Screening
- Task 3 – Design and Construction of SCR Slipstream Test Chamber
- Task 4 – SCR Test Chamber Installation and Data Collection at Utility Host Sites
- Task 5 – Determination of SCR Blinding Mechanisms
- Task 6 – Final Interpretation, Recommendations, and Reporting



Deliverables

- Utilities gain mechanistic information on SCR catalyst blinding to aid in:
  - Selection of SCR vendors.
  - Negotiating guarantees on SCR performance.
- SCR industry improves its products for low-rank coals
- Insight on mercury emissions
  - Very minimal task.

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Project Budget and Cost Structure

- Multiclient consortium with DOE joint venture funding
- $240,000 industry (utilities, catalyst vendor[s])
- $200,000 NDIC funding
- $293,000 DOE

- Total Project Budget $733,000

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Initial Budget Estimates by Task

Task 1 –	Identification of Test Coals and Utility Host Sites and Final Work Plan	$33,000
Task 2 –	Bench-Scale Testing and Screening	$103,000
Task 3 –	Design and Construction of SCR Slipstream Test Chamber	$121,000
Task 4 –	SCR Test Chamber Installation and Data Collection at Utility Host Sites	$205,000
Task 5 –	Determination of SCR Blinding Mechanisms	$167,000
Task 6 –	Final Interpretation, Recommendations, and Reporting	$104,000

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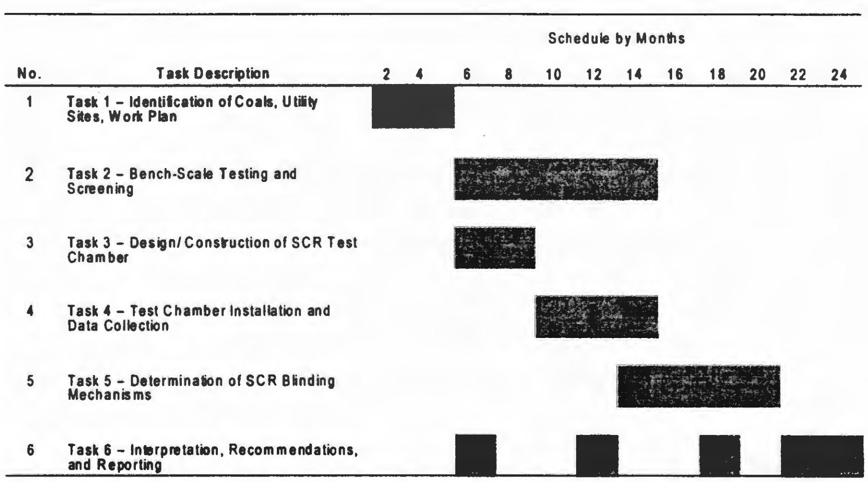
Schedule (24-month duration)



Project Personnel

- Managers: Steve Benson
- PIs: Jay Gunderson, Jason Laumb, Don Toman
- Other key technical staff: John Pavlish, Don McCollor, Dean Evenstad, Bob Jensen, Chris Zygarlicke
- Administrative: Patti Reimer

Status – Task 1

- Task 1 – Identification of Test Coals, Utility Host Sites, and Final Work Plan
  - Test coals for bench-scale testing – range of calcium, phosphorus contents, represents sponsors'/field test coals
  - Utility host sites – boiler type, fuels fired, budget
  - Final work plan – decision on mercury transformations across catalyst

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Status – Task 2

- Task 2 – Bench-Scale Testing and Screening
  - Ash produced from four coals
  - TGA analysis conducted on ashes and catalyst–ash mixtures
  - Thermochemical equilibrium calculations conducted for sulfur- and phosphorus-containing species

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Status – Task 3

- Task 3 – Design and Construction of SCR slipstream test chambers (two)
  - Design complete
  - Construction nearly complete
  - Computer control and communication systems nearly complete

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Status – Task 4

- Task 4 – SCR Test Chamber Installation and Data Collection at Utility Host Sites
  - Coyote site visit complete
  - Baldwin site visit complete
    - Sampling ports installed
    - Nozzle installed
    - First plant to be tested – within the month
  - Schedule Columbia site visit for next month

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Status – Task 5

- Task 5 – Determination of SCR Blinding Mechanisms
  - Some information being developed from the bench-scale testing on kinetics and thermodynamics of sulfate and phosphate phases

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Status – Task 6

- Task 6 – Final Interpretation, Recommendations, and Reporting
  - Kickoff meeting, monthly conference calls, quarterly reports, and progress review meeting

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Task 1 Selection of Test Coals

- Coals selected for bench-scale testing
  - Beulah
  - Antelope
  - Antelope–Rend Lake blend
  - PRB(various)–low sulfur bituminous blend
  - North Rochelle
  - Caballo ??

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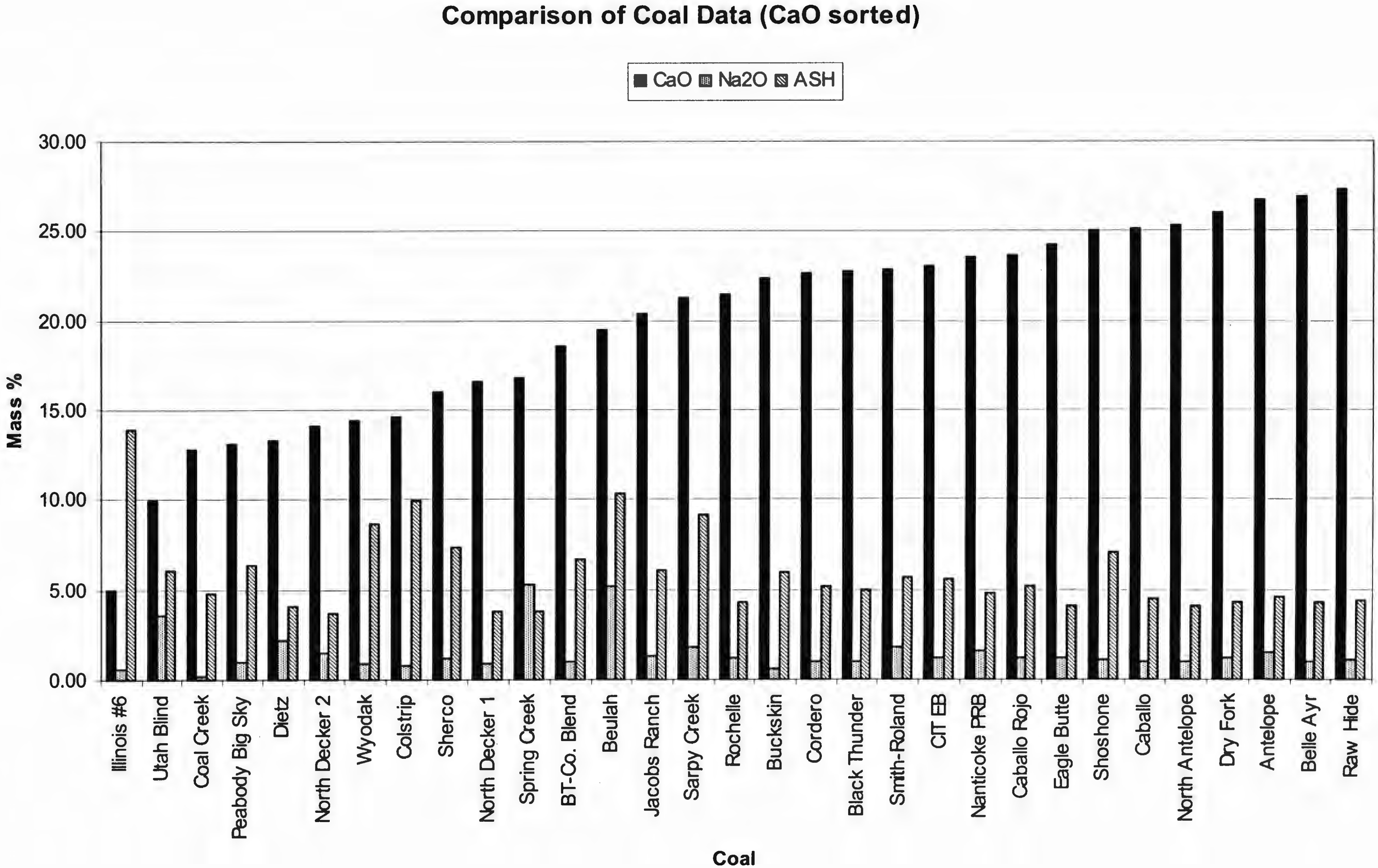
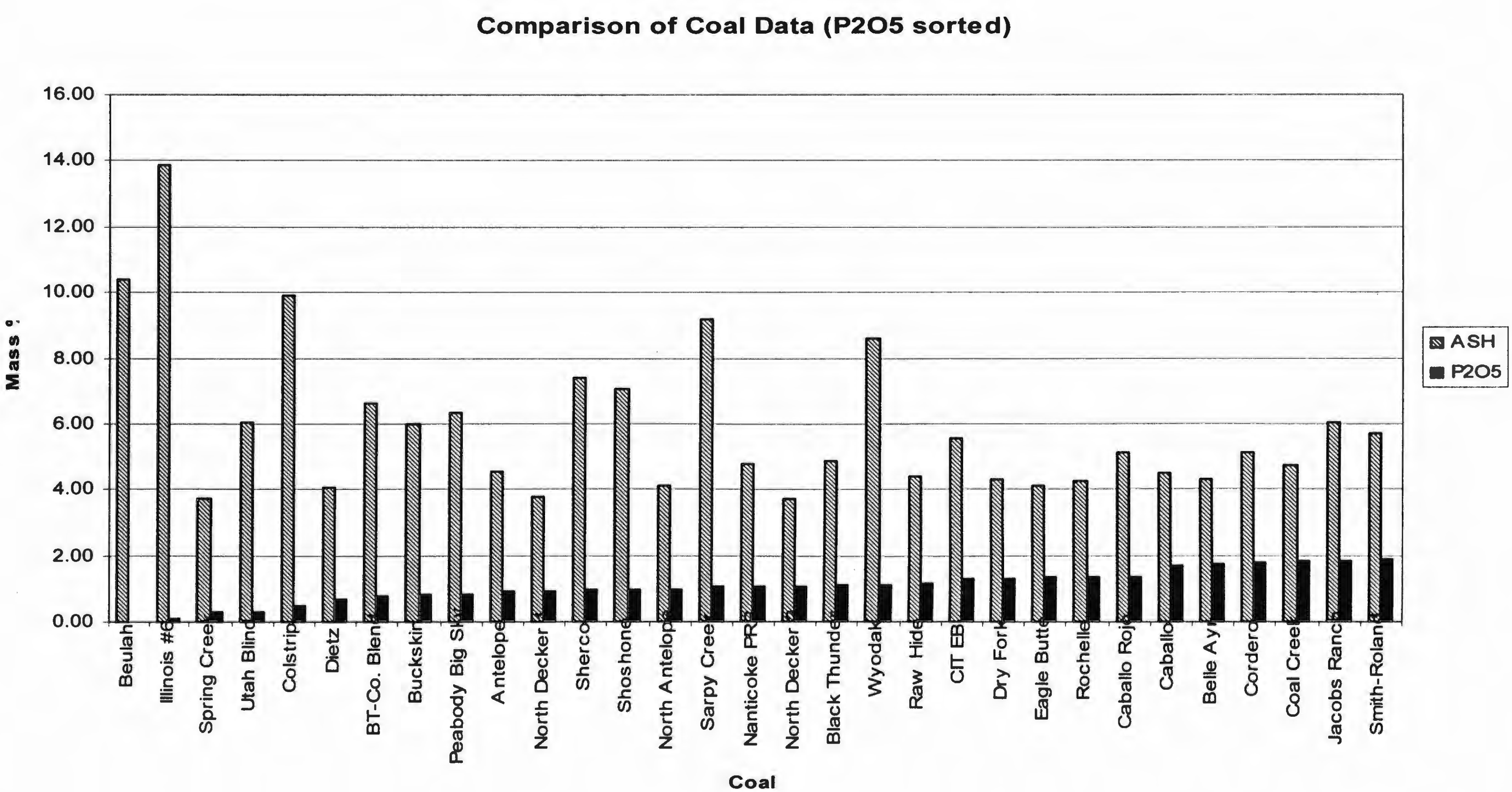
Task 1 Selection of Test Coals



Task 1 Selection of Test Coals



Task 1 Selection of Test Coals

	75% ANTELOPE/ 25% REND LAKE COAL 70–80% -200 MESH	ANTELOPE COAL 70–80% -200 MESH	NANTICOKE 100% PRB	NANTICOKE 52% PRB/48% LSUS	BEULAH CEPS #122
TOTAL MINERAL WT% ON A COAL BASIS:	4.935	3.247	5.489	10.397	8.482
TOTAL WT% ON A MINERAL BASIS:					
QUARTZ	24.2	31.5	22.4	13.9	11.0
KAOLINITE	19.5	17.1	26.3	31.8	4.4
MONTMORILLONITE	3.4	6.5	11.6	5.4	0.0
K AL-SILICATE	10.6	1.6	0.8	19.0	0.0
MIXED AL-SILICA	2.1	1.0	1.2	2.1	4.9
FE SILICATE	0.0	0.0	0.0	0.0	6.6
CA SILICATE	0.1	0.4	0.2	0.0	7.2
CA ALUMINATE	0.0	0.0	0.0	0.0	9.0
PYRITE	0.8	0.0	0.0	0.2	2.6
PYRRHOTITE	16.6	4.8	0.0	4.0	0.1
CA AL-P	6.4	13.5	10.3	2.0	0.0
GYPSUM/BARITE	0.0	0.1	0.0	0.0	18.4
GYPSUM/AL-SILIC	0.6	0.9	2.7	0.4	0.5
SI-RICH	2.4	3.7	3.4	2.0	0.5
UNCLASSIFIED	8.7	8.7	12.6	12.6	0.1
TOTALS	100.0	100.0	100.0	100.0	0.0

Task 1 Selection of Test Coals

WDXRF Analysis Report

	Nanticoke 100% PRB		Nanticoke 52%PRB/48%LSUS		Beulah CEPS #122	
Oxides, wt%	(a)	(b)	(a)	(b)	(a)	(b)
SiO2	27.9	32.0	43.4	48.4	31.5	39.7
Al2O3	17.7	20.3	26.7	29.7	14.2	17.9
Fe2O3	6.2	7.1	4.8	5.3	7.3	9.2
TiO2	1.5	1.8	1.6	1.8	0.8	1.0
P2O5	1.0	1.2	0.4	0.4	0.2	0.2
CaO	24.8	28.5	8.5	9.4	15.8	19.9
MgO	6.6	7.6	2.6	2.9	5.8	7.3
Na2O	1.0	1.2	0.7	0.7	3.1	3.9
K2O	0.4	0.5	1.2	1.3	0.8	1.0
SO3	12.9	----	10.2	----	20.6	----
Total						

(a) Oxide concentrations normalized to a closure of 100%.
(b) Oxide concentrations renormalized to a SO3-free basis

Task 1 Utility Host Selection

Field Test 1 – Columbia

– P.C.-fired which may be important for partitioning differences compared to cyclone
– High potential blinding coal in Caballo, which can be burned nearly 100% for the entire test
– Good fit operationally, we've tested them before and know the unit; NH4, hookups, electrical, plant personnel assistance, and codes should all be OK
– Proximity; 1200 miles with only 16–20 hours travel time round trip (pulling a trailer).

Field Test 2 – Baldwin Plant

– Cyclone fired
– Units already are equipped to do slipstream testing
– Plant currently fires a blend of antelope and tires – plant is willing to fire 100%
– Good high potential blinding coal in Antelope, which should run moderately close to 100%
– Good fit operationally with codes, hookups, plant personnel assistance, NH4, etc.
– Proximity: 2100 miles with 60-70 travel hours round trip (just southeast of St. Louis about 30 miles).

Field Test #3 -- Coyote

– Cyclone fired
– High potential blinding with high alkali (Ca-Na-Mg), plus fairly high S.
– Excellent fit operationally with exact numbers on piping, etc.; all hookups, electrical, NH4, codes, plant personnel assistence, all no problem.
–Experience working there before.
–Very close proximity: 500 miles and 8-10 hours travel time round trip.
– The cheapest to do, which means if we run into problems like cost overruns on the other field tests, we can no doubt still find a way to do this test because it is so close.

Task 1 Work Plan

- Work plan
  - Measurement of Hg transformations across catalyst ??

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SCR Blinding Bench-Scale Study

Project Review Meeting

May 23, 2001

Jason D. Laumb

Overview

- Hypothesis
- Fuel data
- Fuel combustion (CEPS)
- TGA analysis
- Morphology analysis
- FACT modeling
- Conclusions

Bench-Scale Testing

- Working hypothesis
  - Calcium and other alkaline-earth and alkali-rich small particles are deposited that are subsequently reacted with gas-phase components causing blinding of catalyst.
  - Sulfates and phosphate are responsible for the formation of deposits that blind catalysts

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Bench-Scale Testing

- Calcium-rich small particles are deposited that are subsequently reacted with gas-phase components causing blinding of catalyst.
  - Production of ash from selected coals with and without phosphorus-bearing minerals under simulated combustion conditions using CEPS unit.
  - Collection and characterization of size-fractionated ash to determine distribution of elements as a function of particle size and vapor phase (1 to 3 micron size).
  - Information can be used ultimately to assess a coal's potential to blind a catalyst.

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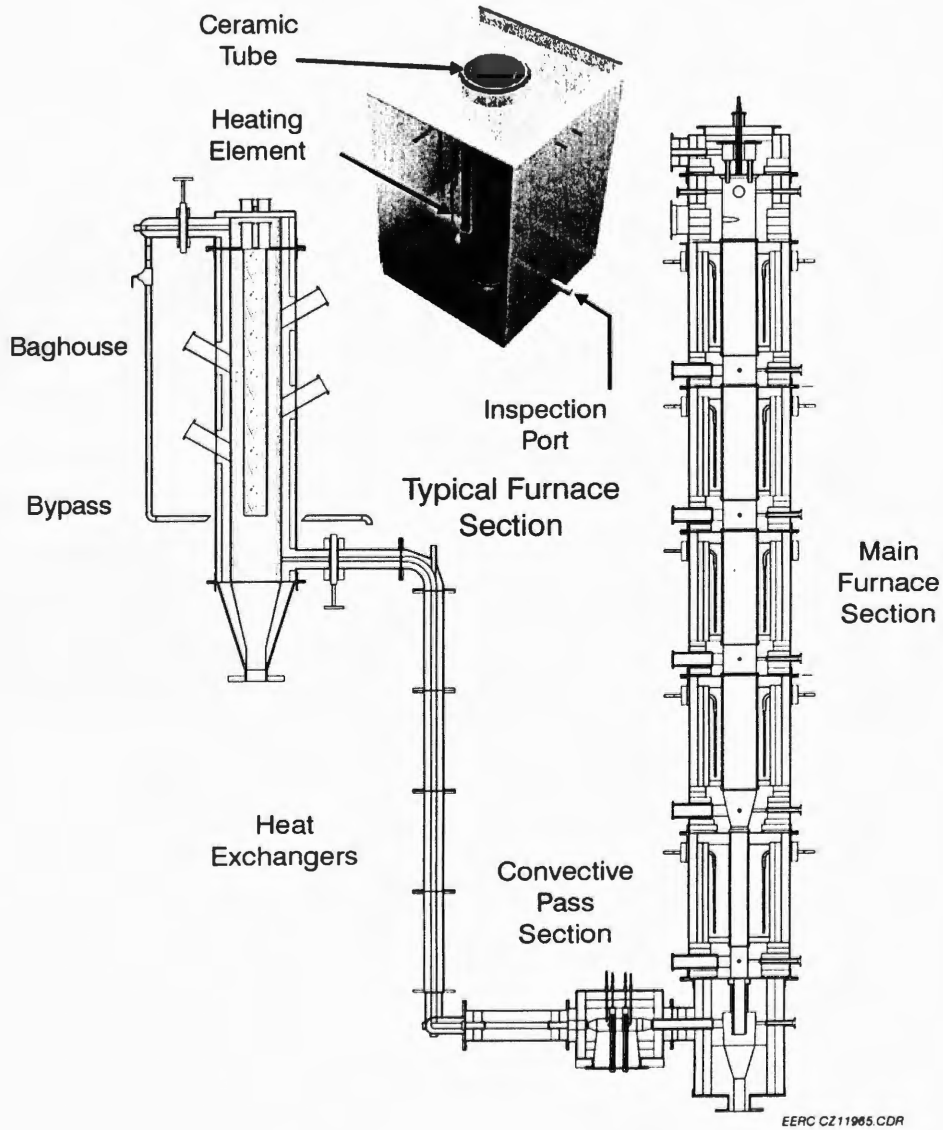
CEPS Unit


Ceramic
Tube
Heating
Element
Baghouse
Bypass
Inspection
Port
Typical Furnace
Section
Main
Furnace
Section
Heat
Exchangers
Convective
Pass
Section
EERC CZ11965.CDR

Bench-Scale Testing

- Sulfates and phosphates are responsible for the formation of deposits that blind catalysts.
  - Thermal gravimetric analysis to determine the optimum reaction temperature and reaction rates for small calcium- and sodium-rich ash particles.
    - Gas composition will be a simulated flue gas with SO_2 and gas-phase phosphorus compounds.

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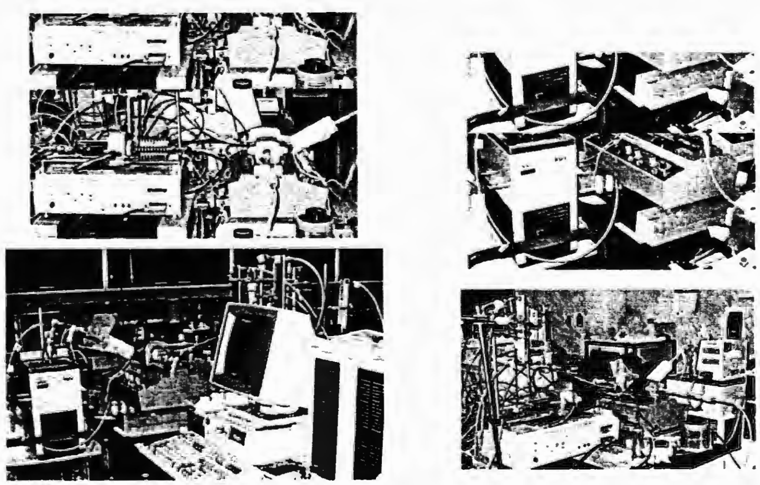
TGA System



TGA Testing

- Isothermal testing to develop reaction rate as a function of temperature
  - This testing will provide key information on the rate of blinding that will occur as a function of temperature and gas composition.
  - 74% N_2
  - 8% H_2O
  - 14% CO_2
  - 4% O_2
  - 100–300 ppm NH_3
  - 0.04% SO_2
  - 1–1000 ppm P

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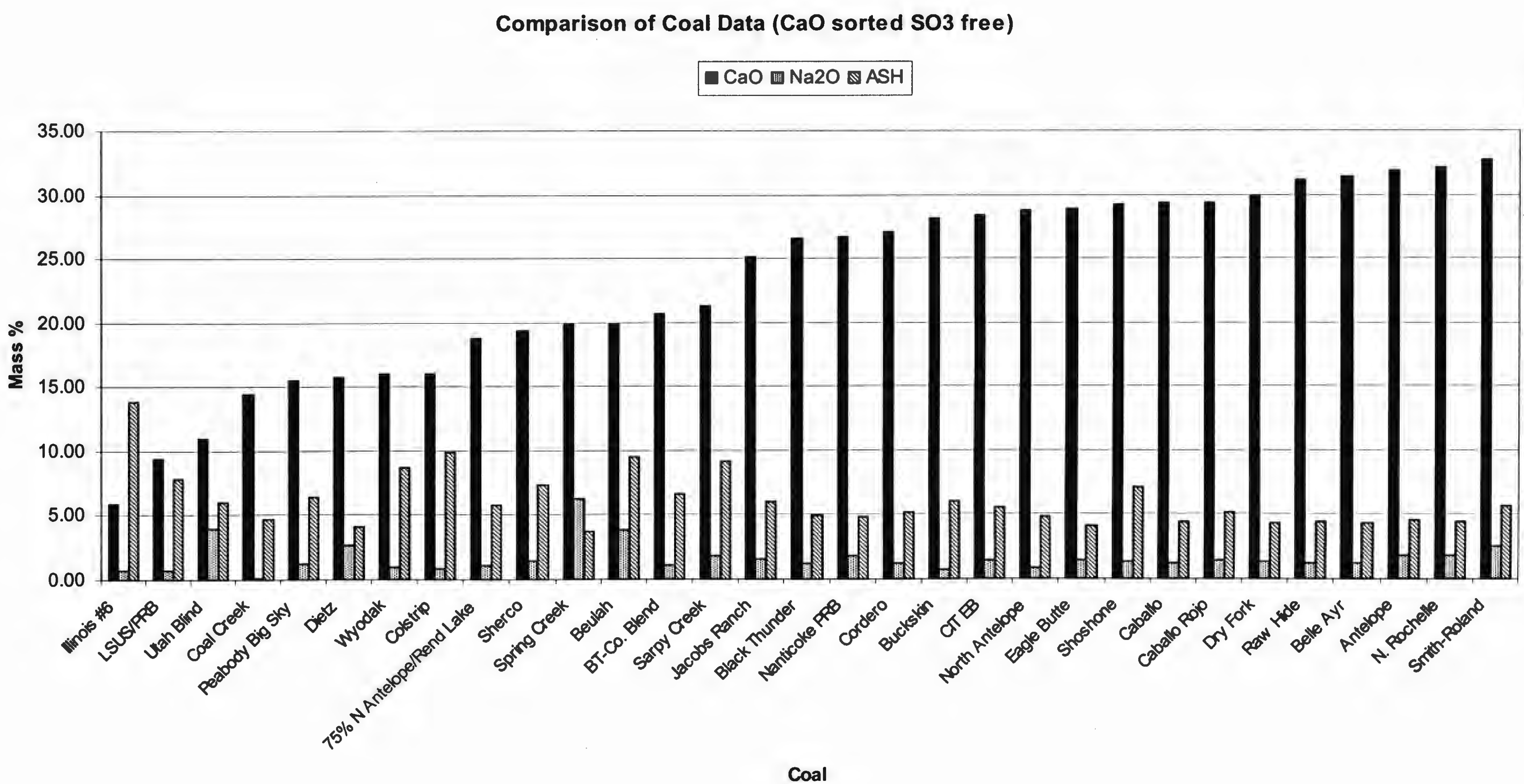
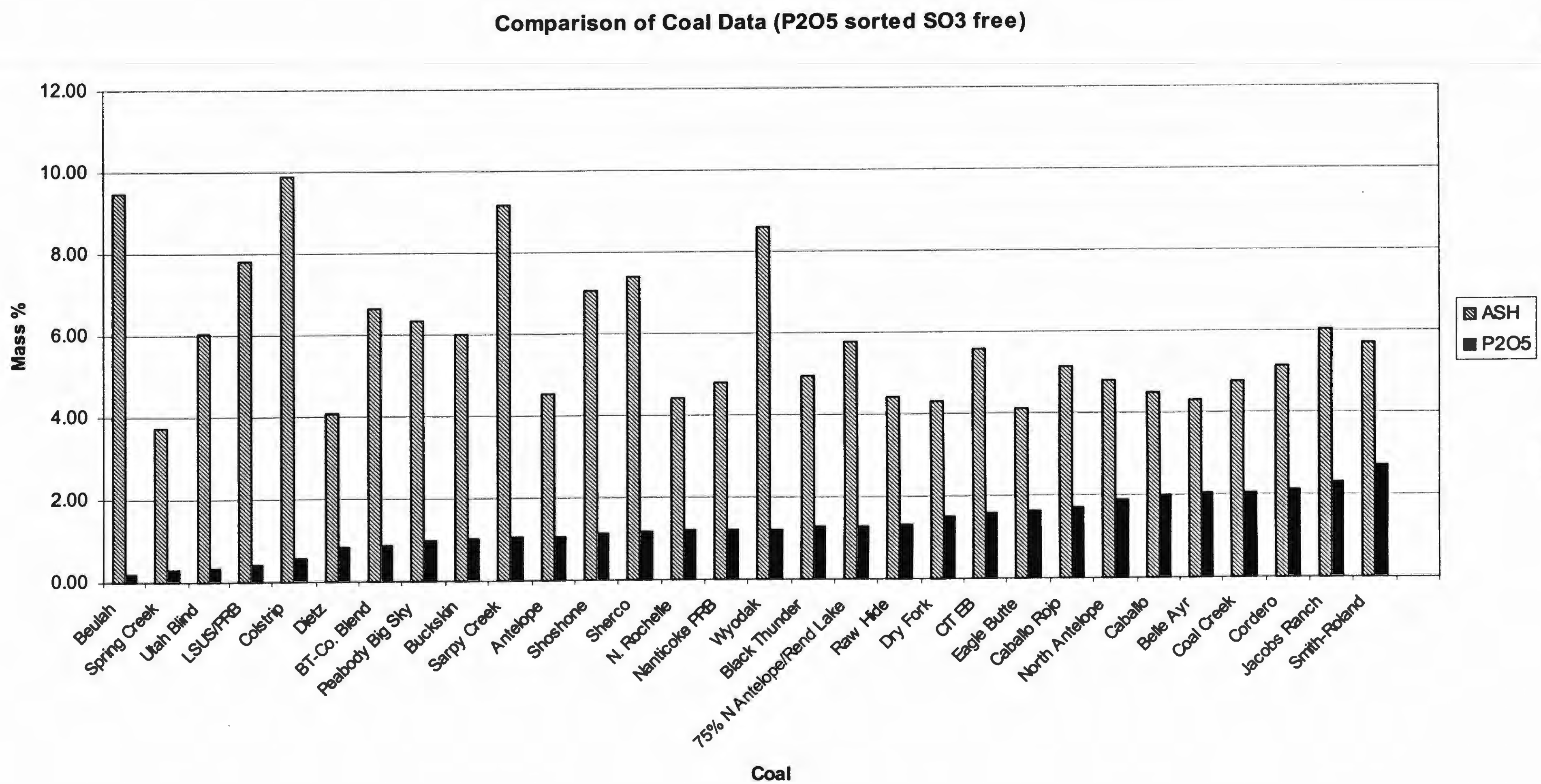
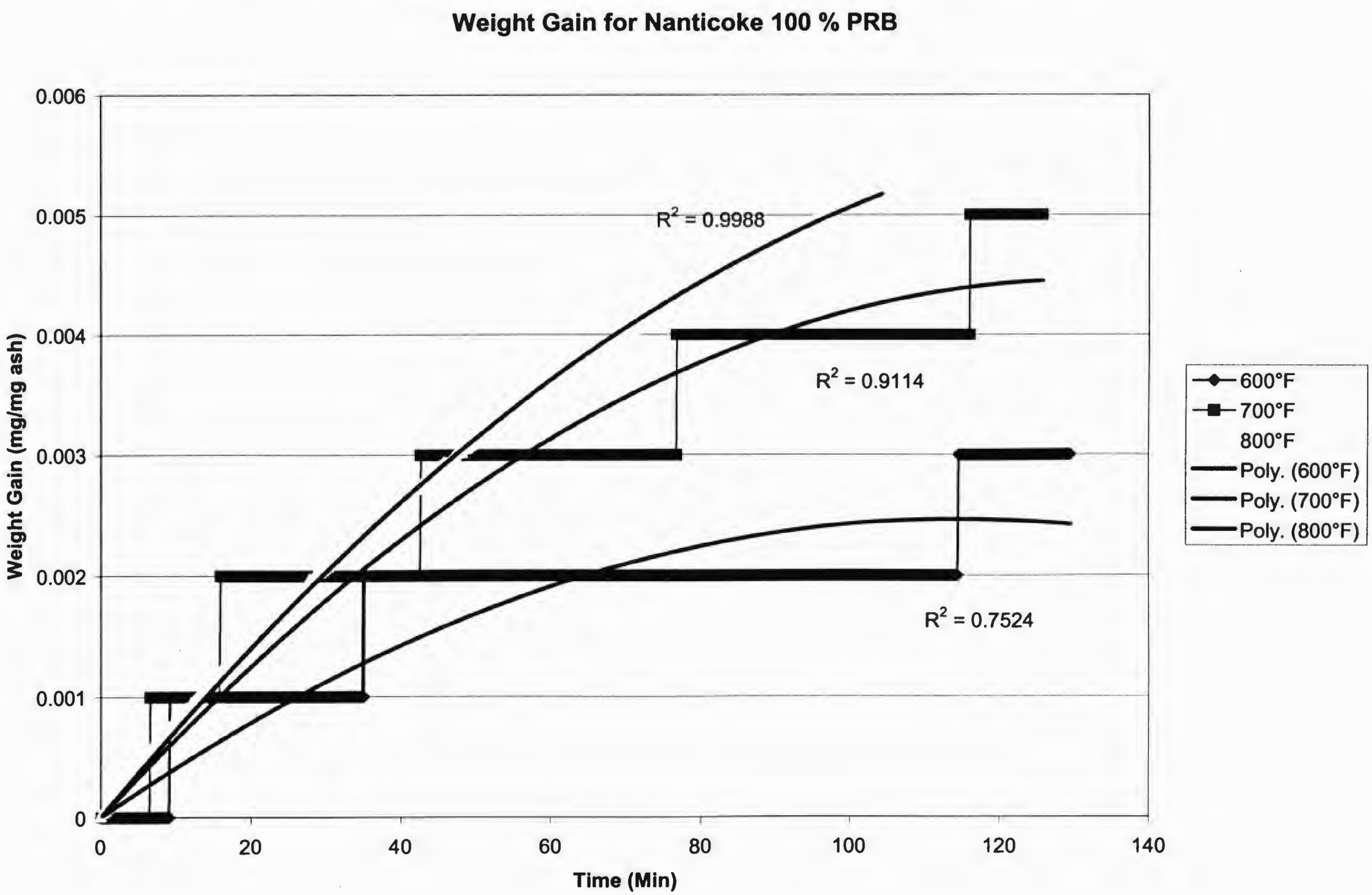
Fuels Analysis



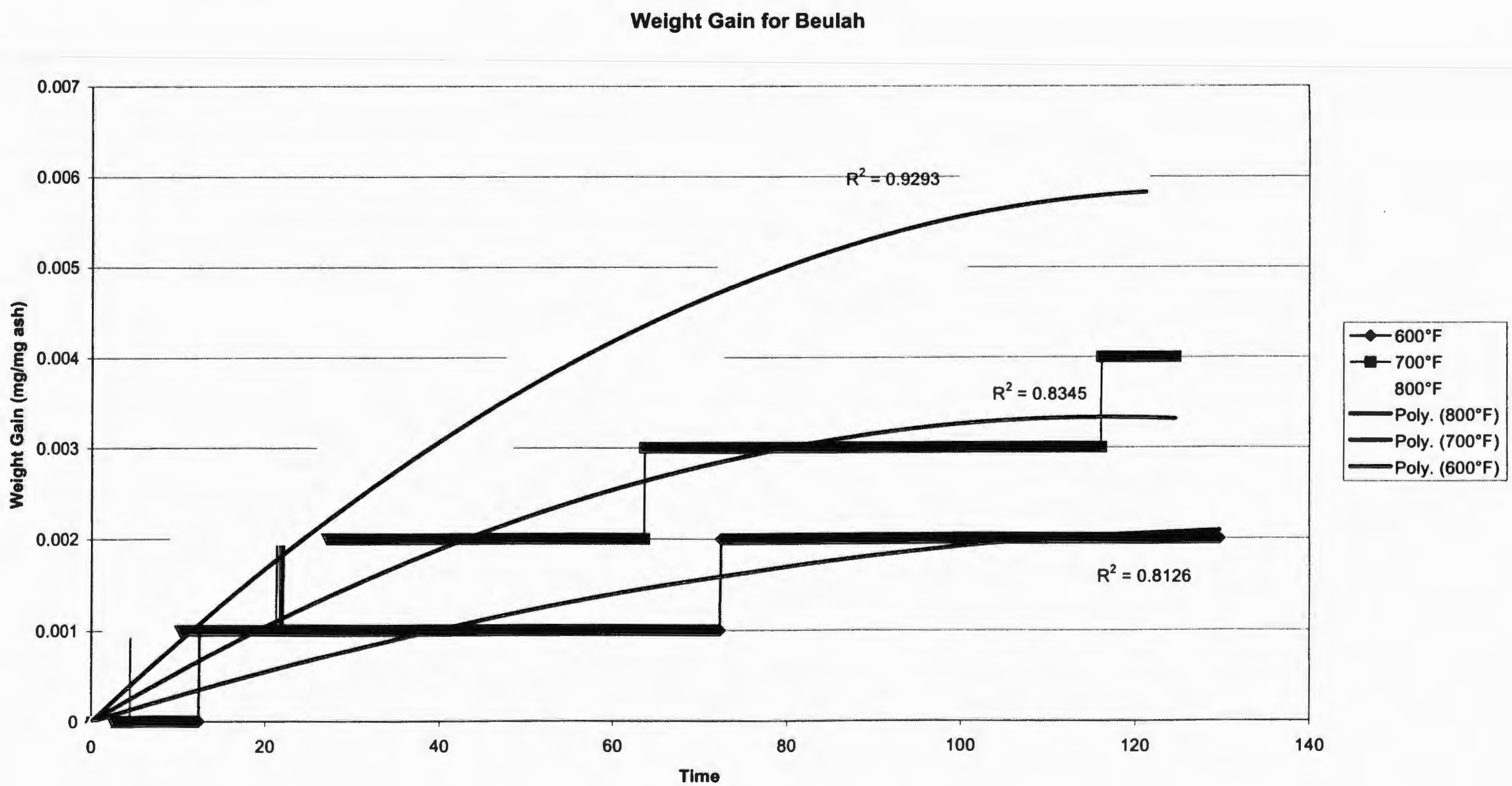
Fuels Analysis



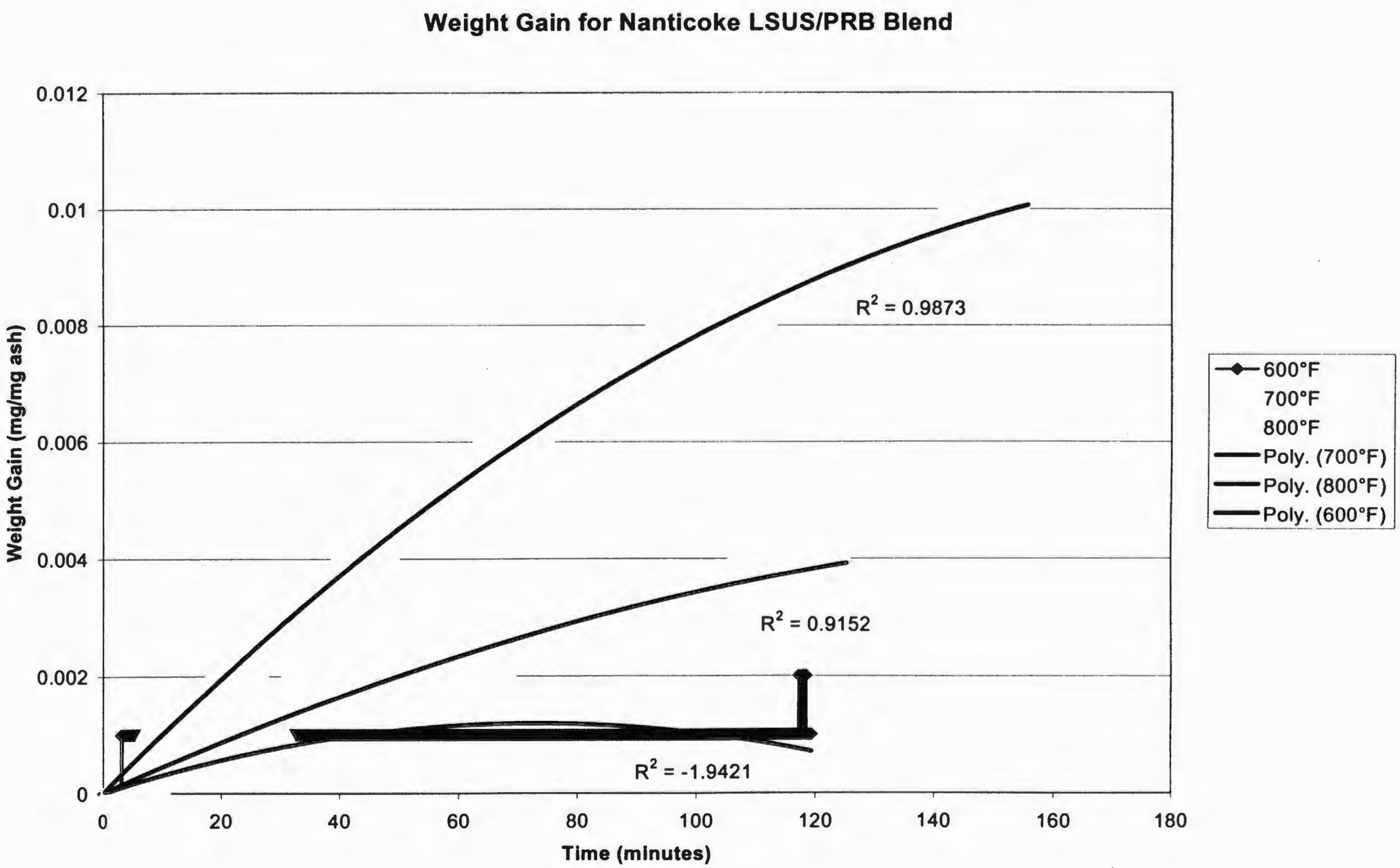
Weight Gain Curves – Baseline



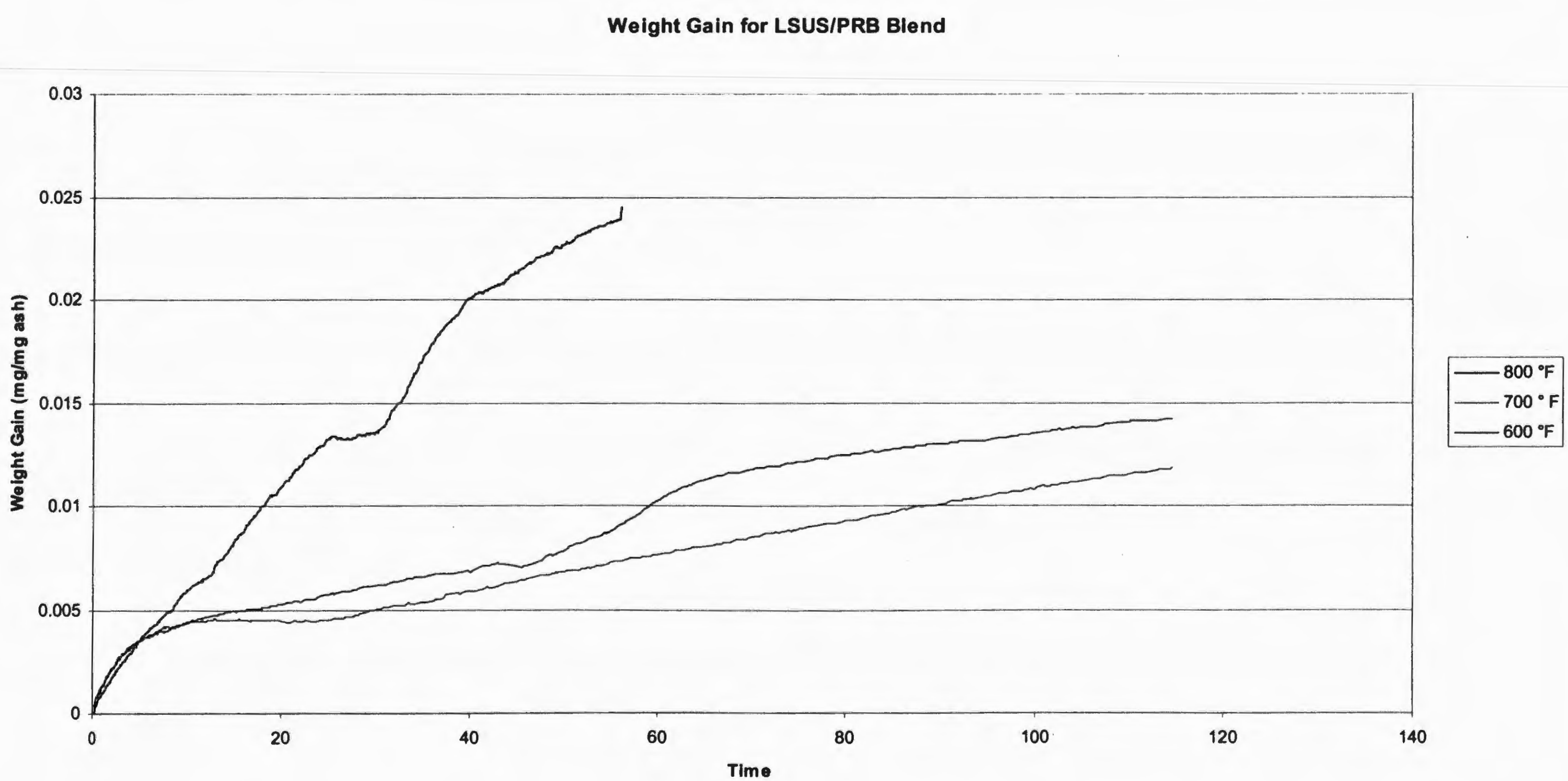
Weight Gain Curves – Baseline



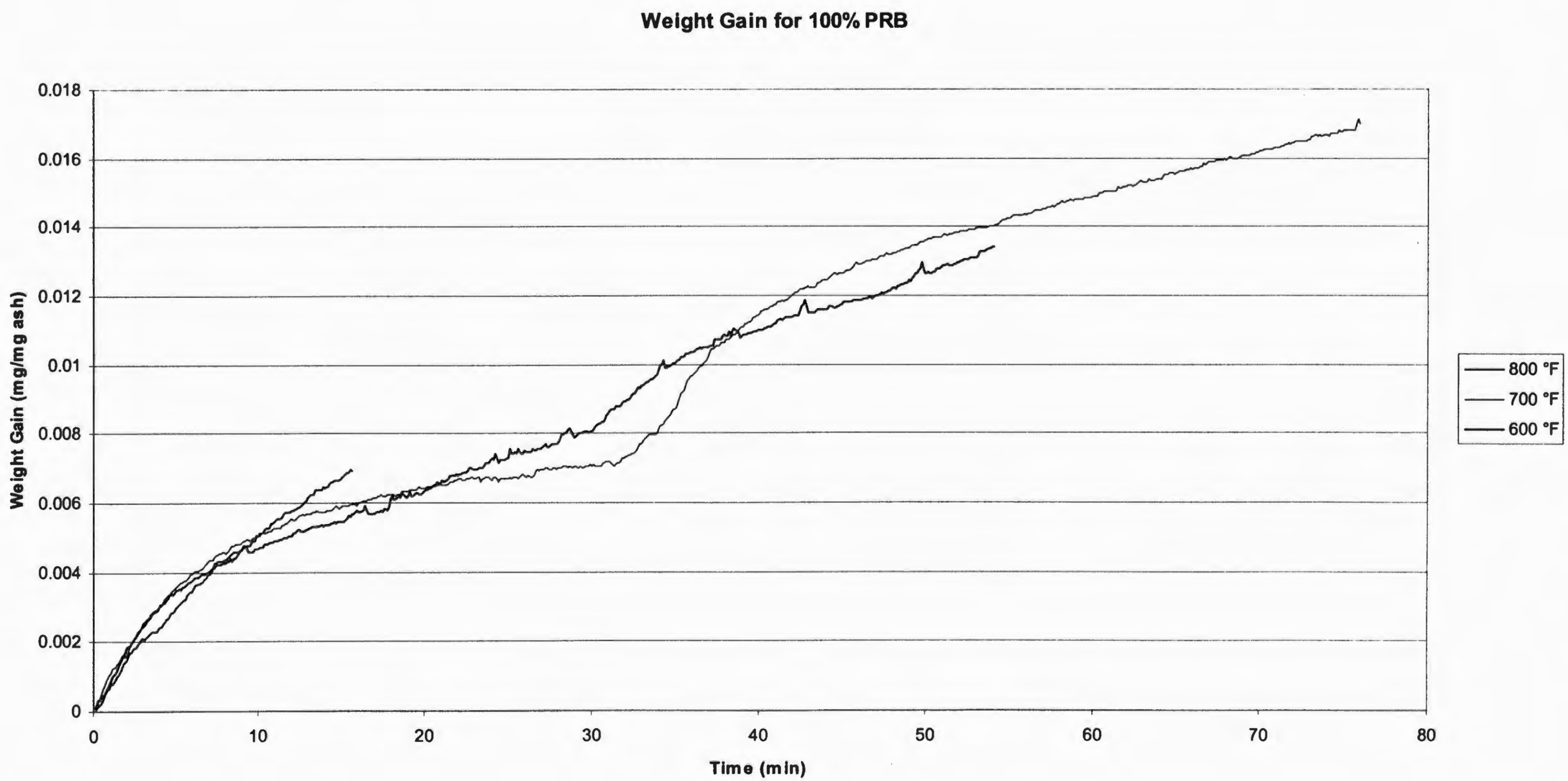
Weight Gain Curves – Baseline



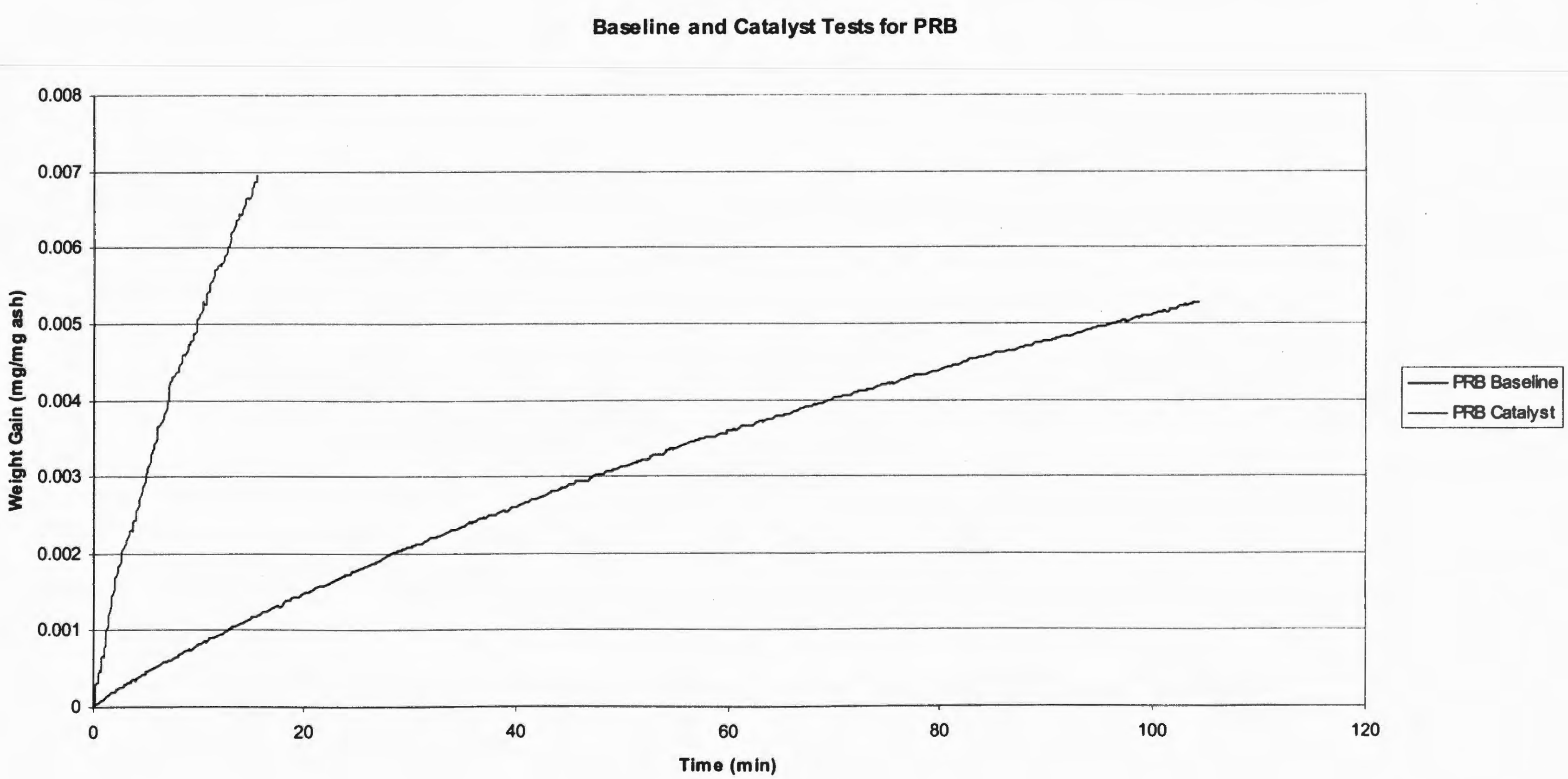
Weight Gain Curves – With NH_3, P



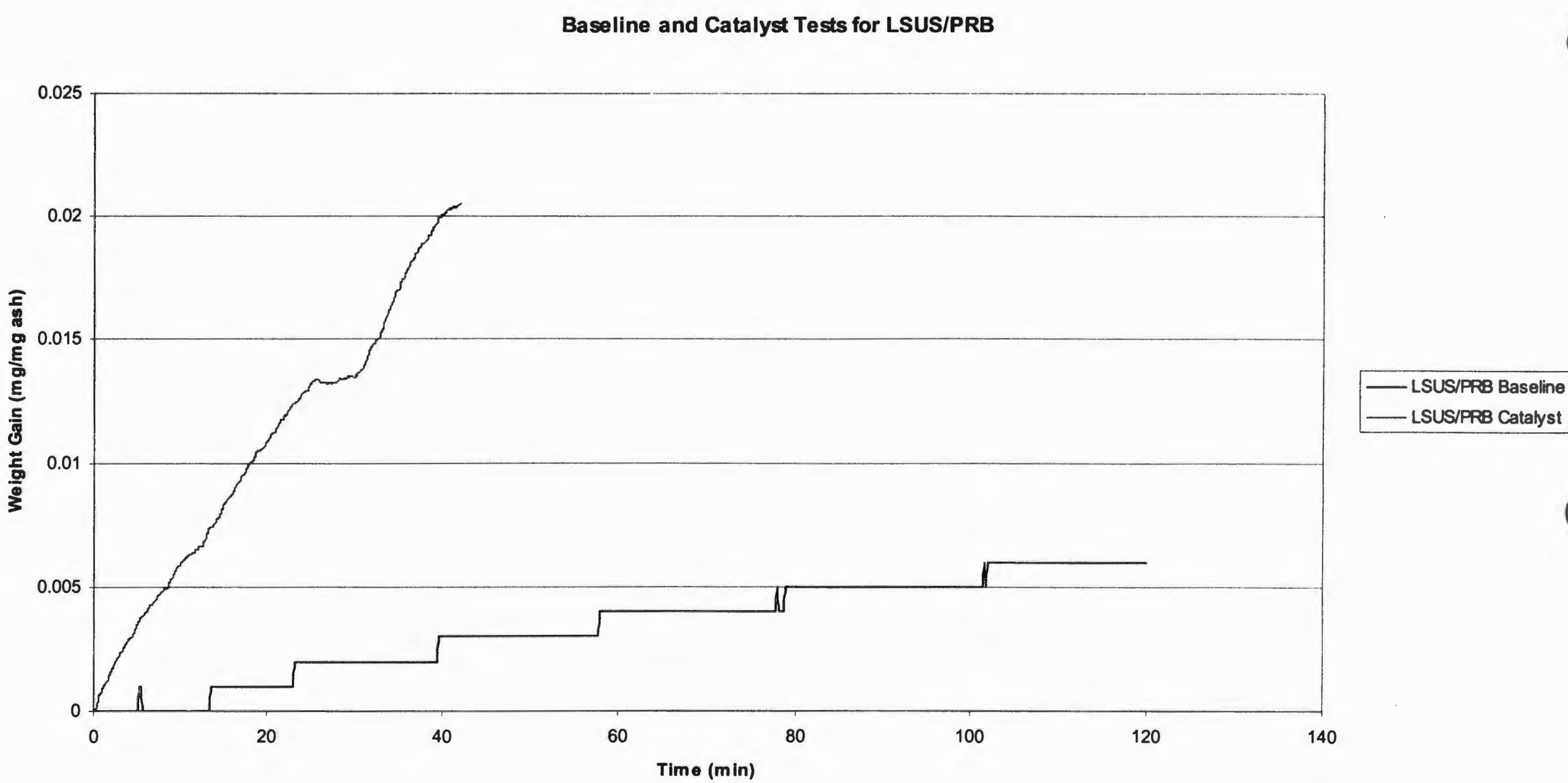
Weight Gain Curves – With NH_3, P



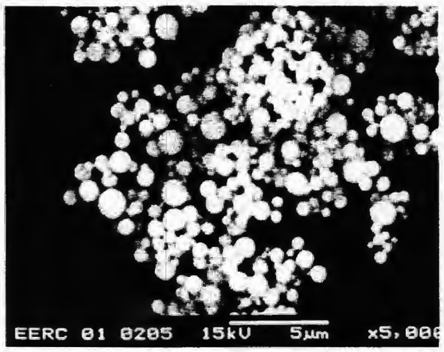
Catalyst Tests – Comparisons



Catalyst Tests – Comparisons



Characterization of Reaction Products, 100% PRB



100 % PRB 800°F

Element	%, Point 1	%, Point 2
Na	0.50	0.00
Mg	5.60	5.00
Al	9.22	11.30
Si	9.00	8.30
P	1.80	1.30
S	0.70	2.10
Cl	0.00	0.00
K	0.30	0.00
Ca	32.40	31.00
Ti	0.00	1.40
Cr	0.00	0.00
Fe	11.60	7.70
Ba	1.50	1.10
O	27.00	30.60

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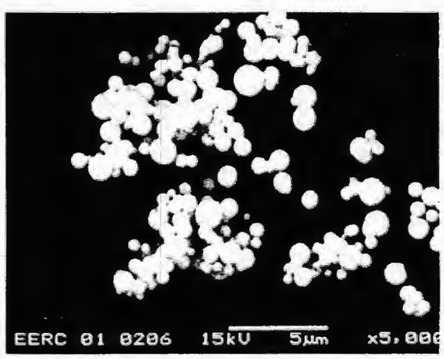
Characterization of Reaction Products, LSUS/PRB



LSUS/PRB 800°F

Element	%, Point 1	%, Point 2
Na	0.40	0.50
Mg	2.10	3.10
Al	15.90	12.60
Si	14.50	21.80
P	2.00	4.00
S	1.00	0.00
Cl	0.10	0.00
K	1.70	1.00
Ca	20.00	10.60
Ti	0.90	3.00
Cr	0.00	0.00
Fe	4.90	5.60
Ba	0.00	1.00
O	36.40	36.50

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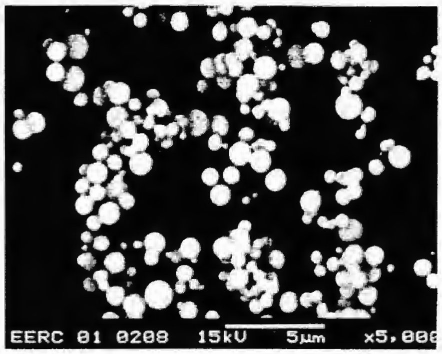
Characterization of Reaction Products, Beulah



Beulah 800°F

Element	%, Point 1	%, Point 2
Na	1.60	1.00
Mg	4.00	5.30
Al	7.10	9.00
Si	22.70	18.10
P	0.00	0.00
S	1.60	2.80
Cl	0.00	0.00
K	1.40	0.50
Ca	17.10	25.00
Ti	0.00	1.50
Cr	0.10	0.00
Fe	5.40	4.00
Ba	5.90	4.60
O	33.00	28.00

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FACT Calculations

- Operating principle
  - Based on minimization of Gibbs free energy
  - Predicts gas, liquid, and solid species as a function of temperature
- Limitations
  - Complete equilibrium is assumed
  - Only considers species in database
  - Each calculation is independent of the others

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FACT Calculations – Ash Composition

Composition Wt %	EERC 01-0204 CEPS C118-316C	EERC 01-0205 CEPS C118-427C	EERC 01-0206 CEPS C119-316C	EERC 01-0207 CEPS C119-427C	EERC 01-0208 CEPS C122-316C	EERC 01-0209 CEPS C122-427C
Si	7.39	9.85	18.39	19.42	17.73	29.38
Al	16.54	13.81	19.42	21.27	12.65	11.69
Fe	17.41	14.69	9.29	10.85	10.37	9.17
Ti	1.66	2.21	3.12	4.72	1.43	0.81
Ca	48.17	50.23	43.31	37.67	39.23	29.91
Mg	6.38	6.42	4.07	3.84	7.12	7.54
Na	0.41	0.24	0.48	0.51	1.09	2.18
K	0.31	0.32	1.22	1.33	0.30	1.30
Ba	1.67	2.14	0.61	0.33	10.01	8.03
Cl	0.07	0.10	0.08	0.05	0.07	0.00

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FACT Calculations – Conditions

Gas Composition, %

N_2	74.00
O_2	4.00
CO_2	14.00
H_2O	8.00
SO_2	0.04
NH_3	100, 300 ppm
P_2O_5	1, 1000 ppm

Particle Loading
1.5 grains/scf (3.4 g/m^3)

Temperature: 1022-482 ^oF

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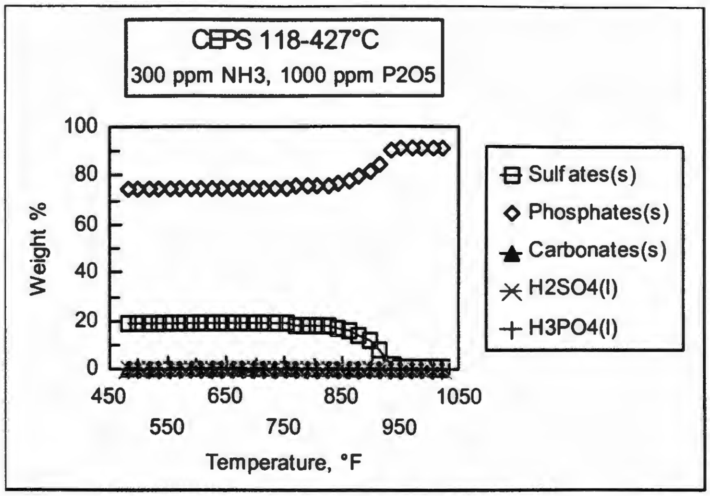
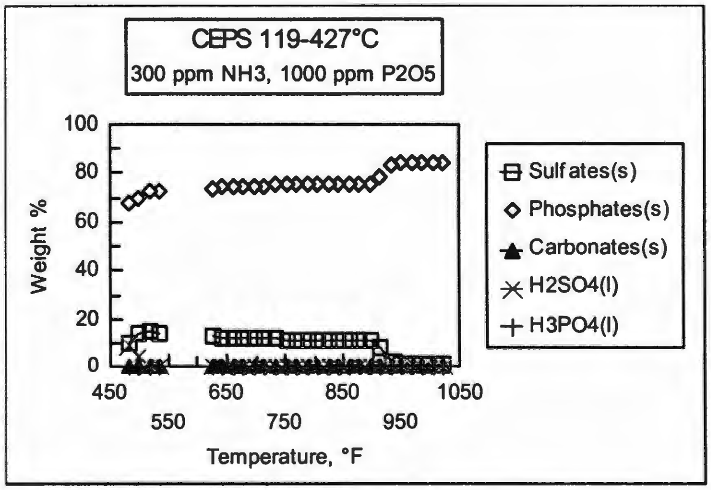
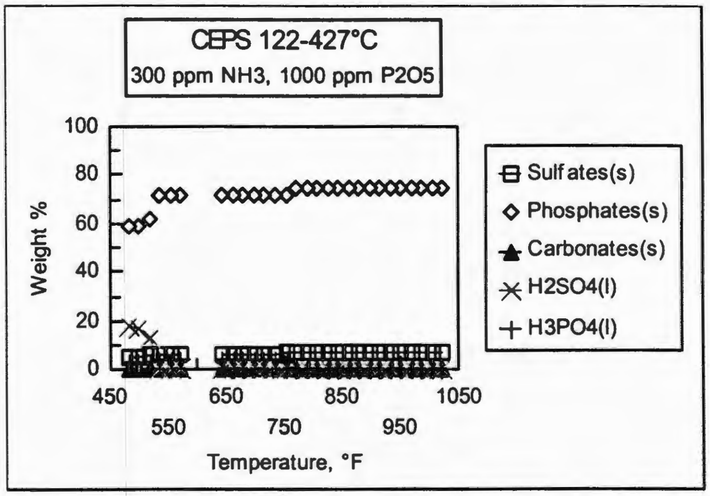
FACT Calculations



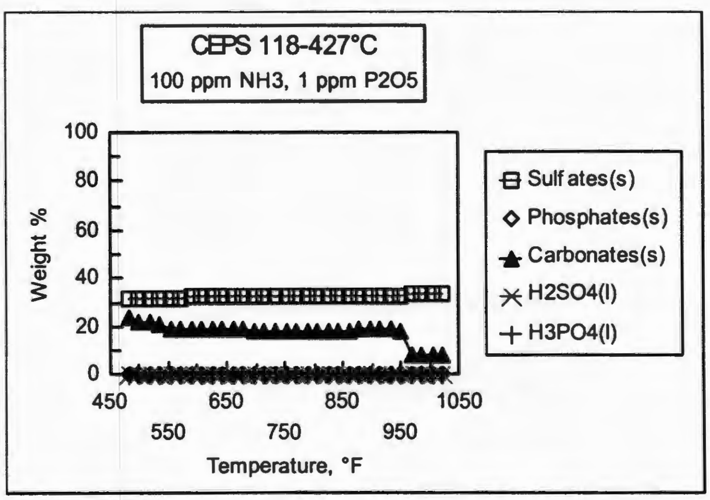
FACT Calculations



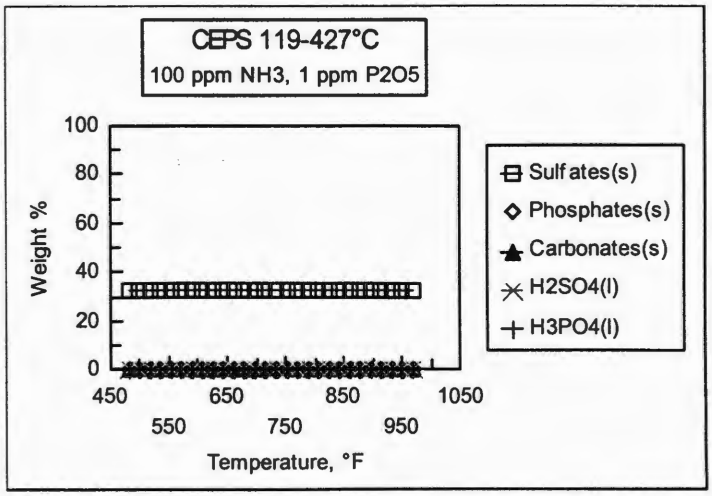
FACT Calculations



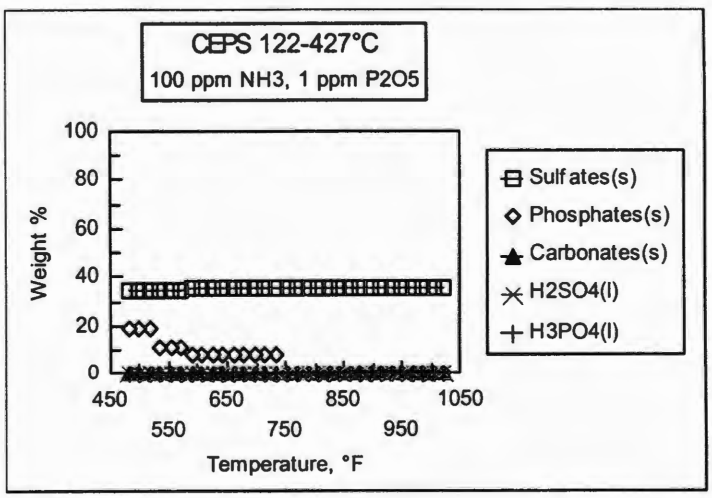
FACT Calculations



FACT Calculations



FACT Calculations



Conclusions

- PRB and lignite coals have the potential to blind SCR catalysts.
- The addition of ammonia, phosphorus, and catalyst enhances the formation of phosphates and sulfates.
- A high blinding potential exists for LSUS/PRB blends.

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Conclusions (cont.)

- FACT modeling also predicts the formation of sulfates and phosphates as well as carbonates.
- Morphology analysis of exposed fly ash shows sulfates and phosphates are present.

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Future Work

- Perform TGA on the remaining ash samples.
- Finish morphology analysis of exposed samples.
- Compare fuels for their potential to blind SCR catalysts

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Task 3: Design and Construction of Slipstream Reactor

- Goals and objectives
- Overview of slipstream SCR test system
- Reactor design
- Operating conditions
- Control scheme
- Sampling methodology
- Plant requirements
- Site visits

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Goals and Objectives

- Determine potential for low-rank coal ash to cause blinding of selective catalytic reduction (SCR) catalysts
- Determine mechanisms of SCR blinding through testing at full-scale installations
- Portable design with modular components
- Maintain consistent operating conditions
- Minimal plant personnel requirements
- Off-site monitoring and control w/remote access

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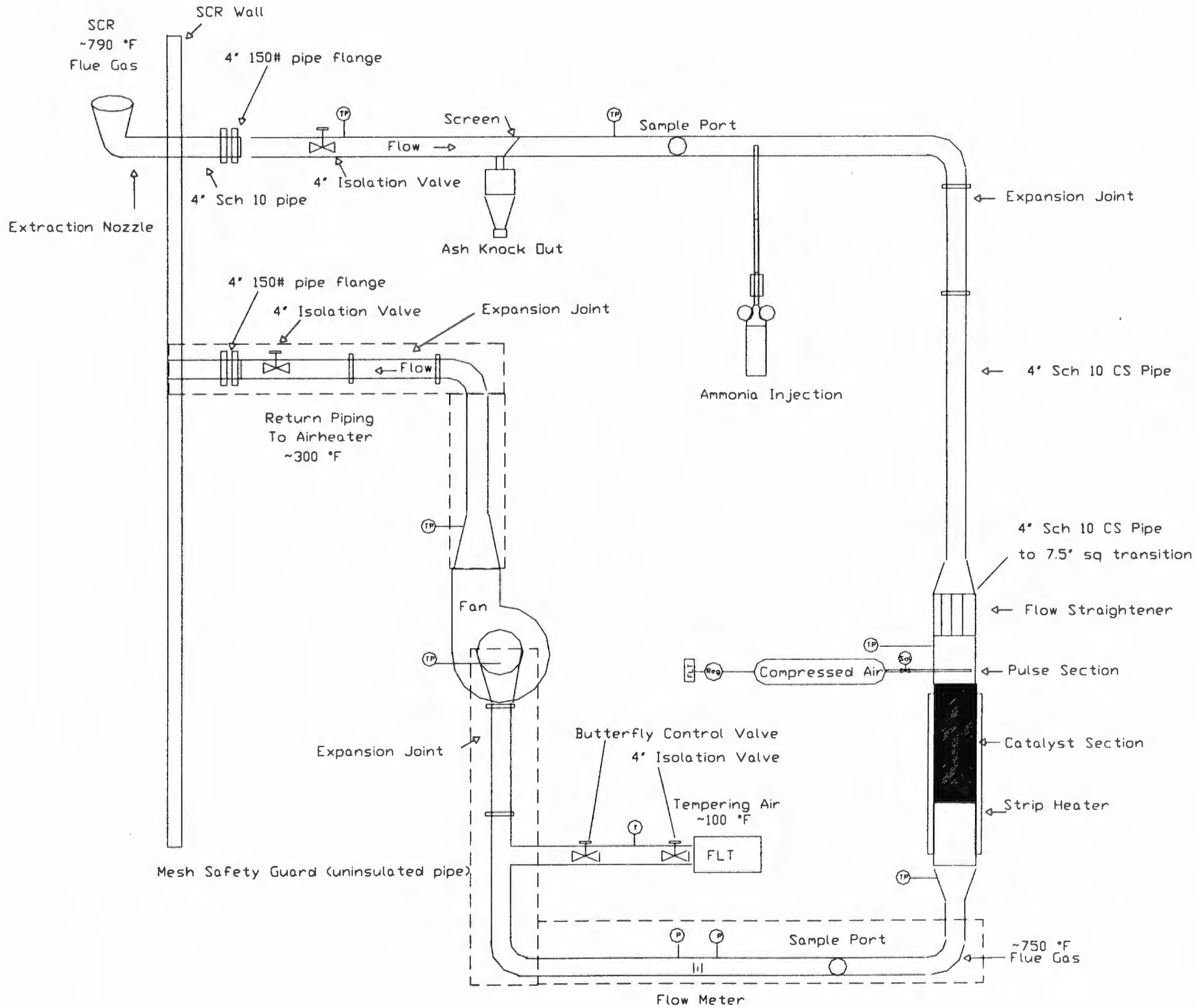
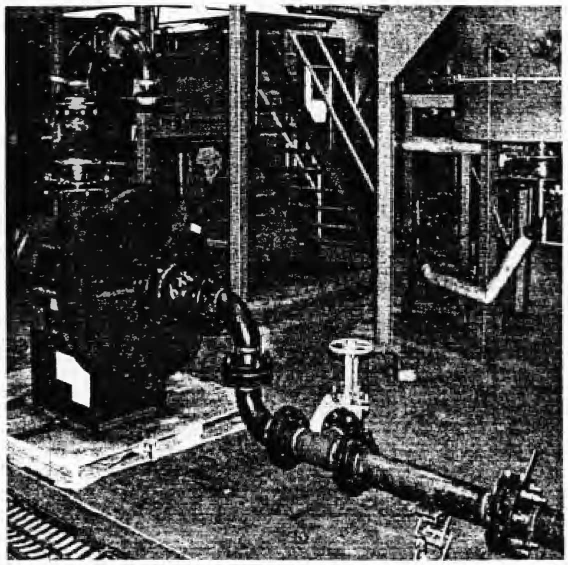
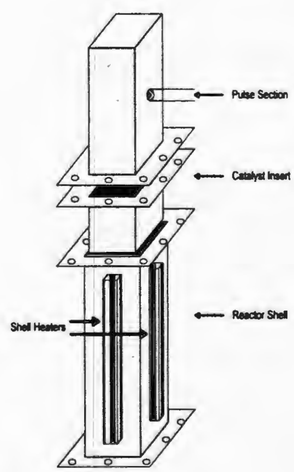
Conceptual Drawing



Induced Draft Fan



Reactor Design



- Transition from 4" pipe to ~7.5" square
- Flow conditioner: 16-gauge c.s. (4x4 matrix by 12" length)
- Pulse cleaning of catalyst surface
- Catalyst supported between flanges
- Reactor shell: ~8.5' square 10-gauge c.s. plate
  - Strip heaters for start-up/shutdown
- On-line measurements
  - Temperature at inlet and exit
  - Catalyst dP
  - Flow rate (calculated face velocity)
- Insulated to minimize heat loss

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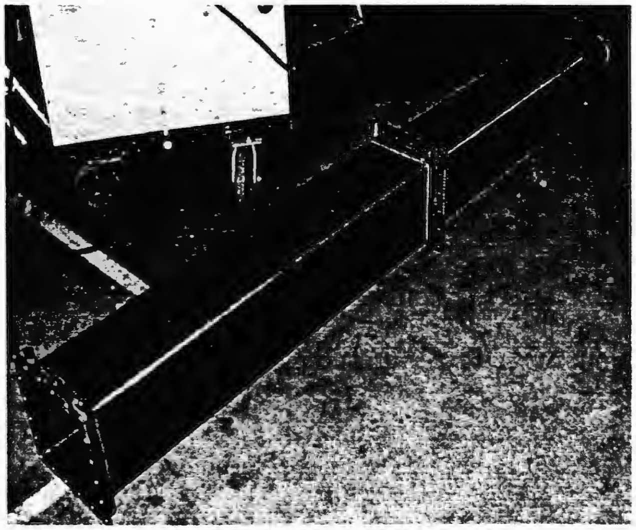
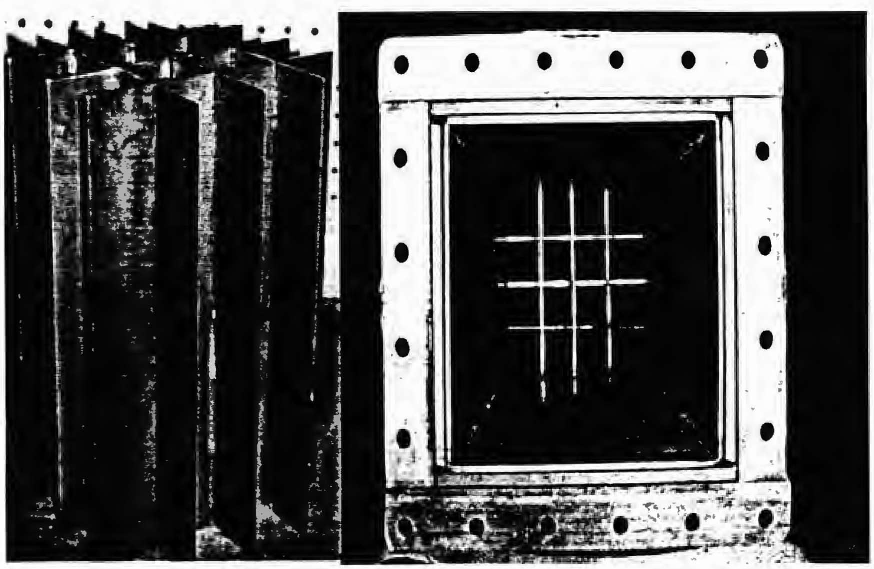
Transition and Reactor Shell



Flow Conditioner



Operating Conditions

- Gas temperature ~ 700°–800°F
- Gas flow rate – 400–500 acfm
- Approach velocity range: 5.0–5.5 m/sec
- Ammonia injection rate – 0.5:1 with NO_x level
- Tempering air for fan ~ 150–200 scfm
- Catalyst dP 0.5–1.0 inches water column
- Fan sized for up to –30 inches water column

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Control Scheme

- Isokinetic sampling
- Orifice meter for flow measurement
- VFD to control flow rate through reactor
- Tempering air to protect fan <350 °F
- Data acquisition – LabTech software
- Heaters to maintain reactor temperature above dew point during start-up and shutdown
- Periodic (as needed) cleaning of catalyst surface by air pulse

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Control Room

- Modular design
  - Compact (crammed tight)
  - Controlled environment
    - ♦ Air-conditioned space
    - ♦ Dust/water protection
  - Detachable walls
  - Lifting supports
  - Wheels
  - Skid-mounted
- 480-V, 3-phase power for fan
- 240-V electrical supply
  - Breaker panel
- Pressure transmitters
  - Orifice meter
  - Catalyst dP
  - System pressure
- Ammonia injection control system
- Data acquisition hardware and software
  - Fan speed, heaters, cleaning, and tempering air controls
  - UPS

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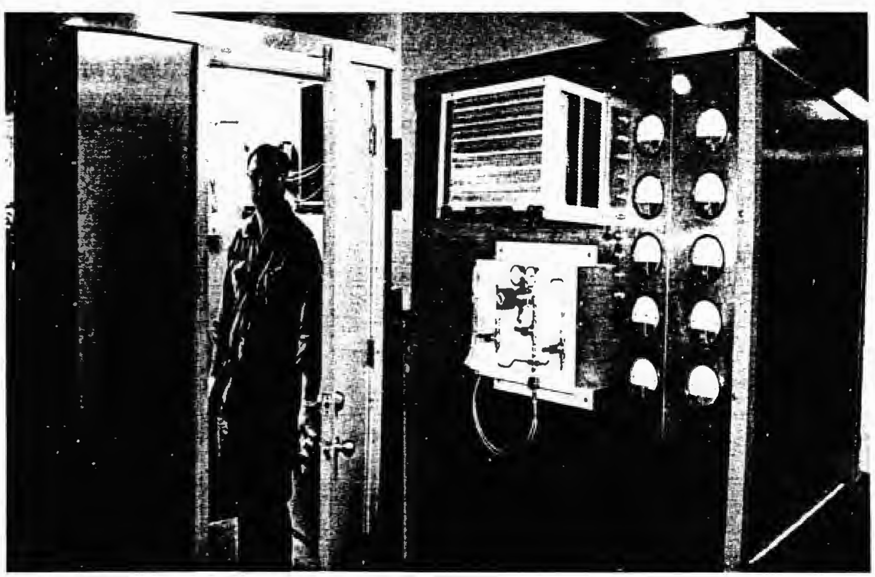
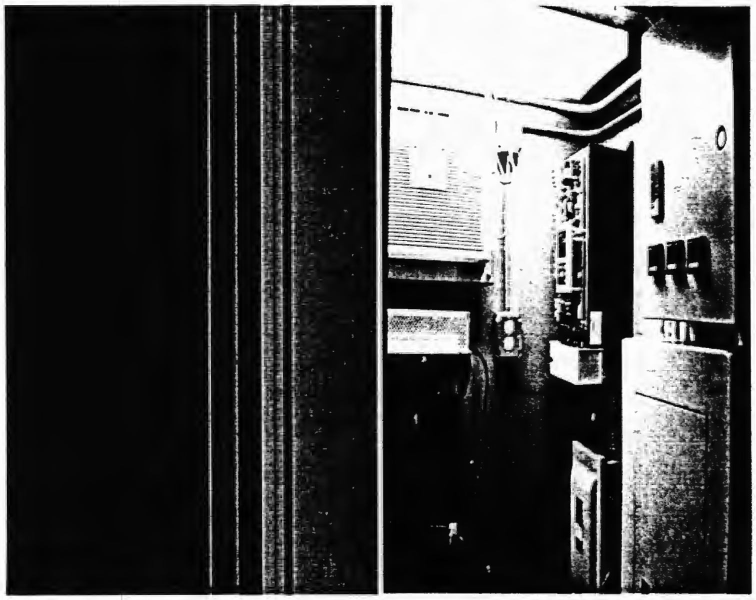
Control Room



Control Room



Sampling Methodology

- Initial reactivity testing of catalyst
- Catalyst samples taken at 2, 4, and 6 months duration
- Analyses:
  - Morphology – scanning electron microscopy and x-ray microanalysis
    - Images
    - Area and point analyses to determine bonding mechanisms
  - Reactivity testing: EERC and catalyst vendor
- On-site sampling
  - SASS train at reactor inlet for size distribution and composition of entrained ash
  - Direct comparison with bench-scale results
  - Gas analysis

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Plant Requirements

- T1/DSL line for remote access
- 60 amps, 480-V, 3-phase power for fan
- 60 amps, 240-V, 60 hertz, single-phase power to control room
- Electrician to provide hookup to control room
- Crane/elevator access to sampling area
- Compressed air for control valve and pulse
- Welder for system supports and field fitting
- 5" inlet port w/150# flange, 4" flanged exhaust port
- Personnel to check system daily
  - Ammonia tank monitoring (changing when empty)
  - System dPs
  - System isolation during outage

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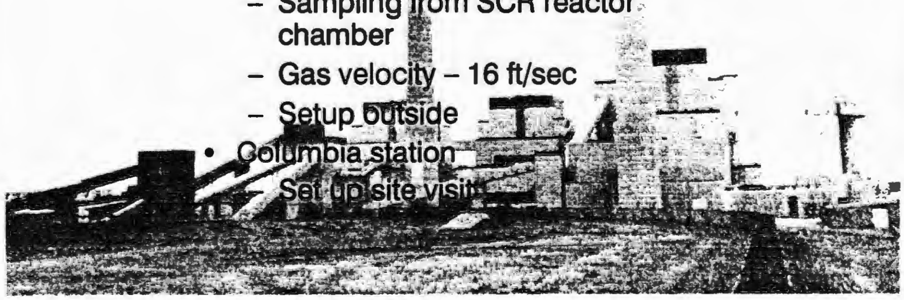
Site Visits

- Coyote station
  - Lignite-fired, cyclone boiler
  - Gas velocity ~ 45 ft/sec
  - Setup inside station
- Baldwin station
  - PRB-fired, cyclone boiler
  - Sampling from SCR reactor chamber
  - Gas velocity – 16 ft/sec
  - Setup outside
- Columbia station
  - Set up site visit



Discussion

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Software and Control Systems

Objectives

- Control system via software on-site
- Observe system operating parameters for EERC and sponsors
- Control system remotely for EERC
- Download data to EERC

Software and Control System Components

- LabTech Control ==> Interface to Unit
- VisionPro ==> Visual Interface
- Realtime Remote ==> Remote Viewing

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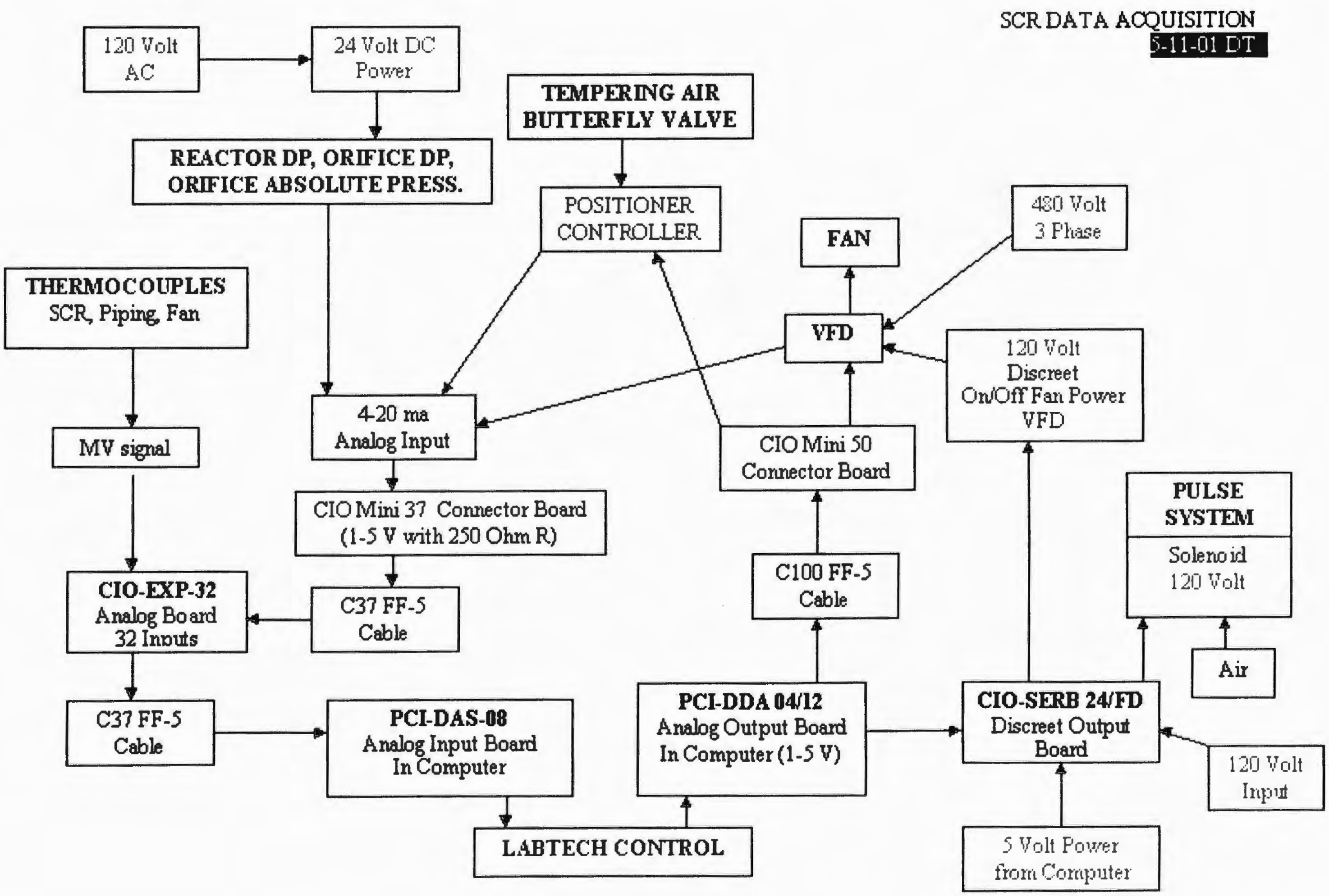
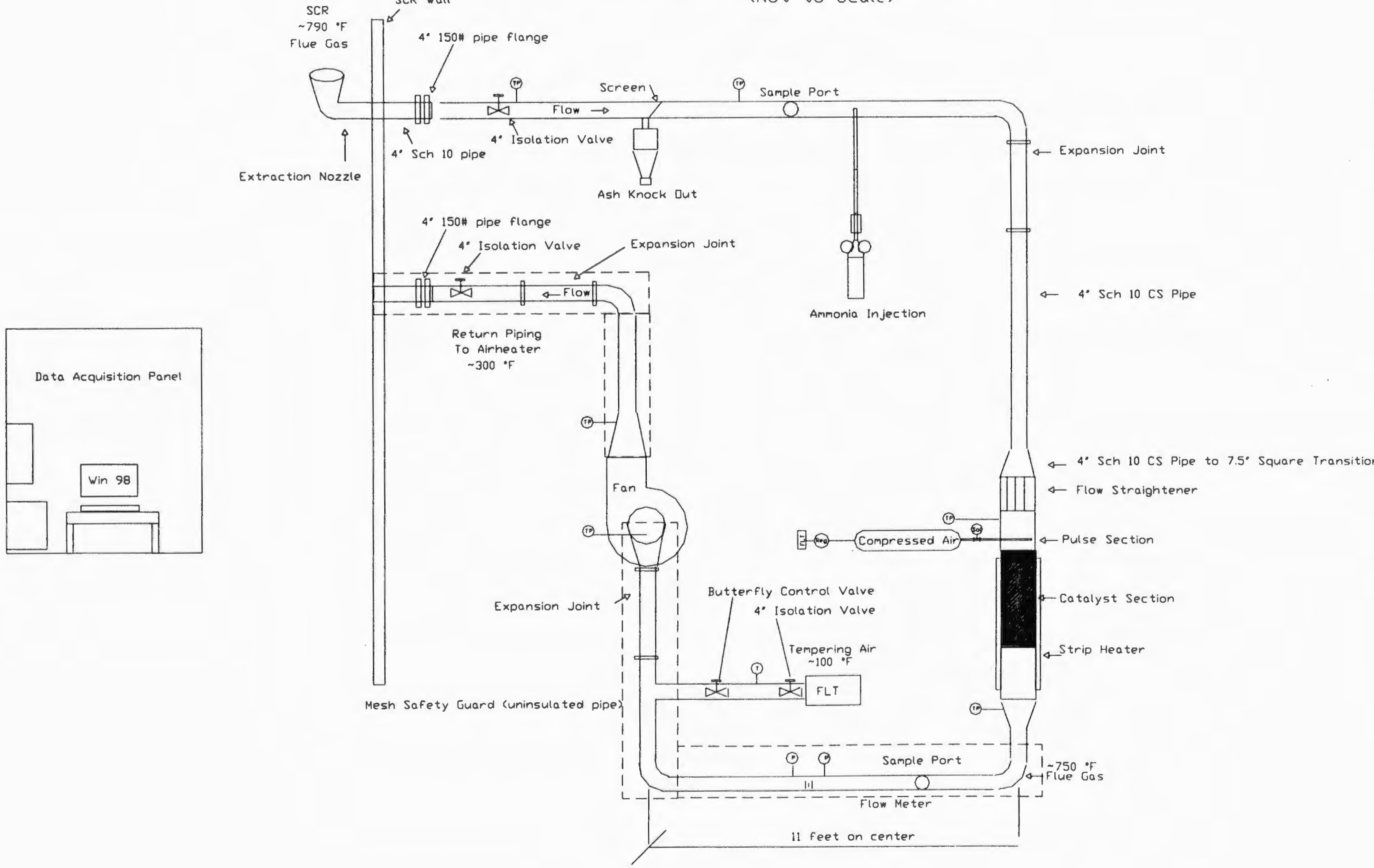
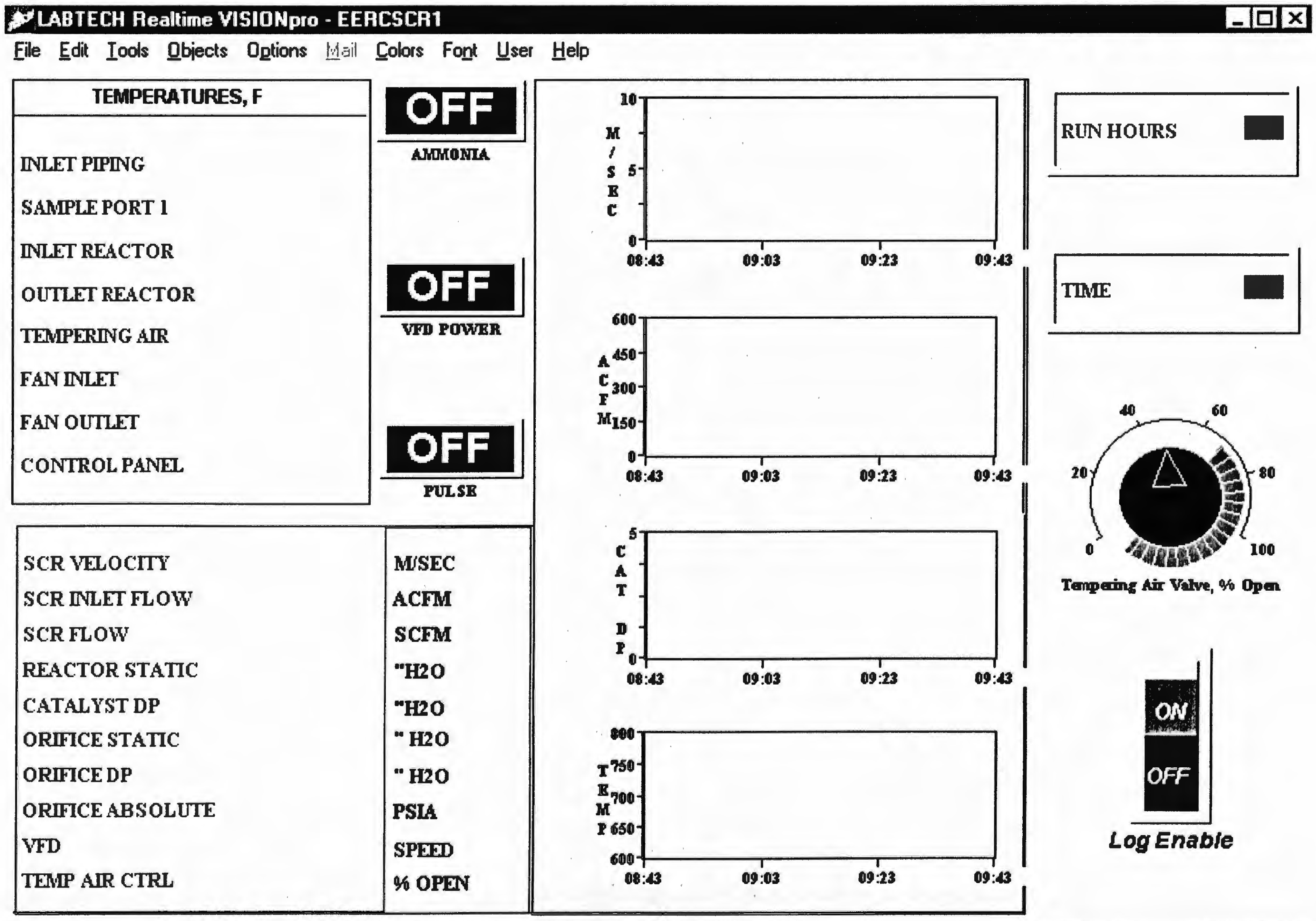
System Design



Slip Stream SCR Schematic
(Not to Scale)




LABTECH Realtime VISIONpro - EERCSCR1
File Edit Tools Objects Options Mail Colors Font User Help
TEMPERATURES, F
INLET PIPING
SAMPLE PORT 1
INLET REACTOR
OUTLET REACTOR
TEMPERING AIR
FAN INLET
FAN OUTLET
CONTROL PANEL
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AMMONIA
OFF
VFD POWER
OFF
PULSE
SCR VELOCITY
SCR INLET FLOW
SCR FLOW
REACTOR STATIC
CATALYST DP
ORIFICE STATIC
ORIFICE DP
ORIFICE ABSOLUTE
VFD
TEMP AIR CTRL
M/SEC
ACFM
SCFM
"H2O
"H2O
" H2O
" H2O
PSIA
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% OPEN
M/SEC
ACFM
CAT DP
TEMP
08:43
09:03
09:23
09:43
RUN HOURS
TIME
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ON
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Log Enable

Realtime Remote - Microsoft Internet Explorer

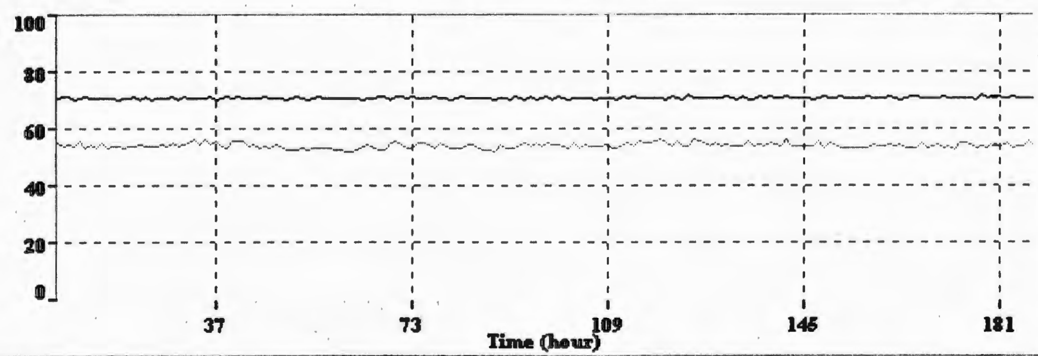
File Edit View Favorites Tools Help

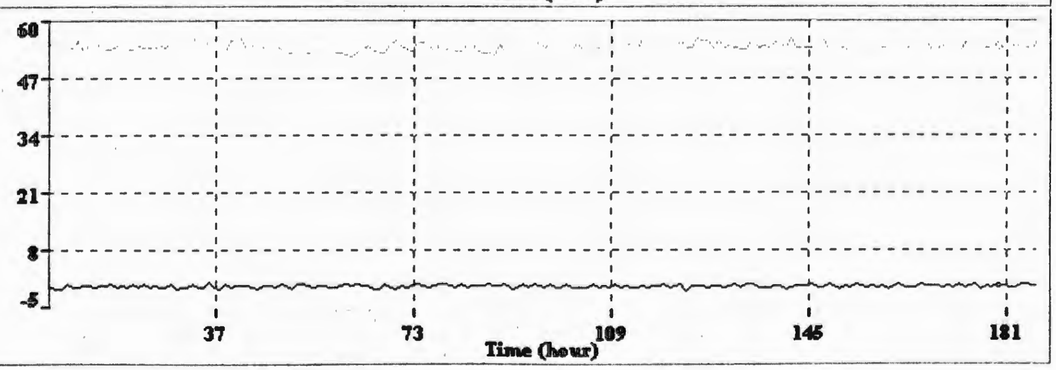
Back Forward Stop Refresh Home Search Favorites History Mail Print Messenger Real.com

Address C:\LTC\SCR\rrauthoring.html Go Links

SCR Realtime Remote

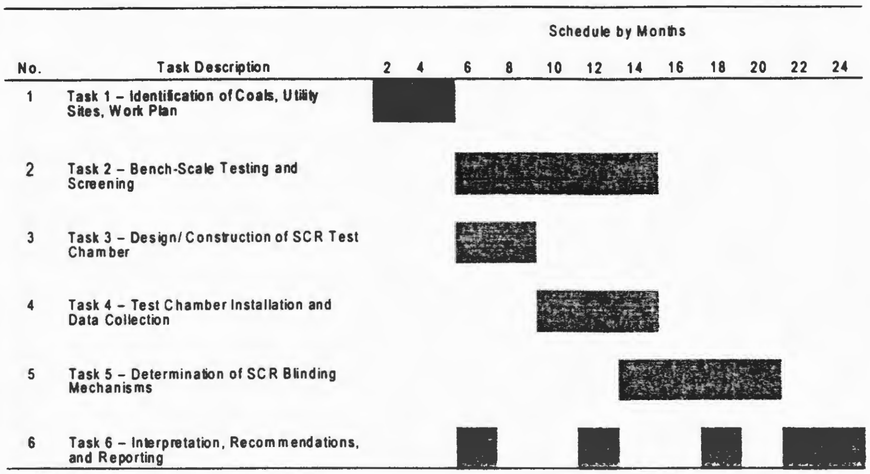
Inlet Reactor Temperature	71.33 F°	SCR Velocity	54.12 M/SEC
SCR Inlet Flow	71.52 ACFM	Catalyst DP	0.19 in. H20





Done My Computer

Schedule (24-month duration)



Schedule – Task 1

- Task 1 – Identification of Test Coals, Utility Host Sites, and Final Work Plan
  - Task completed

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Schedule – Task 2

- Task 2 – Bench-Scale Testing and Screening
  - Produce ash from at least one more fuel
  - Test additional catalyst–ash mixtures

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Schedule – Task 3

- Task 3 – Design and Construction of SCR Slipstream Test Chambers (two)
  - Task nearly complete – completed within the next month

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Schedule – Task 4

- Task 4 – SCR Test Chamber Installation and Data Collection at Utility Host Sites
  - Coyote site visit complete
  - Baldwin site visit complete
    - Install at Baldwin
    - Collect and analyze data and samples
  - Schedule Columbia site visit for next month
    - Install at Columbia about 1 month after Baldwin installation

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Schedule – Task 5

- Task 5 – Determination of SCR Blinding Mechanisms
  - Reduce the bench-scale and thermodynamic modeling data
  - Interpret data from analysis of samples collected from field tests – entrained ash samples and deposits on catalyst

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Schedule – Task 6

- Task 6 – Final Interpretation, Recommendations, and Reporting
  - Continue monthly conference calls
  - Meeting at a plant – Baldwin, Columbia, or Coyote after installation ??
  - Meeting in about 8 months back here to discuss results of first field test

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Evaluation Of SCR Catalyst Blinding For Biomass–Coal Cofiring

Project Informational Meeting

Christopher J. Zygarlicke
Energy & Environmental Research Center
Grand Forks, North Dakota
Wednesday, May 23, 2001

President Bush's Energy Policy
(May 17, 2001)

- Expands and diversifies America's supply of all sources of energy including biomass and other renewables.
- Tax credits to utilities that build wind turbines or harness biomass and other environmentally friendly forms of power.
- "Our energy plan also supports the development of new and renewable sources of energy."
  – George W. Bush, May 17, 2001

Objectives

- Determine potential for blinding of selective catalytic reduction (SCR) catalysts for biomass–coal cofiring
- Determine mechanisms of SCR blinding specific to biomass components

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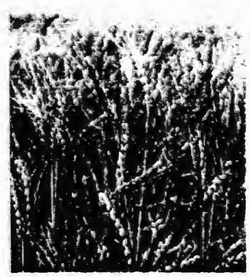
Background

- Biomass and low-rank coals often contain larger relative quantities of alkali and alkaline-earth elements (i.e., potassium, sodium, calcium, and phosphorus) in addition to moderate sulfur levels.
- These constituents have the potential to impair the operation of SCR systems by the formation of sulfate- or phosphate-based deposits on catalyst surfaces, leading to higher NO_x emissions and potentially high ammonia slip.



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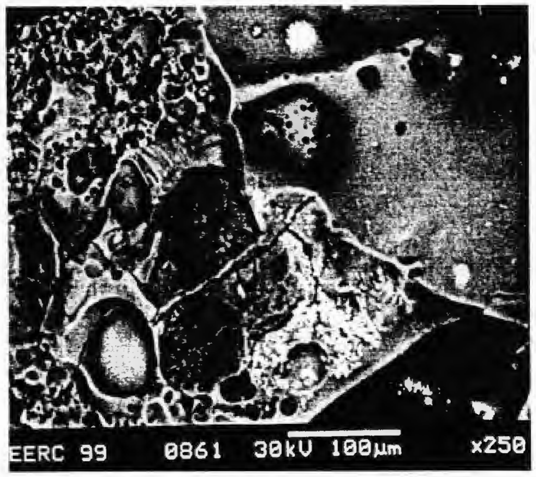
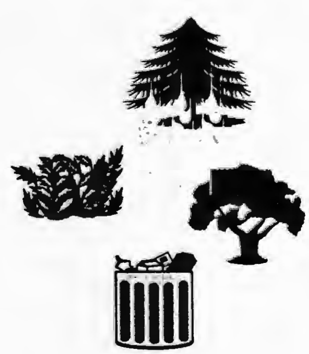
Illinois Coal–Wheat Straw Slag Deposit Angular Coal-Derived Quartz Particle in Potassium–Iron–Silicate Melt Phase



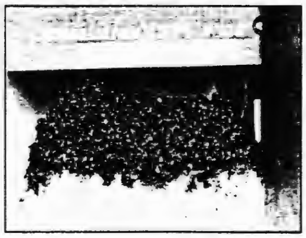
Issues Involving Biomass and SCR

- Potassium: chlorides, sulfates, and perhaps phosphates.
- Calcium: similar to low-rank PRB with potential sulfates and phosphates.
- Organically dispersed K and Ca and very fine silica coupled with alkali and sulfur in coals may create a significant flux of fine particulate in SCR.
- Coal mineral components may interact with and immobilize some of the volatile potassium.

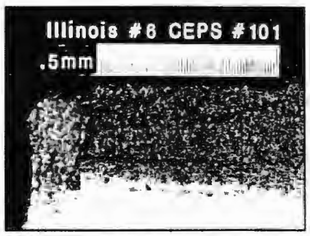


Energy & Environmental Research Center

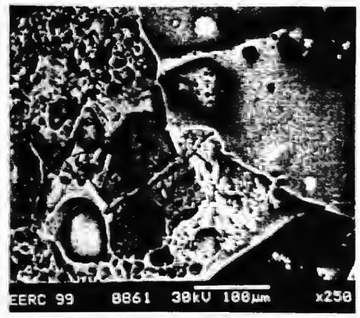
Observations for Higher Temperature Fouling Bench-Scale Ash Probe



100% Wheat Straw



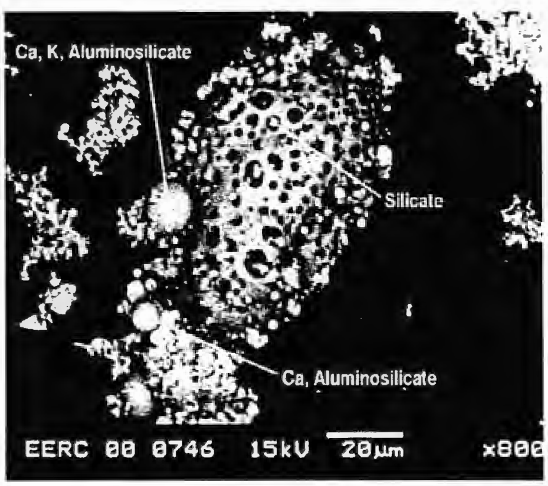
100% Illinois No. 6 Coal



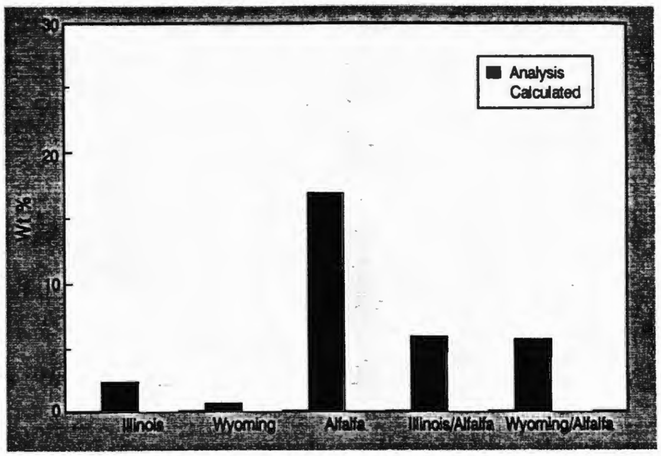
80–20 Blend Illinois–Wheat Straw

Angular coal-derived quartz particle in a otassium–iron–silicate melt phase

Alfalfa Deposit Morphology



Potassium Concentration in Alfalfa and Coal–Alfalfa Blends



Average Unclassified Composition of Fly Ash, wt%

	Wyoming 100% Coal	Wheat Straw 100% Biomass	Wyoming Wheat Straw 80%–20% Blend
Si	21.4	45.1	14.5
Al	17.7	0.9	11.1
Fe	7.6	0.9	3.4
Ti	1.7	0.2	0.8
P	0.8	3.7	1.4
Ca	38.7	17.1	23.7
Mg	6.2	6.3	2.6
Na	0.6	1.9	1.4
K	1.5	21.2	4.9
S	1.9	0.6	10.5
Ba	1.4	0.4	1.4
Cl	0.0	1.7	24.3

Energy & Environmental Research Center

Project Work Plan

- Selection of utility boilers for testing
- Biomass resource acquisition and characterization
- Bench-scale biomass SCR blinding under separate DOE project
- Four to six months of testing for SCR blinding in two full-scale utility boiler units
  - Skid-mounted test rigs
  - Two different boilers burning different coals and different biomass types
- Determine root causes and mitigation measures for blinding deposits

Energy & Environmental Research Center

Deliverables

- Utilities gain mechanistic information on SCR catalyst blinding to aid in:
  - Selection of SCR vendors
  - Negotiating guarantees on SCR performance
  - Selecting biomass fuels
- SCR industry improves its products for biomass
- Continued positive promotion of biomass and renewable energy

Energy & Environmental Research Center

Project Budget and Cost Structure

- Multiclient consortium with DOE joint venture funding
- $150,000 Industry (utilities, NDIC?, EPRI?)
- $100,000 DOE

- Total Project Budget $250,000

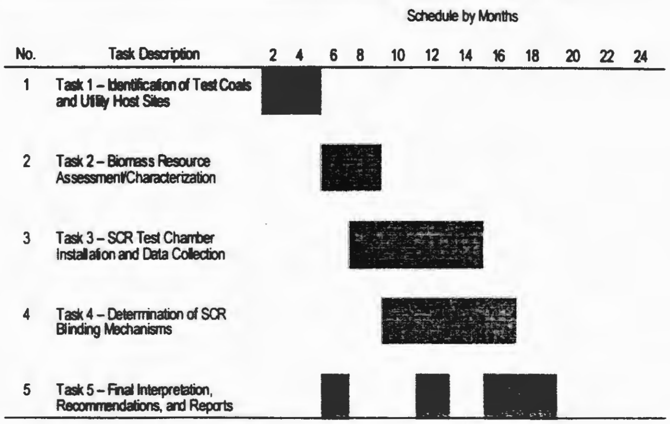
Energy & Environmental Research Center

Budget by Task

Task 1 – Identification of Test Coals and Utility Host Sites	$20,000
Task 2 – Biomass Resource Assessment and Characterization	$60,000
Task 3 – SCR Test Chamber Installation and Data Collection at Utility Host Sites	$80,000
Task 4 – Determination of SCR Blinding Mechanisms	$60,000
Task 5 – Final Interpretation, Recommendations, and Reporting	$30,000

Energy & Environmental Research Center

Schedule *(24-month duration)*



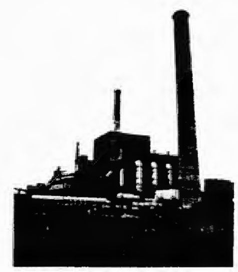
Energy & Environmental Research Center

Project Personnel

- Manager: Chris Zygarlicke
- PIs: Bruce Folkedahl, Jay Gunderson, and Jason Laumb
- Administrative: Stacie Klegstad

Objectives of Remainder of Meeting

- Answer questions
- Determine need
- View SCR reactors
- Direction and future



SCR Blinding Project Participants

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SCR Blinding Project Participants (cont.)

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Jay Gunderson
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E-Mail: jgunderson@undeerc.org

Sheryl Landis
Phone: (701) 777-5124
E-Mail: slandis@undeerc.org

INDUSTRIAL COMMISSION OF NORTH DAKOTA

John Hoeven
Governor

Wayne Stenehjem
Attorney General

Roger Johnson
Commissioner of Agriculture

Memorandum

TO: Karen Gutenkunst

FR: Karlene Fine
Executive Director and Secretary

DT: August 20, 2001

RE: GRANT PAYMENT

Please have a check(s) prepared in the following amount to the entity(s) listed below as per their contract.

UND - EERC $22,500
ATTN: GRANTS & CONTRACTS OFFICE
FY00-XXXVI-100 EVLUATION POTENTIAL SCR CATALYST BLINDING
PO BOX 9018
GRAND FORKS, ND 58202-9018 **(Fourth Payment)**

Please pay from the 2001-2003 biennium. If you have any questions, please call. Please forward the check(s) to the appropriate person(s) and make a copy for my files.

Thanks. KF

Karlene K. Fine, Executive Director and Secretary
State Capitol, 10th Floor - 600 E Boulevard Ave Dept 405 - Bismarck, ND 58505-0840
E-Mail: kfine@state.nd.us
Phone: (701) 328-3722 FAX: (701) 328-2820
"Your Gateway to North Dakota": discovernd.com

INDUSTRIAL COMMISSION OF NORTH DAKOTA

LIGNITE RESEARCH, DEVELOPMENT AND MARKETING PROGRAM

MEMORANDUM

August 14, 2001

TO: Karlene Fine, Executive Director and Secretary
North Dakota Industrial Commission

FROM: Clifford R. Porter, Director CRP
Lignite Research, Development and Marketing Program

SUBJECT: FY00-XXXVI-100: "Evaluation of Potential SCR Catalyst Blinding During Coal Combustion"; Contractor: Energy & Environmental Research Center; Recommendation for Payment of $22,500 for Third of Seven Quarterly Reports (4/1/01 – 6/30/01).

I have reviewed the third quarterly report (April 1, 2001 – June 30, 2001) from the contractor (Energy & Environmental Research Center) regarding Contract No. FY00-XXXVI-100 for the project titled "Evaluation of Potential SCR Catalyst Blinding During Coal Combustion".

This third of seven quarterly reports is adequate to determine that the contractor has complied with the statement of work.

The contractor has met the terms of contract FY00-XXXVI-100 required for receiving the $22,500 payment for the third quarterly report. I recommend payment of the $22,500.

CRP/vg: 24.S.30.A

LIGNITE RESEARCH COUNCIL
John Dwyer, Chairman
Clifford Porter, Director & Technical Advisor
P.O. Box 2277
Bismarck, N.D. 58502
(701) 258-7117 (701) 258-2755 Fax

INDUSTRIAL COMMISSION OF NORTH DAKOTA
Karlene Fine
Executive Director
600 East Boulevard, State Capitol
Bismarck, N.D. 58505
(701) 328-3722 (701) 328-2820 Fax

100

Energy & Environmental Research Center

UNIVERSITY OF NORTH DAKOTA

15 North 23rd Street — PO Box 9018 / Grand Forks, ND 58202-9018 / Phone: (701) 777-5000 Fax: 777-5181
Web Site: www.undeerc.org

July 31, 2001

Ms. Karlene Fine
Executive Director
Industrial Commission of North Dakota
10th Floor
600 East Boulevard
Bismarck, ND 58505-0310

Dear Ms. Fine:

Subject: JV Task 31 – Evaluation of Potential SCR Catalyst Blinding During Coal Combustion
Contract FY00-XXXVI-100

Please find enclosed the April 1 – June 30, 2001 Quarterly Status Report for the subject task. This work was performed at the University of North Dakota Energy & Environmental Research Center under the subject contract.

If you have any questions, please call me at (701) 777-5177, fax at (701) 777-5181, or e-mail at sbenson@undeerc.org.

Sincerely,

Steven A. Benson
Senior Research Advisor

SAB/kmd

Enclosure

c/enc: Clifford Porter, Lignite Energy Council

JV TASK 31 – EVALUATION OF POTENTIAL SCR CATALYST BLINDING DURING COAL COMBUSTION
Quarterly Report
April 1 – June 30, 2001

Bench-Scale Testing

Ash has been produced for coals submitted to the EERC using the conversion and environmental process simulator (CEPS). The CEPS is a small-scale combustion system used to produce fly ash under closely controlled conditions. The coals were combusted using the CEPS, and the fly ash produced has been aerodynamically classified. The smaller size fraction of ash (less than 10 micrometers) was obtained for thermal gravimetric analysis (TGA). The coals received for testing include Beulah (OtterTail), Cordero (Otter Tail), low-sulfur U.S. bituminous (LSUS) (Kinectrics), Powder River Basin (PRB) (Kinectrics), LSUS–PRB blend (Kinectrics), Antelope–Rend Lake blend (AmerenUE), and North Antelope (Dynegy).

TGA Analysis

The working hypothesis for the TGA portion of the bench-scale testing is that the less-than-5-micrometer-size fraction of ash produced from PRB coals reacts with vapor-phase sulfur dioxide and/or phosphorus compounds resulting in particle-to-particle bonding that has the potential to form deposits in the temperature range where SCR (selective catalytic reduction) catalysts are used. The TGA testing is focused on determining the reactivity of the less-than-5-micrometer ash produced from selected PRB and blends to sulfur dioxide and gas-phase phosphorus species as a function of temperature. Testing was conducted to determine the weight gain with flue gas containing ammonia and vapor-phase phosphorus. The results are shown for 100% PRB and LSUS–PRB blend in Figures 1 and 2, respectively. The results show an increase in the weight gains when ammonia and phosphorus were added. Ground catalyst was mixed with 100% PRB and LSUS–PRB and placed in the TGA. Increases in weight gain were observed when catalyst was added as compared to baseline cases for 100% PRB and LSUS–PRB as shown in Figures 3 and 4, respectively.

SCR Reactor Design/Construction – Status of Construction Activities

The reactors have been completed and are in the process of being installed. The SCR reactor is approximately 8.5-inch-square by 8-foot-long steel housing that will consist of three sections: one flow straightener and two catalyst test sections. A purge section will be installed ahead of the section to remove accumulated dust (see Figure 5). Strip heaters will be installed on the catalyst section, and the entire housing will be insulated for temperature control. Thermocouples and pressure taps will be located in the purge sections for measurements before and after each section.

Support brackets located on the piping entering and leaving the reactor will enable individual sections of the SCR to be removed.

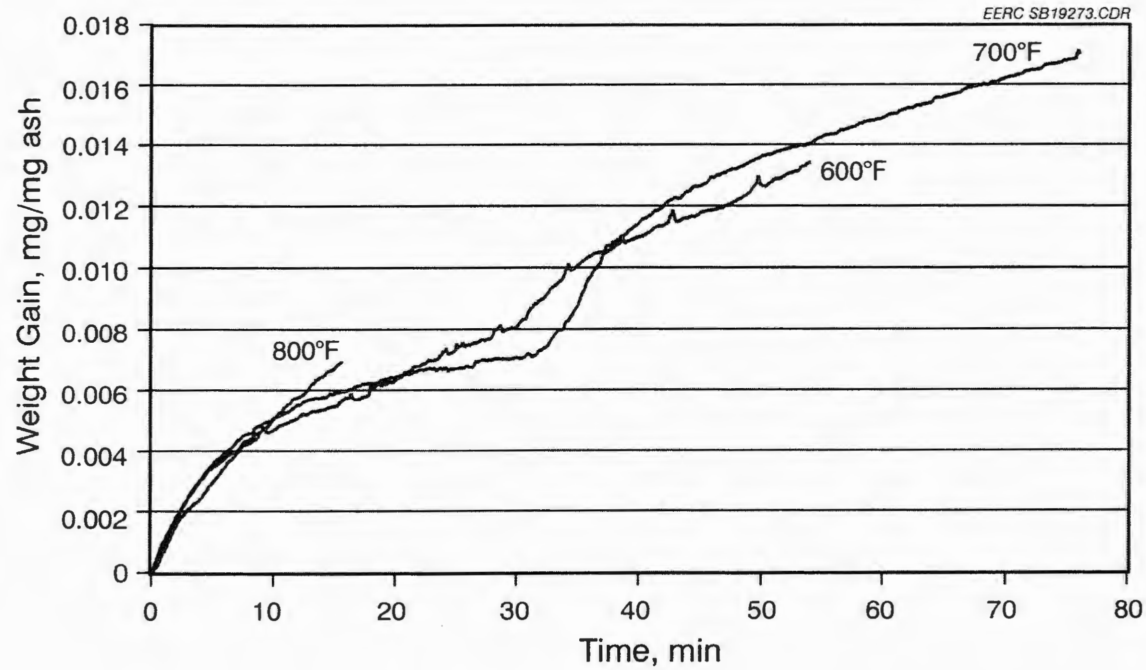

Figure 1. Weight gain curves for 100% PRB Nanticoke ash (less than 3 micrometers) with ammonia and phosphorus compounds.

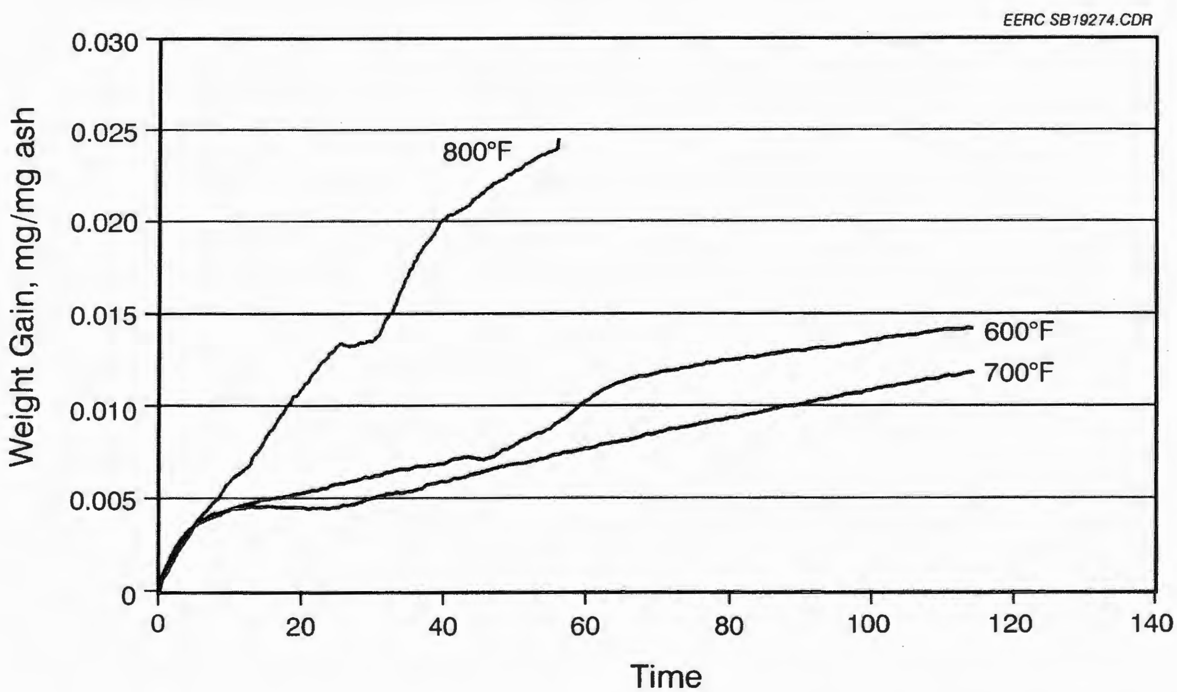

Figure 2. Weight gain curves for LSUS–PRB Nanticoke blend ash (less than 3 micrometers) with ammonia and phosphorous compounds.

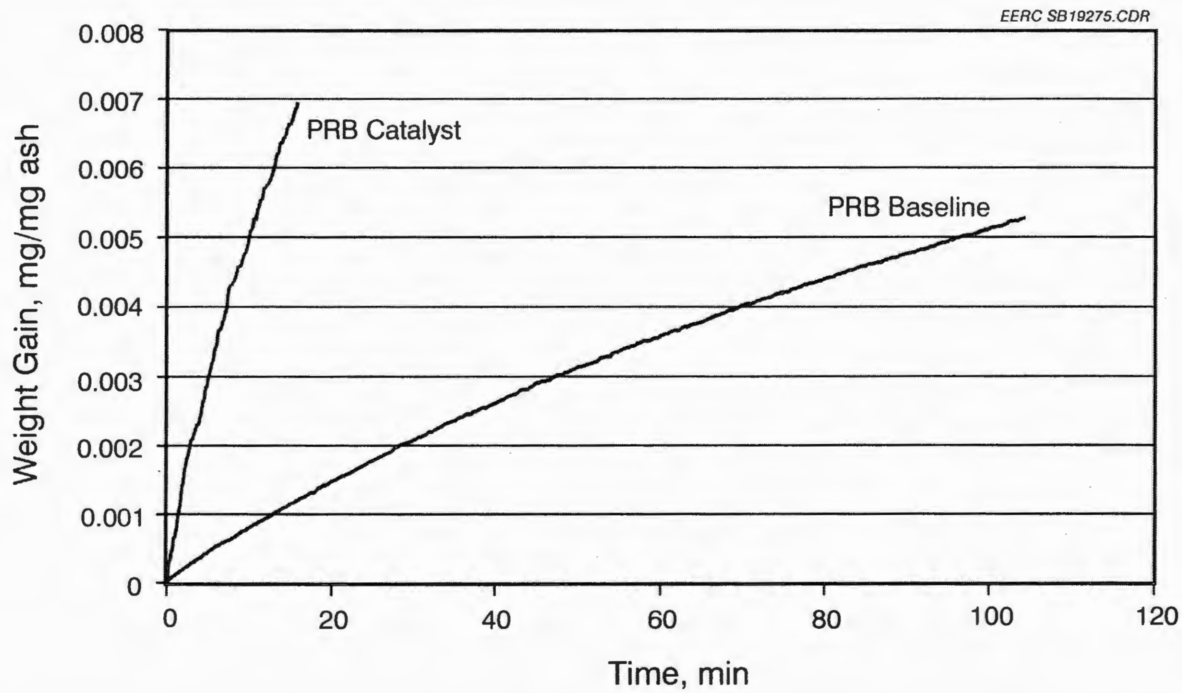

Figure 3. Weight gain curves for baseline PRB Nanticoke ash and PRB Nanticoke ash with catalyst.

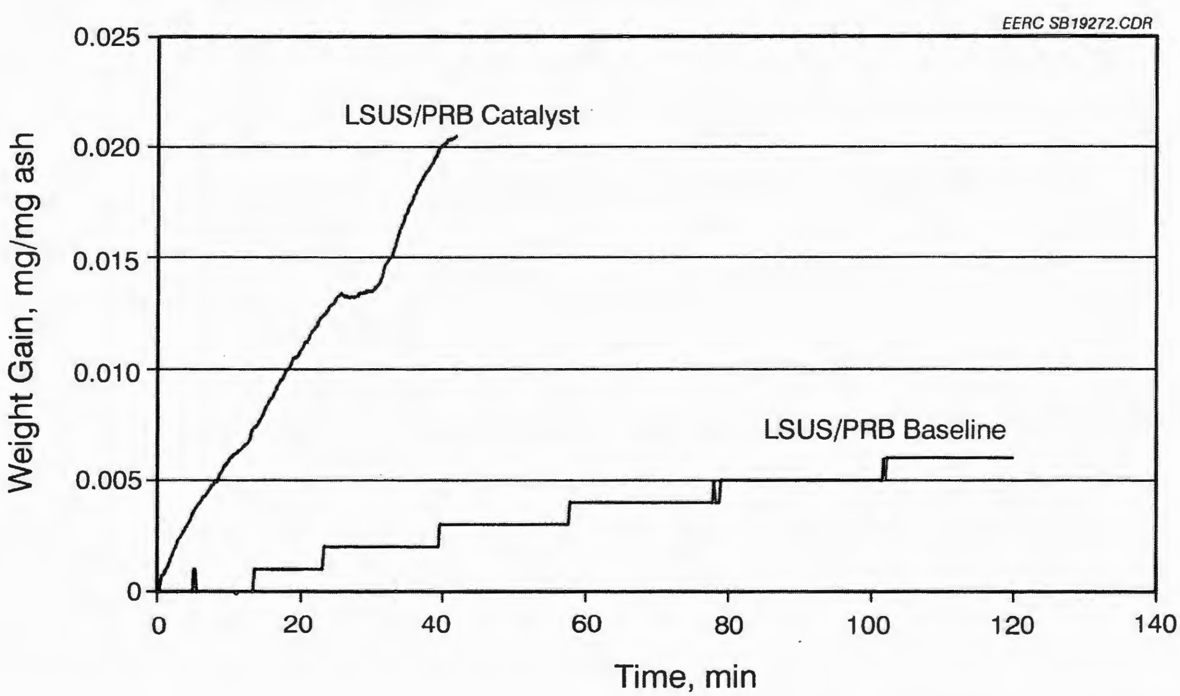

Figure 4. Weight gain curves for baseline LSUS–PRB Nanticoke blend ash and LSUS–PRB Nanticoke blend ash with catalyst.

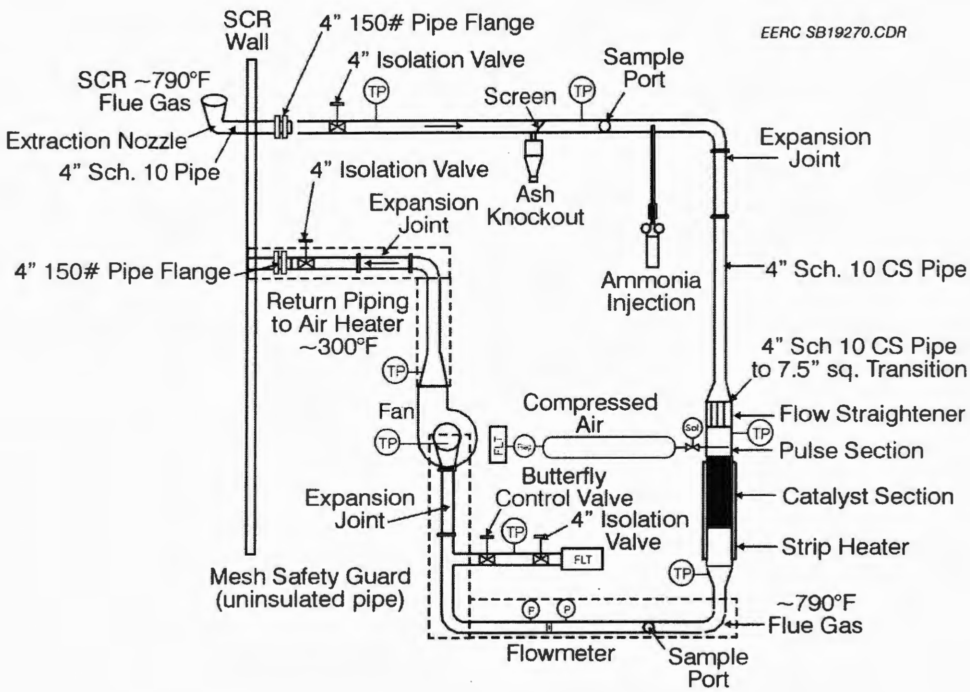

Figure 5. Conceptual drawing of SCR reactor.

The first section will be a short length (6-inch length) used as a flow straightener. The catalyst test section is 3.28 ft (1 m) in length. The catalyst sections will consist of three 2.5 inch × 7.5 inch plate type sections.

A steel catalyst holder will hold the catalyst pieces together inside the reactor (Figure 6). The catalyst holders will be placed on each end of the catalyst section. The holder consists of an angle iron welded together in a square with bars spanning between two of the flanged sides. One leg of the angle is sandwiched between the reactor shell flanges, and the other holds the catalyst sections tightly together in place. The holder will keep the catalyst away from the reactor shell, prevent flow around the catalyst, and allow for easy removal of the catalyst from the reactor.

To remove the catalyst for inspection or catalyst replacement, the catalyst section to be removed will be unbolted and slid out from the reactor (support brackets will hold the remaining reactor pieces in place). Once a catalyst reactor section is removed, the top catalyst holder will be removed, and the section(s) of interest will be removed by pushing it up from the bottom and out the top. A new section then will be inserted from the top to replace the piece removed.

A remote computer located at the EERC will control the reactor. However a computer will be on-site to allow for monitoring purposes. Several reactor temperatures, pressure drop across the catalyst, and pressure drop across an orifice meter will all be monitored. Additional slots are available on the data acquisition boards for future equipment and monitors.

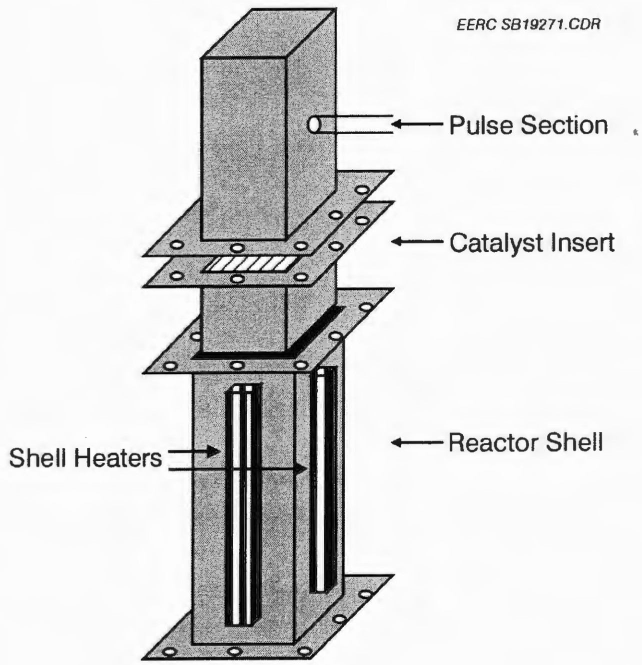

Figure 6. SCR catalyst section.

Operating Conditions

To achieve an approach velocity of 5.2 m/s (17.0 ft/s), approximately 400 acfm (200 scfm) of flue gas will be extracted from the convective pass of the utility boiler. The extraction will be immediately downstream from the economizer at a temperature in the 700°F range. The total gas flow through the reactor represents a thermal load of approximately 300 kW. A trap will be used upstream of the reactor to eliminate large fly ash agglomerates and deposit fragments that may plug the reactor.

Field Testing

One of the reactors is in the process of being installed at Baldwin. A site visit was held at Columbia station and a reactor will be installed in September.

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DOE F 4600.5#
(1-93)

Replaces EIA-459E
All Other Editions Are Obsolete

U.S DEPARTMENT OF ENERGY

FEDERAL ASSISTANCE MANAGEMENT SUMMARY REPORT

OMB Burden Disclosure Statement

11/1/00 - 7/15/02
OMB Control No.
1910-0400

1. Program/Project Identification No. DE-FC26-98FT40321	2. Program/Project Title JV Task 31- Evaluation of Potential SCR Catalyst Blinding During Coal Combustion	3. Reporting Period 4/1/01 through 6/30/01
4. Name and Address	Energy & Environmental Research Center University of North Dakota PO Box 9018, Grand Forks, ND 58202-9018 (701) 777-5000	5. Program /Project Start Date 4/15/98 6. Completion Date 3/31/03

7. FY	8. Months or Quarters	1st			2nd			3rd			4th		
01	Quarters	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP

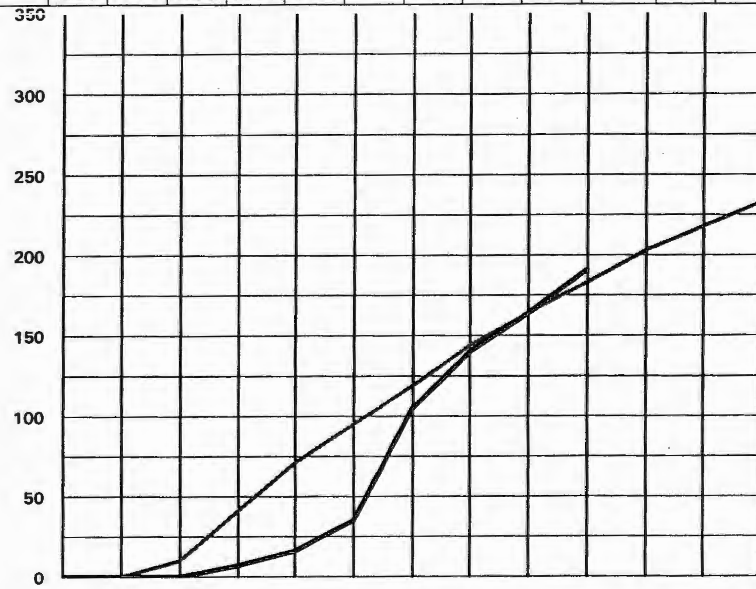
9. Cost Status — a. Dollars Expressed in Thousands — b. Dollar Scale

10. Cost Chart

Fund Source		Quarter 1st	2nd	3rd	4th	Cum. to Date	Tot. Plan
DOE	P	41	78	64	50	183	335
	A	7	98	86		191	
	P						
	A						
	P						
	A						
	P						
	A						
Total P		41	78	64	50	183	335
Total A		7	98	86		191	
Variance		34	(20)	(22)		(8)	

P= Planned A = Actual

Total Planned Costs for Program/Project
$ 335

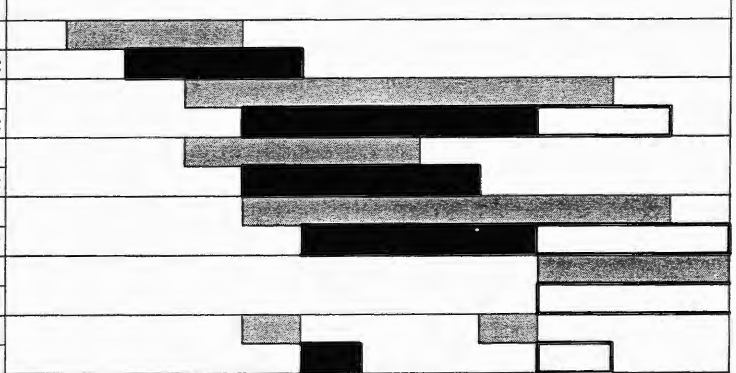


c. Cumulative Accrued Costs

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Planned			41			119			183			233
Actual			7			105			191			
Variance			34			14			(8)			

11. Major Milestone Status — Units Planned / Units Complete

Milestone	
Identification	P / C
Bench-Scale Testing and Screening	P / C
SCR Design and Construction	P / C
SCR Installation, Data Collection	P / C
SCR Blinding Determination	P / C
Interpretation and Reports	P / C
	P / C
	P / C
	P / C



12. Remarks

13. Signature of Recipient and Date
[signature] 7/20/01

14. Signature of U.S. Department of Energy (DOE) Reviewing Representative and Date

FILE: J:\JVs\Task31
DOE F 4600.5#
(1-93)
Replaces EIA-459E
All Other Editions Are Obsolete

U.S DEPARTMENT OF ENERGY

FEDERAL ASSISTANCE MANAGEMENT SUMMARY REPORT

OMB Control No.
1910-0400

OMB Burden Disclosure Statement

1. Program/Project Identification No. DE-FC26-98FT40321

2. Program/Project Title JV Task 31- Evaluation of Potential SCR Catalyst Blinding During Coal Combustion

3. Reporting Period 4/1/01 through 6/30/01

4. Name and Address Energy & Environmental Research Center, University of North Dakota, PO Box 9018, Grand Forks, ND 58202-9018 (701) 777-5000

5. Program /Project Start Date 4/15/98

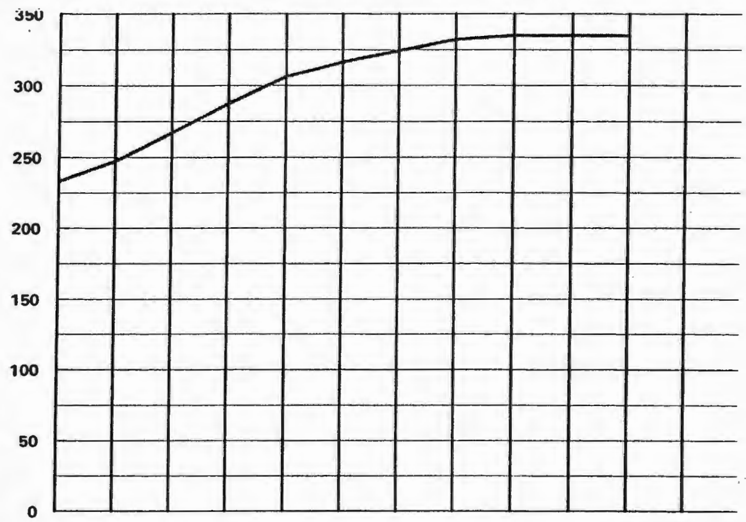
6. Completion Date 3/31/03

7. FY 02

8. Months or Quarters Quarters

1st			2nd			3rd			4th		
OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP

9. Cost Status a. Dollars Expressed in Thousands b. Dollar Scale



10. Cost Chart

Fund Source		Quarter 1st	2nd	3rd	4th	Cum. to Date	Tot. Plan
DOE	P	54	37	11			335
	A						
	P						
	A						
	P						
	A						
	P						
	A						
Total P		54	37	11			335
Total A							
Variance							

P= Planned A = Actual

Total Planned Costs for Program/Project
$ 293

c. Cumulative Accrued Costs

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Planned			287			324			335			335
Actual												
Variance												

11. Major Milestone Status

Milestone	Units Planned / Units Complete
Indentification	P / C
Bench-Scale Testing and Screeing	P / C
SCR Desing and Construction	P / C
SCR Installation, Data Collection	P / C
SCR Blinding Determination	P / C
Interpretation and Reports	P / C
	P / C
	P / C
	P / C

12. Remarks

13. Signature of Recipient and Date 7/10/01

14. Signature of U.S. Department of Energy (DOE) Reviewing Representative and Date

INDUSTRIAL COMMISSION OF NORTH DAKOTA

John Hoeven
Governor

Wayne Stenehjem
Attorney General

Roger Johnson
Commissioner of Agriculture

Memorandum

TO: Karen Gutenkunst

FR: Karlene Fine
Executive Director and Secretary

DT: November 5, 2001

RE: GRANT PAYMENT

Please have a check(s) prepared in the following amount to the entity(s) listed below as per their contract.

UND - EERC $22,500
ATTN: GRANTS & CONTRACTS OFFICE
FY00-XXXVI-100 EVLUATION POTENTIAL SCR CATALYST BLINDING
PO BOX 9018
GRAND FORKS, ND 58202-9018 (Fifth Payment)

Please pay from the 2001-2003 biennium. If you have any questions, please call. Please forward the check(s) to the appropriate person(s) and make a copy for my files.

Thanks. KF

Karlene K. Fine, Executive Director and Secretary
State Capitol, 10th Floor - 600 E Boulevard Ave Dept 405 - Bismarck, ND 58505-0840
E-Mail: kfine@state.nd.us
Phone: (701) 328-3722 FAX: (701) 328-2820
"Your Gateway to North Dakota": discovernd.com

INDUSTRIAL COMMISSION OF NORTH DAKOTA

LIGNITE RESEARCH, DEVELOPMENT AND MARKETING PROGRAM

Governor,
John Hoeven
Attorney General,
Wayne Stenehjem
Commissioner of Agriculture,
Roger Johnson

MEMORANDUM

November 2, 2001

TO: Karlene Fine, Executive Director and Secretary
North Dakota Industrial Commission

FROM: Clifford R. Porter, Director
Lignite Research, Development and Marketing Program

SUBJECT: FY00-XXXVI-100: "Evaluation of Potential SCR Catalyst Blinding During Coal Combustion"; Contractor: Energy & Environmental Research Center; Recommendation for Payment of $22,500 for Fourth of Seven Quarterly Reports (7/1/01 – 9/30/01).

I have reviewed the fourth quarterly report (July 1, 2001 – September 30, 2001) from the contractor (Energy & Environmental Research Center) regarding Contract No. FY00-XXXVI-100 for the project titled "Evaluation of Potential SCR Catalyst Blinding During Coal Combustion".

This fourth of seven quarterly reports is adequate to determine that the contractor has complied with the statement of work.

The contractor has met the terms of contract FY00-XXXVI-100 required for receiving the $22,500 payment for the fourth quarterly report. I recommend payment of the $22,500.

CRP/vg: 24.S.30.A

OK to pay

LIGNITE RESEARCH COUNCIL
John Dwyer, Chairman
Clifford Porter, Director & Technical Advisor
P.O. Box 2277
Bismarck, N.D. 58502
(701) 258-7117 (701) 258-2755 Fax

INDUSTRIAL COMMISSION OF NORTH DAKOTA
Karlene Fine
Executive Director
600 East Boulevard, State Capitol
Bismarck, N.D. 58505
(701) 328-3722 (701) 328-2820 Fax

Energy &
Environmental
Research
Center

UNIVERSITY OF NORTH DAKOTA

15 North 23rd Street — PO Box 9018 / Grand Forks, ND 58202-9018 / Phone: (701) 777-5000 Fax: 777-5181
Web Site: www.undeerc.org

October 23, 2001

Ms. Karlene Fine
Executive Director
Industrial Commission of North Dakota
10th Floor
600 East Boulevard Avenue
Bismarck, ND 58505-0310

Dear Ms. Fine:

Subject: JV Task 31 – Evaluation of Potential SCR Catalyst Blinding During Coal Combustion
Contract FY00-XXXVI-100

Please find enclosed the July 1 – September 30, 2001 Quarterly Status Report for the subject task. This work was performed at the University of North Dakota Energy & Environmental Research Center under the subject contract.

If you have any questions, please call me at (701) 777-5177, fax at (701) 777-5181, or e-mail at sbenson@undeerc.org.

Sincerely,

Jason Laumb for SB

Steven A. Benson
Senior Research Manager

SAB/kmd

Enclosure

c/enc: Clifford Porter, Lignite Energy Council

EVALUATION OF POTENTIAL SCR CATALYST BLINDING DURING COAL COMBUSTION
Quarterly Report
July 1 – September 30, 2001

SCR Reactor Design/Construction – Status of Construction Activities

The reactors have been completed and are in the process of being installed. The selective catalytic reduction (SCR) reactor is approximately 8.5-inches square with an 8-ft-long steel housing that will consist of three sections: one flow straightener and two catalyst test sections. A purge section has been installed ahead of the section to remove accumulated dust (see Figure 1). Strip heaters will be installed on the catalyst section, and the entire housing will be insulated for temperature control. Thermocouples and pressure taps will be located in the purge sections for measurements before and after each section.

Support brackets located on the piping entering and leaving the reactor will enable individual sections of the SCR to be removed.

The first section will be a short length (6 inches) used as a flow straightener. The catalyst test section is 3.28 ft (1 m) in length. The catalyst sections will consist of three 2.5-inch × 7.5-inch plate-type sections.

A steel catalyst holder will hold the catalyst pieces together inside the reactor (Figure 2). The catalyst holders will be placed on each end of the catalyst section. The holder consists of an

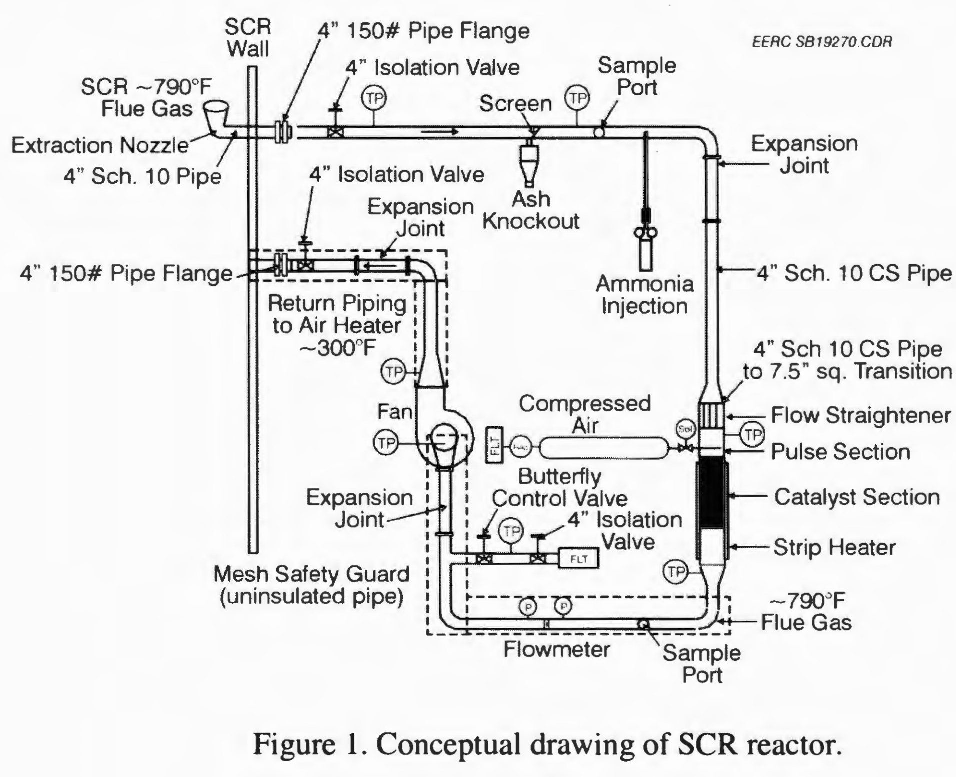


Figure 1. Conceptual drawing of SCR reactor.

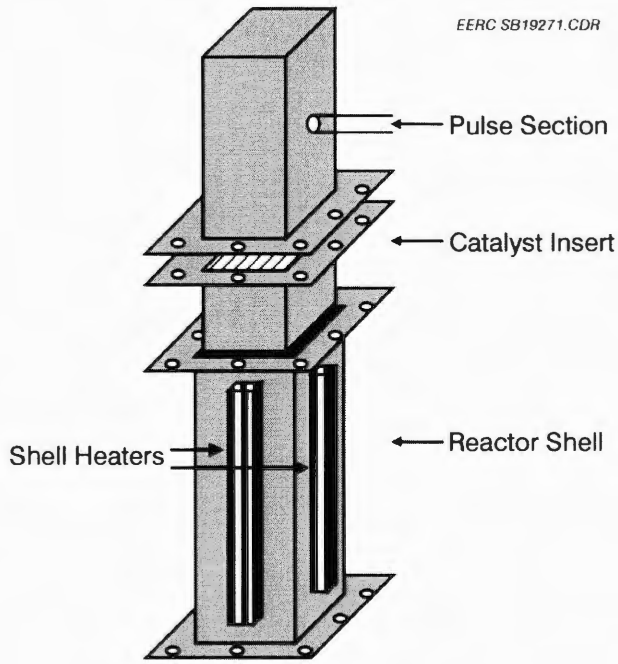


Figure 2. SCR catalyst section.

angle iron welded together in a square, with bars spanning between two of the flanged sides. One leg of the angle is sandwiched between the reactor shell flanges, and the other holds the catalyst sections tightly together in place. The holder will keep the catalyst away from the reactor shell, prevent flow around the catalyst, and allow for easy removal of the catalyst from the reactor.

To remove the catalyst for inspection or replacement, the catalyst section to be removed will be unbolted and slid out from the reactor (support brackets will hold the remaining reactor pieces in place). Once a catalyst reactor section is removed, the top catalyst holder will be removed, and the section(s) of interest will be removed by pushing it up from the bottom and out the top. A new section then will be inserted from the top to replace the piece removed.

A remote computer located at the EERC will control the reactor. However, a computer will be on-site to allow for monitoring purposes. Several reactor temperatures, pressure drop across the catalyst, and pressure drop across an orifice meter will all be monitored. Additional slots are available on the data acquisition boards for future equipment and monitors.

Operating Conditions

To achieve an approach velocity of 5.2 m/s (17.0 ft/s), approximately 400 acfm (200 scfm) of flue gas will be extracted from the convective pass of the utility boiler. The extraction will be immediately downstream from the economizer at a temperature in the 700°F range. The total gas flow through the reactor represents a thermal load of approximately 300 kW.

Field Testing

One of the reactors has been installed at the Baldwin station. The second reactor is ready for installation at the Columbia station as soon as the nozzle assembly is installed by Columbia personnel. The installation needs to be completed during an outage. The Columbia station is not scheduled for an outage until February 2002. A February installation will not delay the project any more since the reactor at Baldwin will be installed at the Coyote station in March.

The figures below contain example data from 1 week of operation of the reactor at the Baldwin station. Figure 3 contains the volumetric flow rates in standard and actual cubic feet per minute and the pressure drop across the catalyst in inches of water. Notice the drop in differential pressure during sootblowing episodes. Figure 4 contains the piping inlet, reactor inlet, and reactor outlet temperatures. The SCR unit has been allowed to cycle with the power station. The reactor temperature has been hovering around 700°F.

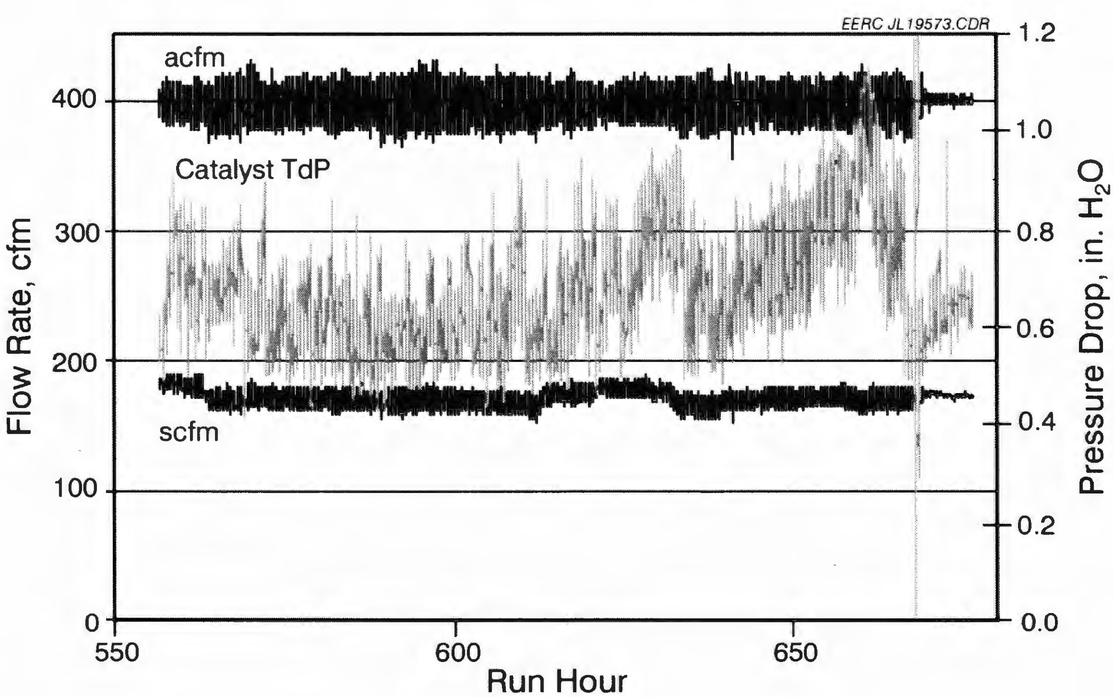


Figure 3. Volumetric flow rates and pressure drop for 1 week.

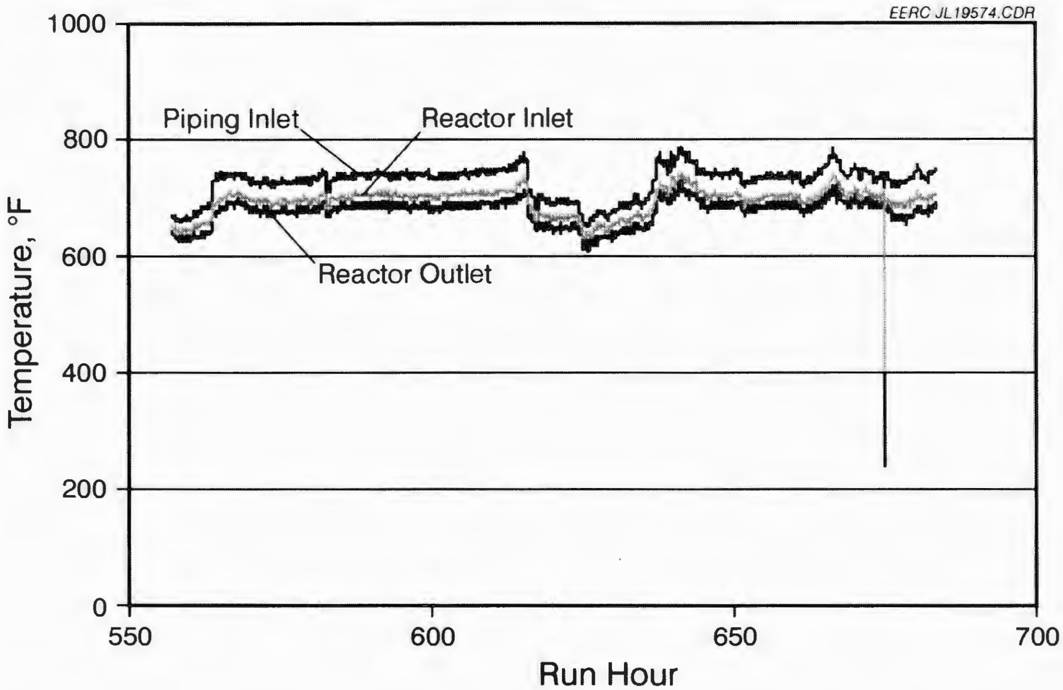


Figure 4. Reactor temperatures for 1 week.

CONFERENCE CALL

SCR Binding Project

Thursday, October 25, 2001

Discussion Items

1. **Installation at Baldwin**

   - The reactor was started September 12 and has been running almost continuously since (860 hours, 35 days).
   - The reactor dp has been increasing steadily since the installation and is now up to approximately 0.65 inches of water from 0.5 inches of water. Sootblowing cycles have been adjusted accordingly. When the reactor is brought off line the cycles will be changed to three times daily.

2. **Installation at Columbia**

   - A door assembly and nozzle has been shipped to the Columbia station. Installation will begin as soon as there is an outage. The other SCR reactor is completed and awaiting assembly.
   - Catalyst for the reactor was ordered from Hitachi in August. No word from Hitachi on progress in making the catalyst. Should we try another catalyst manufacturer?

3. **Installation at Coyote**

   - The initial field trip has been made. A nozzle will be designed and delivered to Coyote in the next month for installation. The reactor will be installed in late March when testing is complete at Baldwin.

4. **Timeline**

   - The project overall is approximately 4 months behind our original schedule. The project cannot take more delays. It is important that the host plants be ready to assist when time comes for installation of the reactor.

5. **Poster Presentation**

   - Jason Laumb will be presenting a poster at an Engineering Foundation Conference on some of the preliminary bench-scale work and the SCR reactor installation at Baldwin. Are there any issues you don't want discussed in the poster or at the conference?

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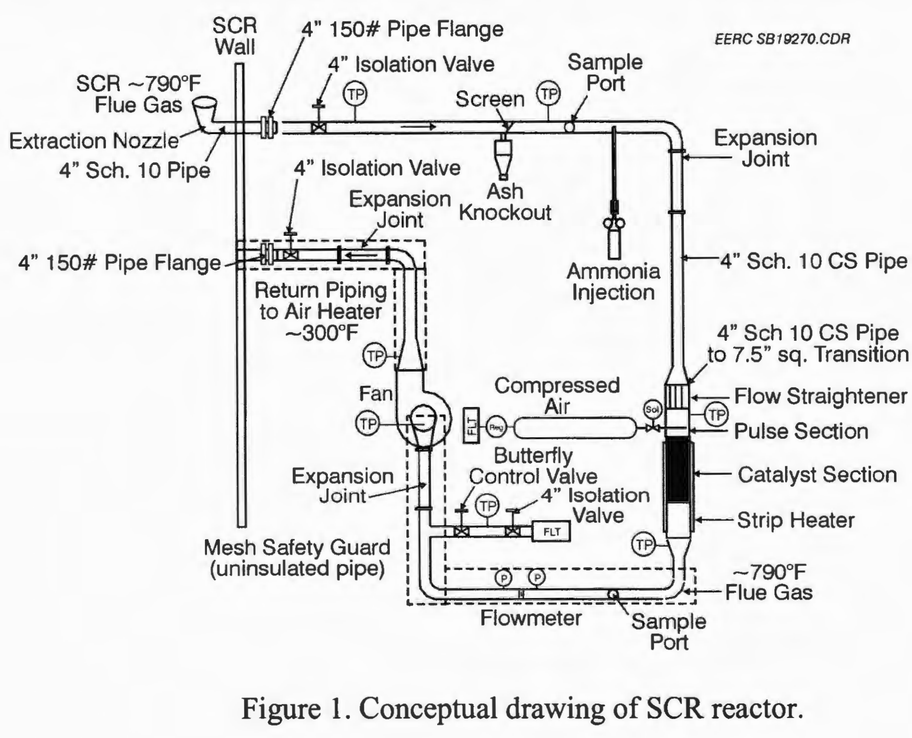

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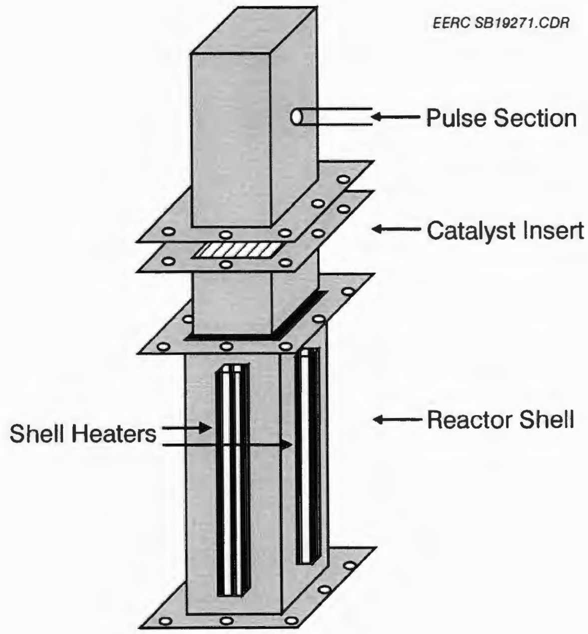

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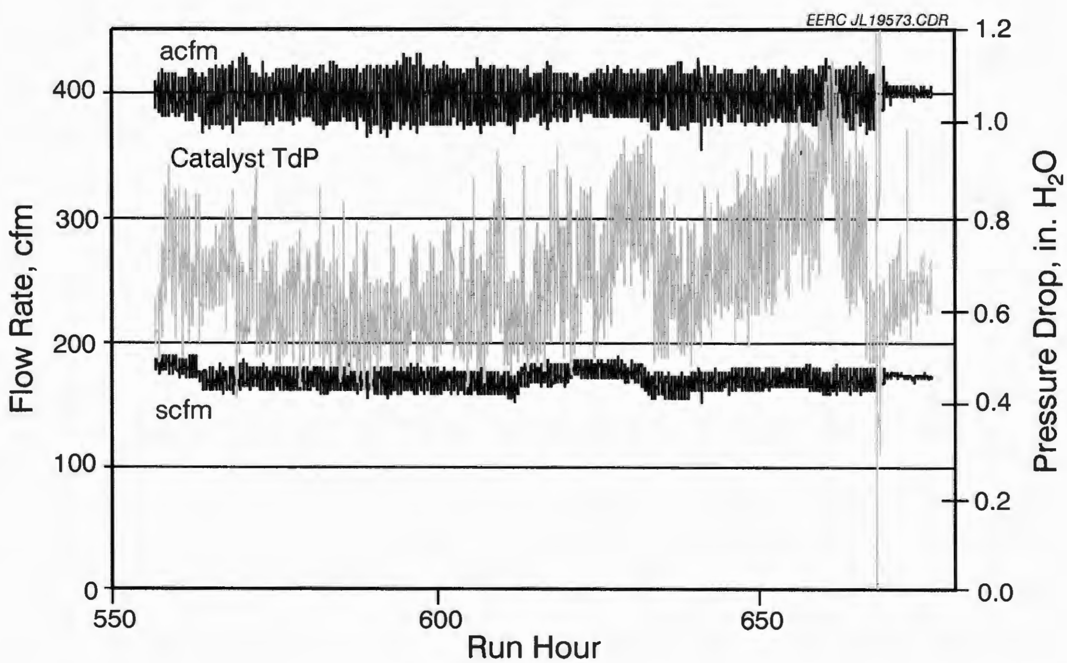


Figure 3. Volumetric flow rates and pressure drop for 1 week.

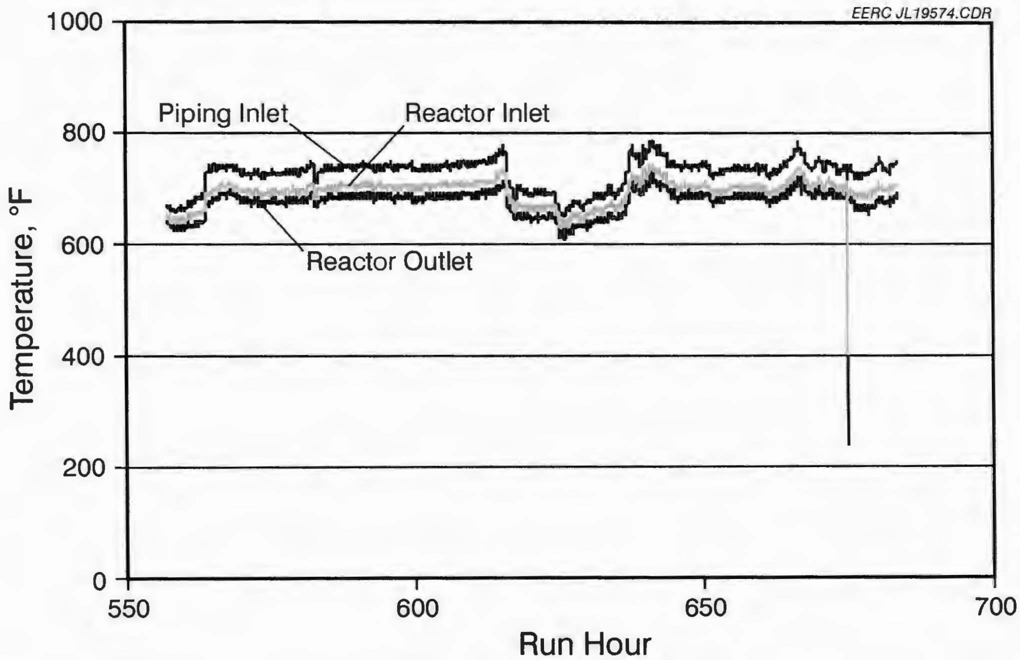


Figure 4. Reactor temperatures for 1 week.

Clifford Porter

From: Reimer, Patti J. [preimer@undeerc.org]
Sent: Wednesday, October 24, 2001 9:04 AM
To: 'MANGAL Rene -KINECTRICS'
Cc: 'cporter@lignite.com'; 'pritchardsg@cormetech.com'; 'DOCONNOR@epri.com'; 'edmundovasquez@alliant-energy.com'; 'kenneth_b_stuckmeyer@ameren.com'; 'Dean_Engelman@dynegy.com'; 'mark_liefer@dynegy.com'; 'blair.seckington@ontariopowergeneration.com'; 'walter.nischt@hal.hitachi.com'; 'Susan.Maley@netl.doe.gov'; 'fgh@topsoe.com'; 'howard.franklin@hal.hitachi.com'; 'DanaMaas@alliant-energy.com'
Subject: RE: SCR Blinding Project Conference Call Agenda

I am sorry for the confusion. The time for the conference call is 1:00 central time.

-----Original Message-----
From: MANGAL Rene -KINECTRICS [mailto:Rene.Mangal@kinectrics.com]
Sent: Wednesday, October 24, 2001 6:05 AM
To: 'Reimer, Patti J.'
Subject: RE: SCR Blinding Project Conference Call Agenda

Patti
Is this 1:00 p.m. eastern time?

-----Original Message-----
From: Reimer, Patti J. [mailto:preimer@undeerc.org]
Sent: Tuesday, October 23, 2001 5:00 PM
To: 'tgraumann@otpco.com'; 'cporter@lignite.com'; 'pritchardsg@cormetech.com'; 'DOCONNOR@epri.com'; 'edmundovasquez@alliant-energy.com'; 'kenneth_b_stuckmeyer@ameren.com'; 'Dean_Engelman@dynegy.com'; 'mark_liefer@dynegy.com'; 'Rene.Mangal@kinectrics.com'; 'blair.seckington@ontariopowergeneration.com'; 'walter.nischt@hal.hitachi.com'; 'Susan.Maley@netl.doe.gov'; 'ziaul_karim@dynegy.com'; 'fgh@topsoe.com'; 'howard.franklin@hal.hitachi.com'; 'DanaMaas@alliant-energy.com'
Cc: Benson, Steven A.; Toman, Donald L.; Gunderson, Jay R.; Laumb, Jason; Zygarlicke, Chris J.; Landis, Sheryl
Subject: SCR Blinding Project Conference Call Agenda

Attached below is a copy of the agenda and latest quarterly report for the conference call which is scheduled for this Thursday, October 25, at 1:00 p.m. If you have problems retrieving the file, let me know by e-mail or telephone at (701) 777-5070 and I can fax you a copy. The numbers for the call are the same as before and just in case you need them, the instructions for the call are as follows:

As soon as you are available for the call, dial (701) 777-4456. You will be prompted to enter a passcode, which is 1445 (be certain to hit the # key after entering the passcode number). You will then hear a beep, which means that you are on the line and connected. Please stay on the line even though no one else is on yet. Steve will be on the line a couple of minutes early. If you have trouble connecting, please call Linda at (701) 777-3206 and ask for assistance.

If you cannot participate in this meeting, please let me know so I can tell Steve.

<<scrconfcall1025agenda&report.pdf>>

Thank you,
Patti Reimer

Energy & Environmental Research Center
University of North Dakota
PO Box 9018
15 North 23rd Street
Grand Forks, ND 58202-9018
Phone: (701) 777-5070
Fax: (701) 777-5181
E-mail: preimer@undeerc.org

SCR Blinding Bench-Scale/Pilot-Scale Study

Engineering Foundation Conference

Snowbird Utah

Jason D. Laumb

Energy & Environmental Research Center

Bench-Scale Testing

- Working Hypothesis
  - Calcium and other alkaline earth and alkali-rich small particles are deposited that are subsequently reacted with gas phase components causing blinding of catalyst

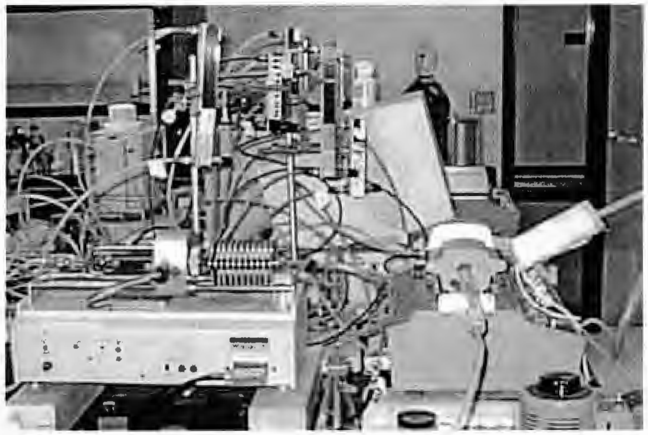
Bench-Scale Testing

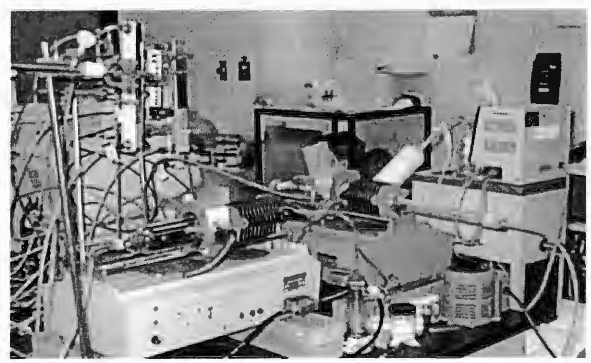
- Production of ash from selected coals under simulated combustion conditions using conversion and environmental process simulator unit
- Collection and characterization of size-fractionated ash to determine distribution of elements as a function of particle size and vapor phase (1 to 3 micron size)
  - Information can be used ultimately to assess a coals potential to blind a catalyst

Bench-Scale Testing

- Sulfates are responsible for the formation of deposits that blind catalysts
  - Thermal gravimetric analysis to determine the optimum reaction temperature and reaction rates for small calcium- and sodium-rich ash particles
    - Gas composition will be a simulated flue gas

TGA System





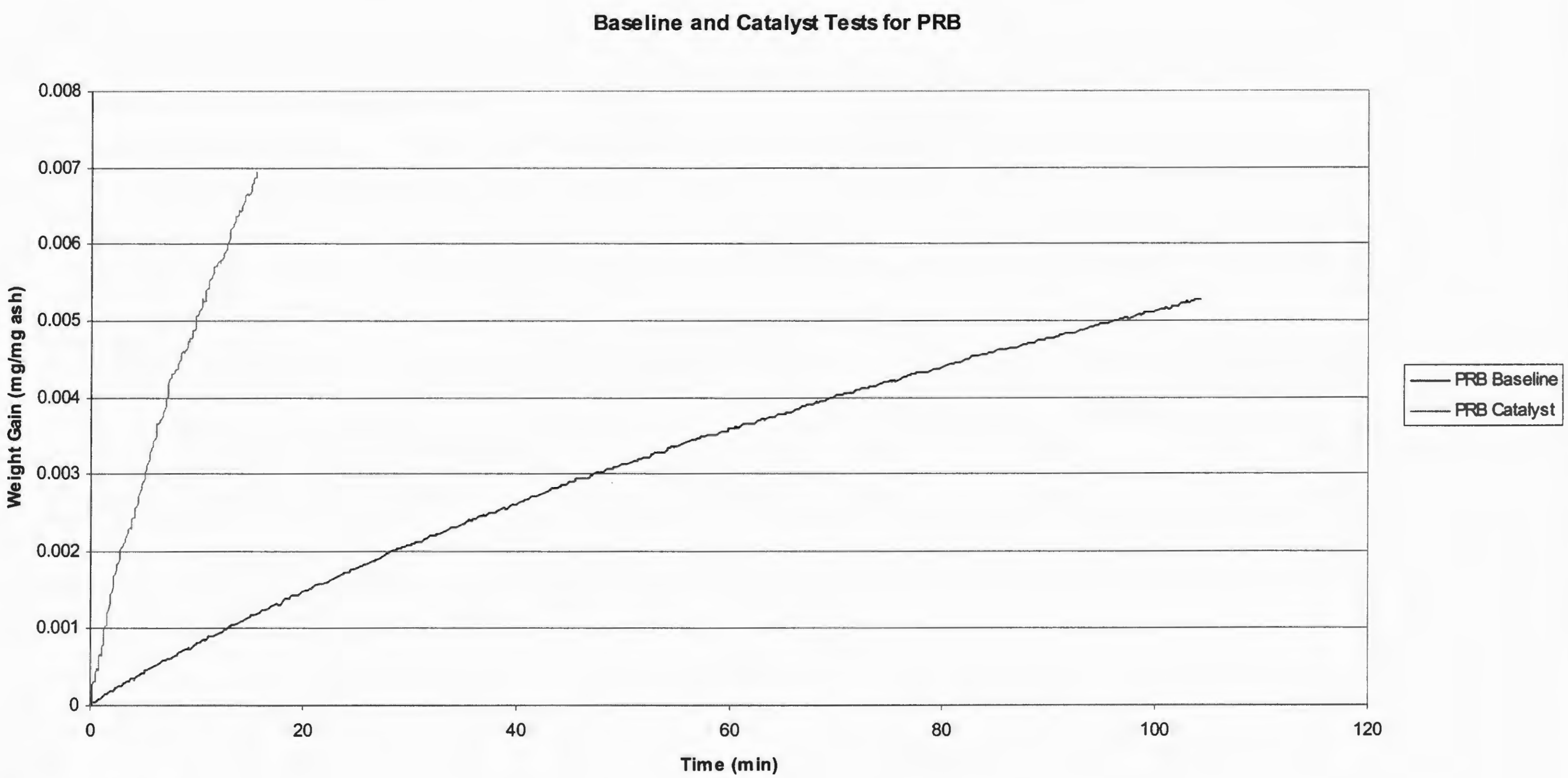
Energy & Environmental Research Center

TGA Testing

Isothermal testing to develop reaction rate as a function of temperature

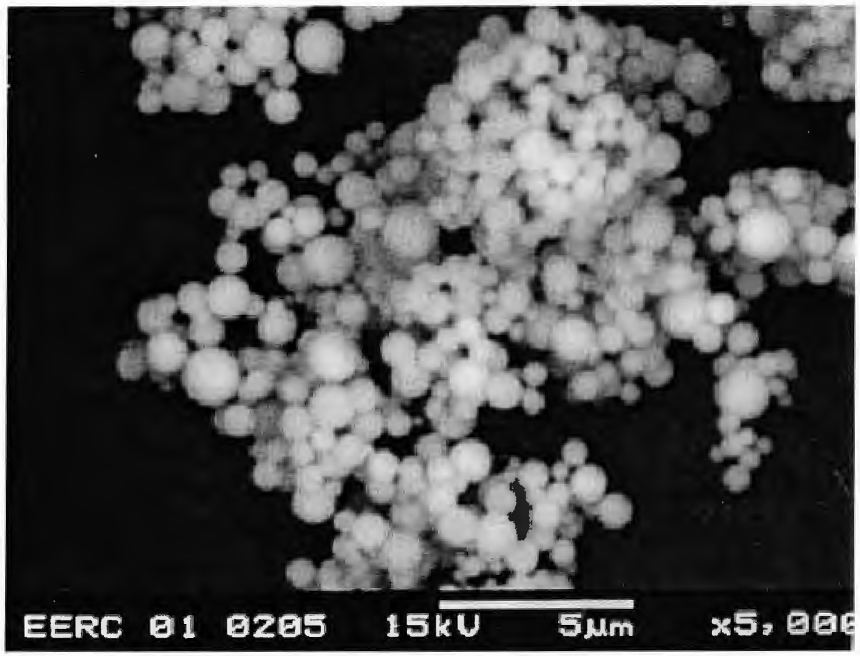
- This testing will provide key information on the rate of blinding that will occur as a function of temperature and gas composition.
- 74% N_2
- 8% H_2O
- 14% CO_2
- 4% O_2
- 100-300 ppm NH_3
- .04% SO_2
- 1-1000ppm P

Catalyst Tests-Comparisons



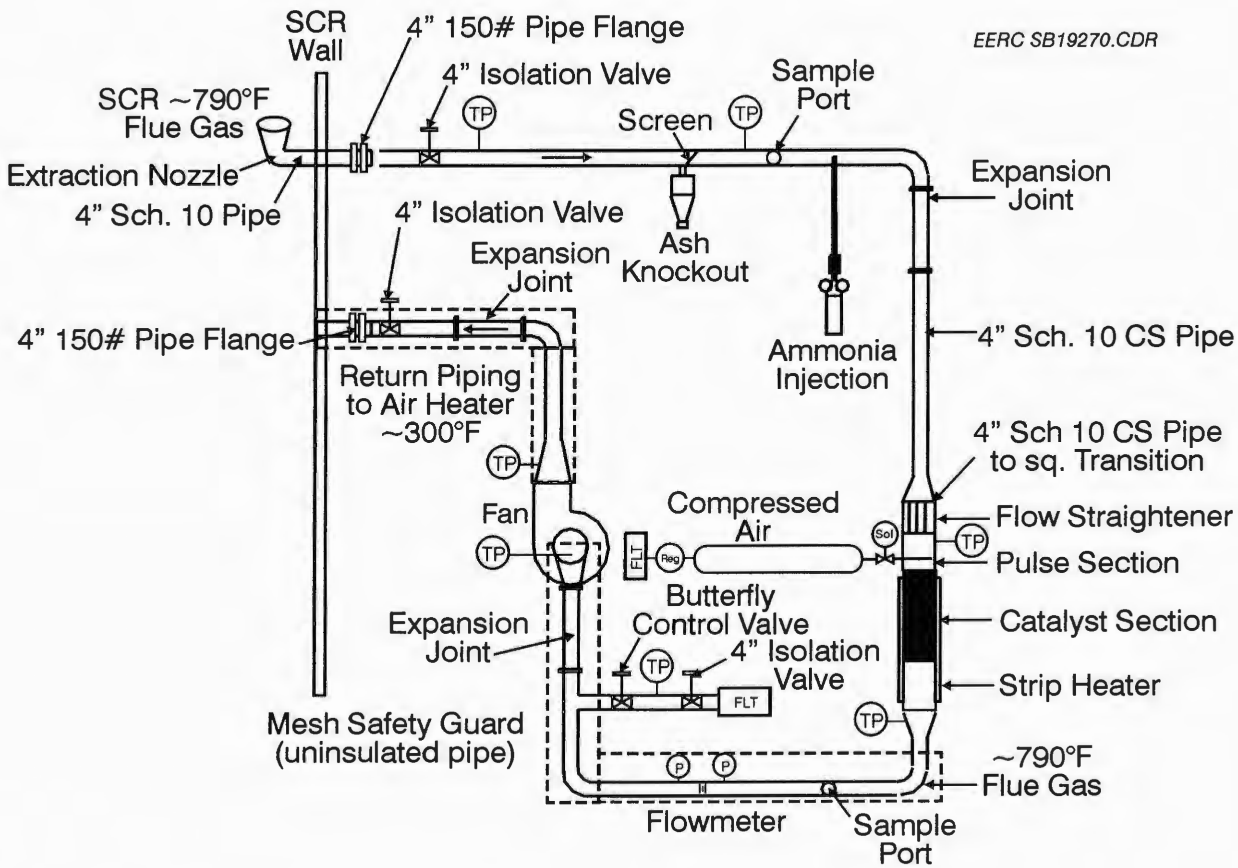
Energy & Environmental Research Center

Characterization of Reaction Products, 100% PRB



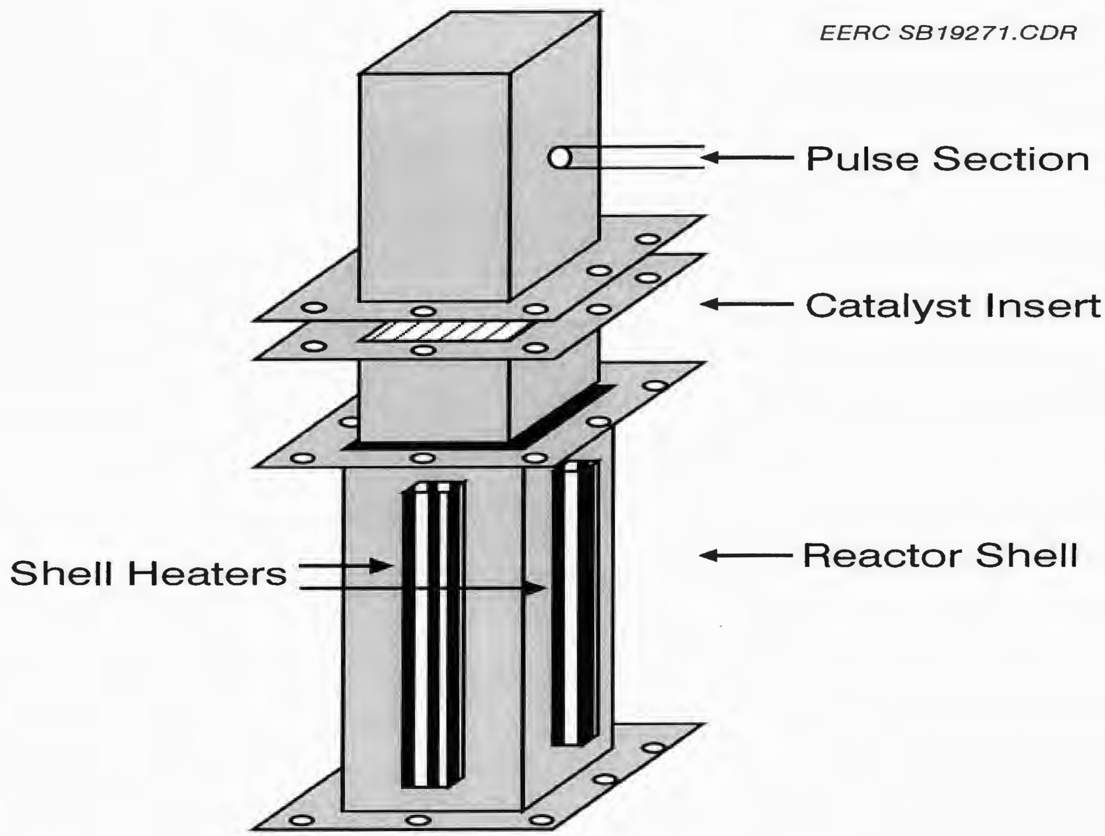
100 % PRB 800°F		
Element	Percent	
Na	0.50	0.00
Mg	5.60	5.00
Al	9.22	11.30
Si	9.00	8.30
P	1.80	1.30
S	0.70	2.10
Cl	0.00	0.00
K	0.30	0.00
Ca	32.40	31.00
Ti	0.00	1.40
Cr	0.00	0.00
Fe	11.60	7.70
Ba	1.50	1.10
O	27.00	30.60

SCR Slipstream Reactor



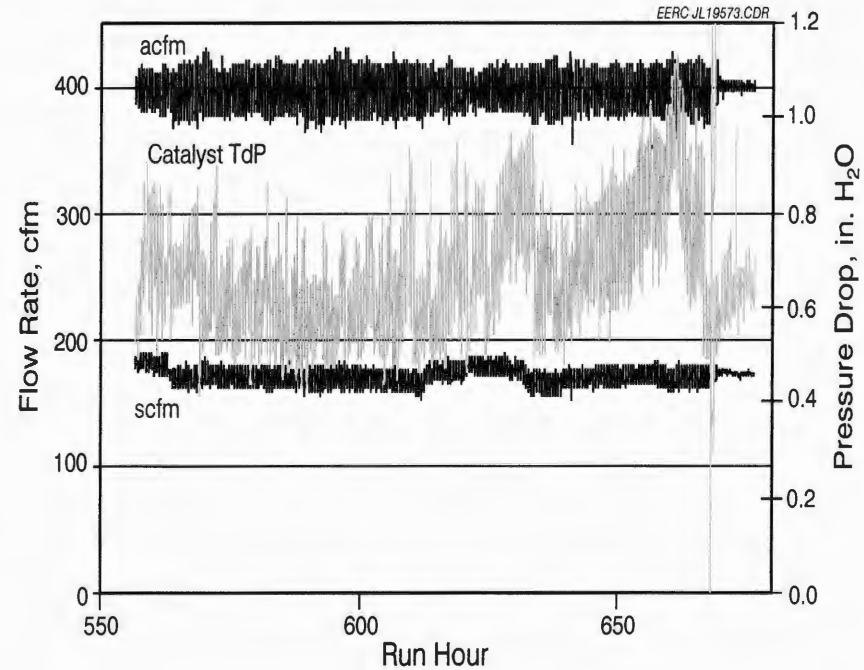
Energy & Environmental Research Center

SCR Catalyst Section



SCR Reactor Flows

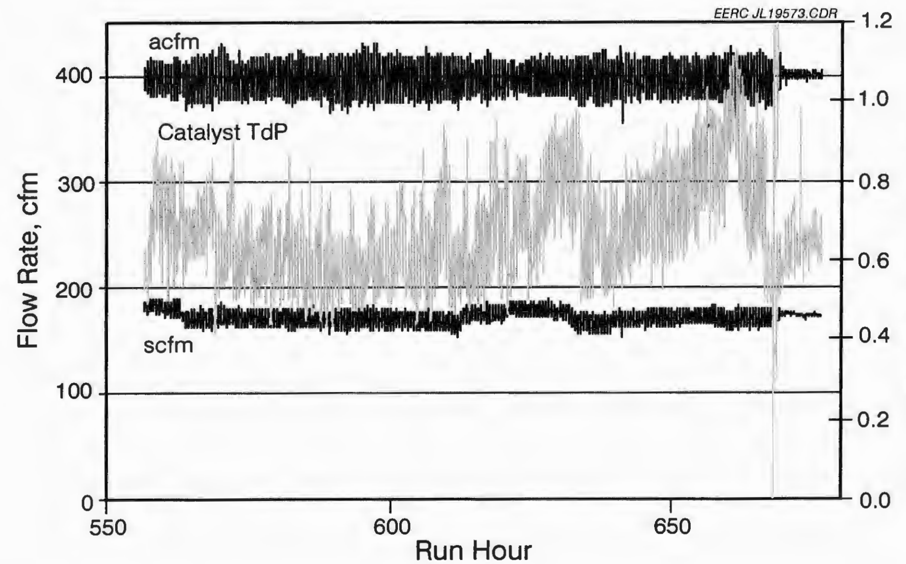
- The reactor has been in operation for approximately 900 hours on a cyclone-fired boiler burning a PRB coal.
- A slight increase in pressure drop across the reactor has been observed.
  - Sootblowing cycles have been adjusted and the dp has stabilized.



Energy & Environmental Research Center

SCR Reactor Temperatures

- The SCR unit is allowed to cycle with the boiler.
- The temperature in the SCR reactor is close to 700°F and within 30°F of the boiler temperature



Energy & Environmental Research Center

Conclusions

- PRB and lignite coals have the potential to blind SCR catalysts.
- Tests so far on a cyclone-fired unit burning a PRB are favorable after 900 hours of operation.
- Future tests will be conducted on a tangentially fired unit burning a PRB and a cyclone unit burning a lignite.

Acknowledgements

- The authors would like to recognize the support of the following sponsors:
  - Department of Energy, Otter Tail Power, Alliant Energy, Ontario Power (Kinetrics), Dynegy, Ameren UE, Hitachi, Cormetech, Haldor Topsoe, North Dakota Industrial Commission, EPRI

CONFERENCE CALL Agenda and Project Status

Evaluation of Potential SCR Catalyst Blinding During Coal Combustion

Wednesday 18, 2001

1. Review of Minutes from November Conference Call

Go through specific points in the minutes that need clarification and updating.

2. Sponsorship/Confidentiality

Sponsorship:

Detroit Edison is considering funding the project. Hopefully we will hear soon. If we get additional sponsorship we may be able to test an additional plant such as a plant that fires blends of PRB subbituminous and high sulfur bituminous coals.

Haldor Topsoe is interested in participating as a catalyst vendor. Flemming Hansen will be joining us on the conference call.

Confidentiality
We have signed confidentiality agreements from:
Hitachi
Otter Tail Power
EPRI
AmerenUE
Industrial Commission

We don't have signed agreements from:
Cormetech
Dynegy
Alliant
Ontario Power
Haldor Topsoe (agreed on language)

3. Bench Scale testing – Status

Ash has been produced for coals submitted to EERC using the conversion and environmental process simulator (CEPS). The CEPS is a small scale combustion system that is used to produce fly ash under closely controlled conditions. The following coals have been combusted using the CEPS and the fly ash produced has been aerodynamically classified. The smaller size fraction of ash (less than 10 micrometers) was obtained for thermal gravimetric analysis. The coals received for testing include: Beulah (OtterTail), Codero (Otter Tail), Low sulfur US (Kinectrics), PRB (Kinectrics), Low sulfur US/PRB blend (Kinectrics), Antelope/Rend Lake blend (AmerenUE), and North Antelope (Dynegy). The compositions of selected coal ashes are listed in Table 1.

Combustion ash has been produced from Beulah, PRB, low sulfur US/PRB blend, Antelope, and Antelope/Rend Lake Blend in the CEPS.

Table 1. Composition of Coal Ashes used in Bench Scale Testing.

	Nanticoke 100% PRB		Nanticoke 52%PRB/48%LSUS		Beulah	
Oxides, wt%	(a)	(b)	(a)	(b)	(a)	(b)
SiO2	27.9	32.0	43.4	48.4	31.5	39.7
Al2O3	17.7	20.3	26.7	29.7	14.2	17.9
Fe2O3	6.2	7.1	4.8	5.3	7.3	9.2
TiO2	1.5	1.8	1.6	1.8	0.8	1.0
P2O5	1.0	1.2	0.4	0.4	0.2	0.2
CaO	24.8	28.5	8.5	9.4	15.8	19.9
MgO	6.6	7.6	2.6	2.9	5.8	7.3
Na2O	1.0	1.2	0.7	0.7	3.1	3.9
K2O	0.4	0.5	1.2	1.3	0.8	1.0
SO3	12.9	----	10.2	----	20.6	----
Total						

(a) Oxide concentrations normalized to a closure of 100%.

(b) Oxide concentrations renormalized to a SO3-free basis

TGA analysis:

The working hypothesis for the TGA portion of the bench scale testing is that the less than 5 micrometer size fraction of ash produced from Powder River Basin coals (PRB) reacts with vapor phase sulfur dioxide and/or phosphorus compounds resulting in particle-to-particle bonding that have the potential to lead to the formation of deposits in the temperature range where SCR catalysts are used. The TGA testing is focused on determining the reactivity of the less than 5 micrometer ash produced from selected PRB and blends to sulfur dioxide and gas phase phosphorus species as a function of temperature. We also want to determine if the presence of ammonia and catalyst have on the rates of reaction of the ash with sulfur dioxide and gas phase phosphorus species. In order to determine the effect of the catalyst we need small samples of the catalyst for our TGA testing. Our aim is to determine the effect the presence of catalyst has on the reactivity of the ash and not on the catalyst reactivity.

Baseline analysis without catalyst -- PRB, low sulfur US/PRB blend, Beulah
Awaiting catalyst – Catalyst samples from Hitachi arrived and tests will be conducted with catalyst.

Updated data from the TGA analysis conducted with sulfur dioxide in a simulated flue gas atmosphere is shown in Figures 1 and 2 for Beulah and Nanticoke PRB, respectively. Figure 3 shows the weight gain for the Nanticoke low sulfur US/PRB blend. The weight gain was plotted on a mg/mg ash versus time for the selected temperatures. The results indicate that sulfation rates increase with increasing temperatures and the PRB appears to have higher sulfation rates than the Beulah. The results from the Nanticoke low sulfur US/PRB blend indicate very high sulfation at 800 F.

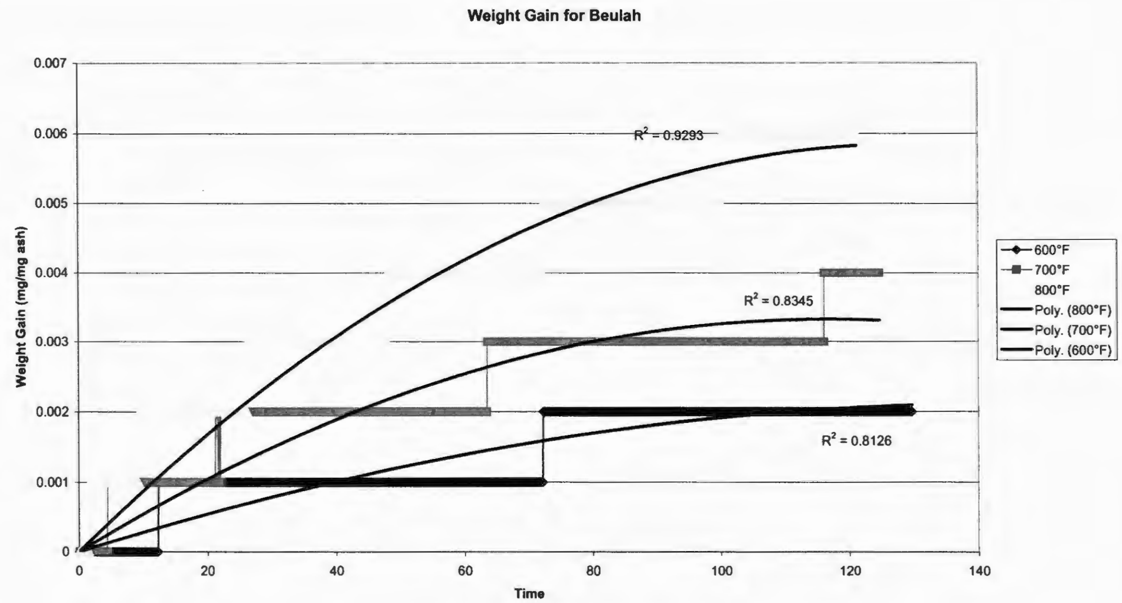


Figure 1. Weight gain curves for Beulah lignite ash (less than 3 micron)

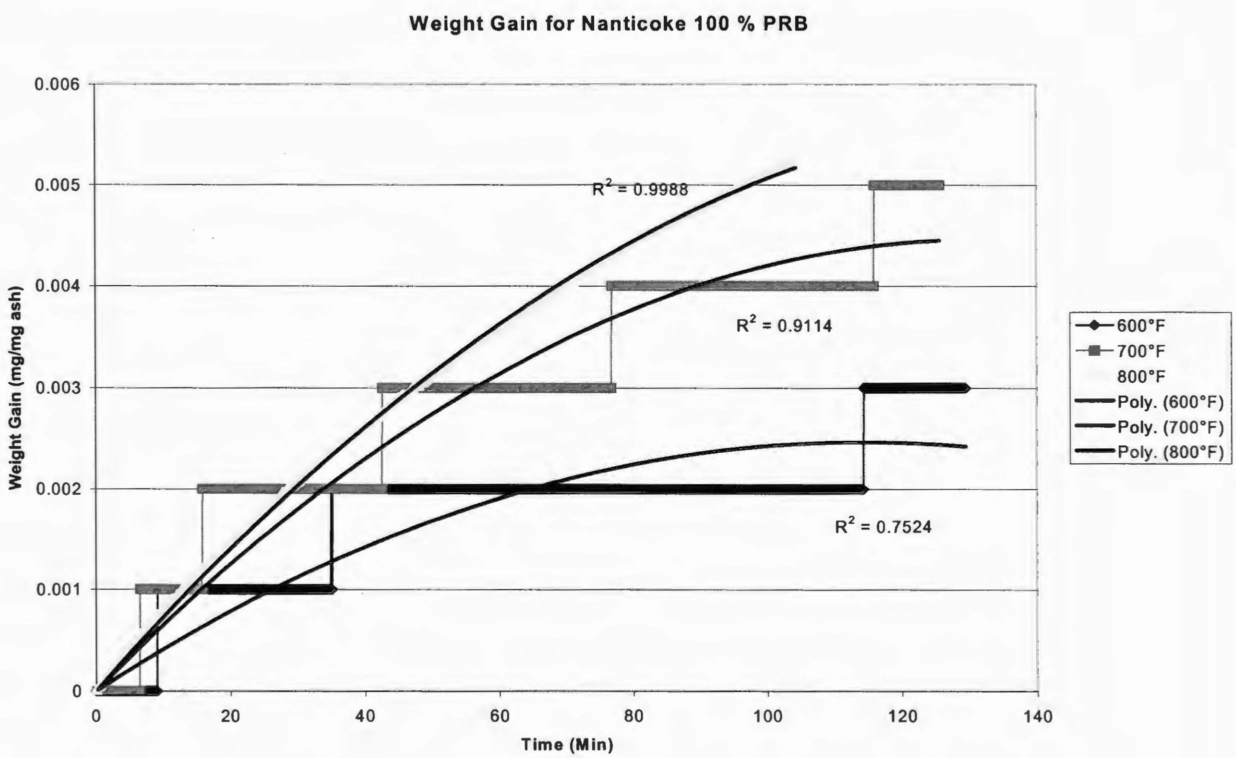


Figure 2. Weight gain curves for Naticoke PRB (less than 3 microns).

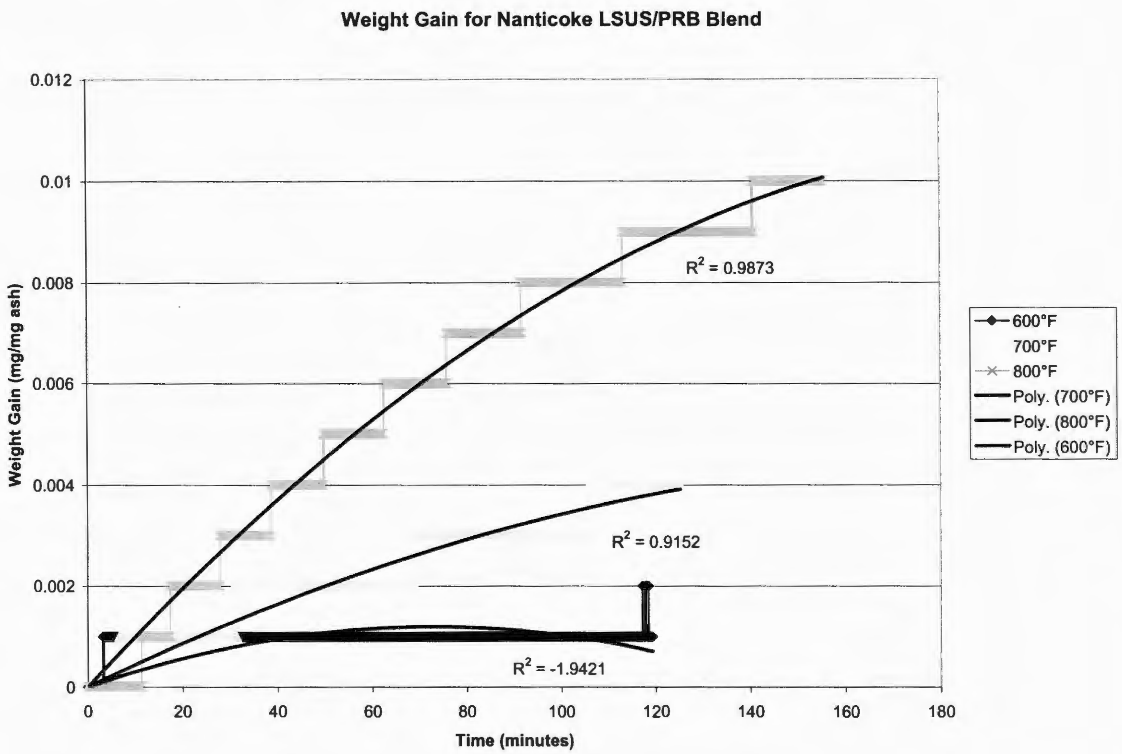


Figure 3. Weight gain for Naticoke US Bit/PRB blend.

Ash tested in the TGA has been submitted for SEM analysis. According to this analysis vapor phase phosphorus is being generated and deposited on the surfaces of particles in those coals that have the phosphorus containing compounds such as the coals from Nanticoke. The other sample (Beulah) did show evidence of forming sulfur species. In all samples the sulfur and phosphorus levels varied from 1 to 2 percent. These data will be more completely evaluated when catalyst samples are received.

4. SCR Reactor Design/Construction – Status of Construction Activities

Nearly all of the components for the SCR reactor have been designed and ordered. The final design for the reactor is awaiting final approval from Hitachi and input from Haldor Topsoe. Once that is finalized the construction of the reactor vessel will be completed.

Discussions with Hitachi have yielded a simple design that will accommodate all of the sampling we need. The reactor design essentially has remained the same except for the number of sections. The number of sections has been reduced from two to one and will be up to 675 mm (26.5 inches) in length. This is a standard size that Hitachi makes and will make the construction easier. Construction on the catalyst section of the reactor could begin as early as the end of this week if personnel are available.

Construction is underway for the control system and piping. All the flanges have been welded that can be welded. Ammonia regulator/flow meter on order. The computer control system is being programmed and debugged. The enclosure for the control systems have been built and mounting of the data acquisition boards, magnehelic, thermocouple panel, transmitters, air conditioning, breaker panel, etc will begin next week. The insulation and heating system has been ordered.

5. Field Testing

Field test sites have been identified and a site visit has been conducted to Coyote and a visit to Baldwin the end of this week. We hope to have the reactors available for installation at power plants by the middle of May. The site visit to Baldwin yielded useful descriptions of their unit. A sample port is being installed and we hope to get our sampling nozzle installed before the outage is over. We need to schedule visit to Columbia.

Table 2. Field test locations

Station	Location	Coal	Other Fuels	Outlet Temp	MWE	Firing Method
Colombia	Portage, WI	PRB Coals - Caballo, Black Thunder, Eagle Butte	NONE	500 to 850 °F	2 X 540	T-Fired
Baldwin	Baldwin, IL	PRB Antelope and Rochelle	2 % tires	(Units 1 & 2) 730 to 760 °F (Unit 3) 750 to 780 °F	3 X 600	Cyclone, Cyclone, PC – T-fired
Coyote	Beulah, ND	Beulah Lignite	NONE	780 °F	425	Cyclone

6. Conference Call/Meetings

Next meeting will be at EERC on May 23 beginning about 8:30 am. We plan to finish by 3:00p so participants can catch the late afternoon flight.

SCR Blinding Bench-/Pilot-Scale Study

Engineering Foundation Conference
Snowbird, Utah
November 1, 2001
Jason D. Laumb

EERC
Energy & Environmental Research Center

1/30/2002

Bench-Scale Testing

- Working hypothesis
  - Calcium and other alkaline-earth and alkali-rich small particles are deposited that are subsequently reacted with gas-phase components, causing blinding of catalyst.

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1/30/2002

Bench-Scale Testing

- Production of ash from selected coals under simulated combustion conditions using a conversion and environmental process simulator unit.
- Collection and characterization of size-fractionated ash to determine distribution of elements as a function of particle size and vapor phase (1 to 3μm size)
- Information can be used ultimately to assess a coal's potential to blind a catalyst.

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1/30/2002

Bench-Scale Testing

- Sulfates are responsible for the formation of deposits that blind catalysts.
  - Thermal gravimetric analysis to determine the optimum reaction temperature and reaction rates for small calcium- and sodium-rich ash particles.
    - ▸Gas composition will be a simulated flue gas.

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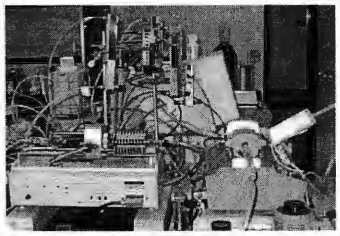
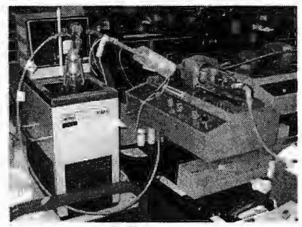
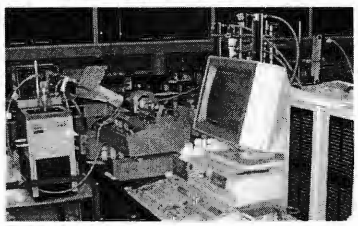
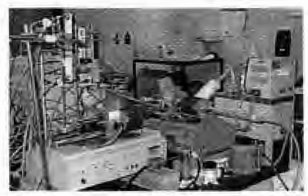
1/30/2002

TGA System









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Energy & Environmental Research Center

1/30/2002

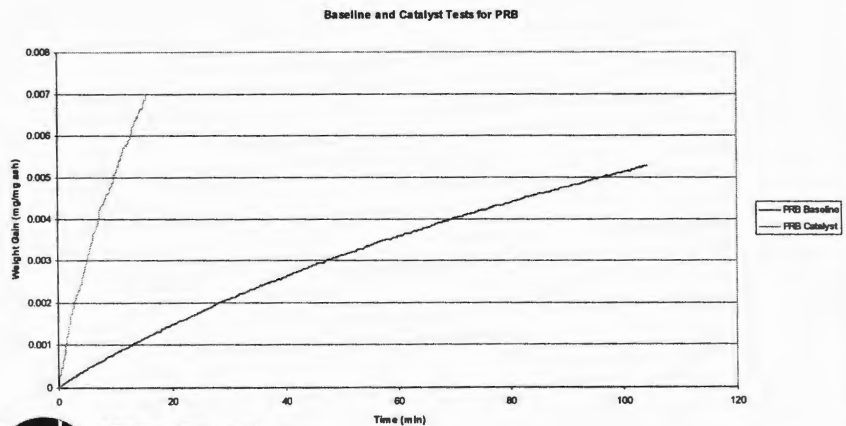
TGA Testing

- Isothermal testing to develop reaction rate as a function of temperature.
  - This testing will provide key information on the rate of blinding that will occur as a function of temperature and gas composition:
    - 74% N_2
    - 8% H_2O
    - 14% CO_2
    - 4% O_2
    - 100–300 ppm NH_3
    - 0.04% SO_2
    - 1–1000 ppm P

EERC
Energy & Environmental Research Center

1/30/2002

Catalyst Tests – Comparisons



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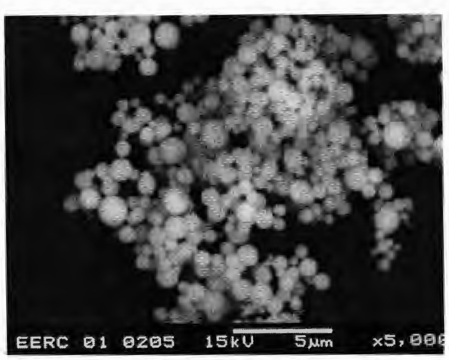
Energy & Environmental Research Center

1/30/2002

Characterization of Reaction Products, 100% PRB

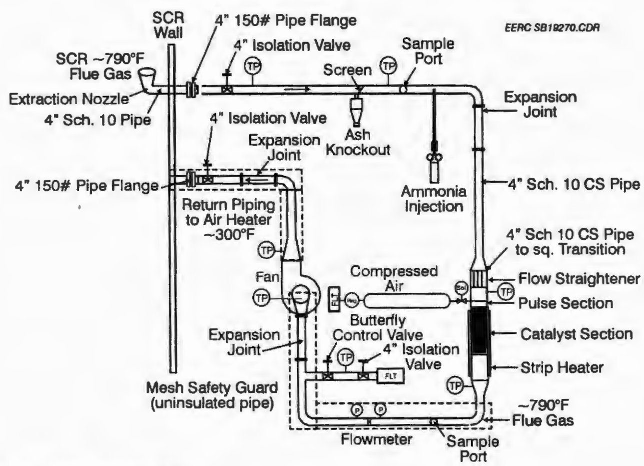


100% PRB 800°F		
Element	Percent	Element
Na	0.50	0.00
Mg	5.60	5.00
Al	9.22	11.30
Si	9.00	8.30
P	1.80	1.30
S	0.70	2.10
Cl	0.00	0.00
K	0.30	0.00
Ca	32.40	31.00
Ti	0.00	1.40
Cr	0.00	0.00
Fe	11.60	7.70
Ba	1.50	1.10
O	27.00	30.60

EERC
Energy & Environmental Research Center

1/30/2002

SCR Slipstream Reactor



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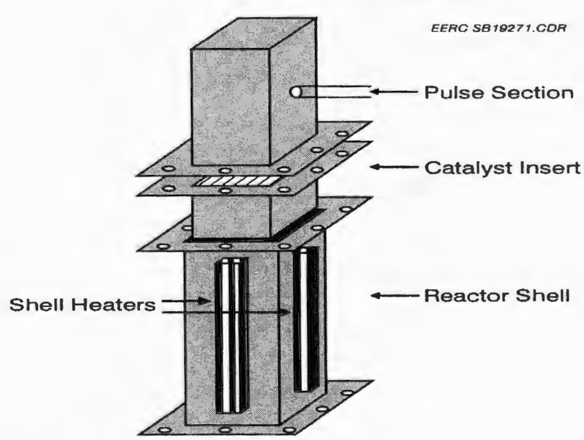
1/30/2002

SCR Catalyst Section



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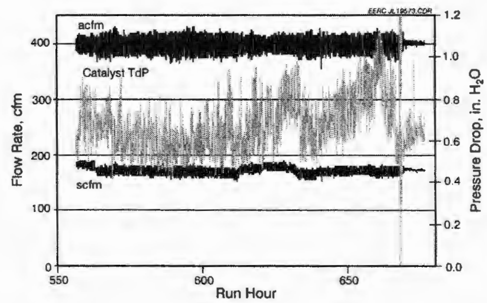
1/30/2002

SCR Reactor Flows

- The reactor has been in operation for approximately 2 months on a cyclone-fired boiler burning a PRB coal.
- A slight increase in pressure drop across the reactor has been observed.
  - Sootblowing cycles have been adjusted and the dP has stabilized.



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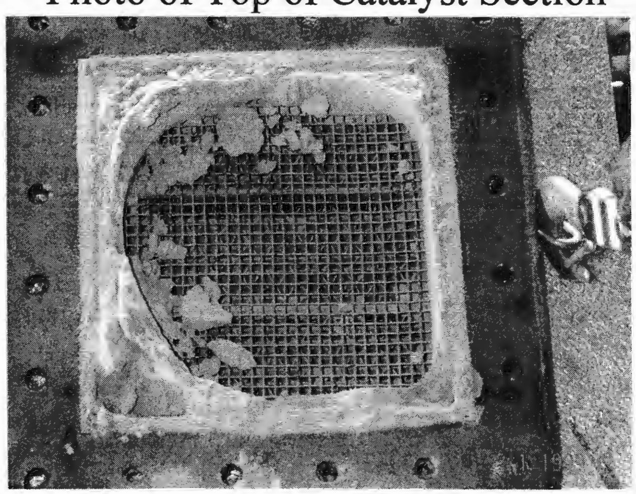
1/30/2002

Photo of Top of Catalyst Section



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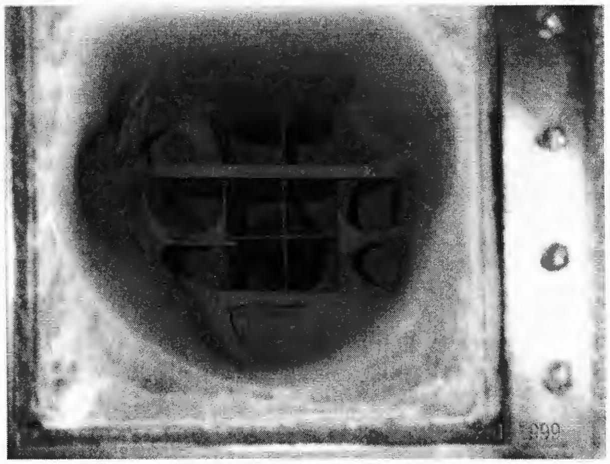
1/30/2002

Photo of Flow Straightener



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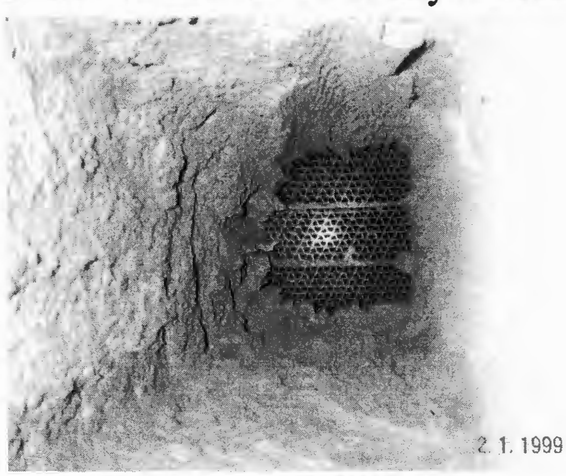
1/30/2002

Photo of bottom of Catalyst Section



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Energy & Environmental Research Center

1/30/2002

Conclusions

- PRB and lignite coals have the potential to blind SCR catalysts.
- Tests so far on a cyclone-fired unit burning a PRB are favorable after 900 hours of operation.
- Future tests will be conducted on a tangentially fired unit burning a PRB and a cyclone unit burning a lignite.

EERC
Energy & Environmental Research Center

1/30/2002

Acknowledgments

- The authors would like to recognize the support of the following sponsors:
  - Department of Energy, Otter Tail Power Company, Alliant Energy, Ontario Power (Kinetrics), Dynegy, Ameren UE, Hitachi, Cormetech, Haldor Topsoe, North Dakota Industrial Commission, EPRI

EERC
Energy & Environmental Research Center

1/30/2002

MEMORANDUM
March 19, 2002

TO: John Dwyer, President
Lignite Energy Council

FROM: Jeff Burgess, Manager of Environmental Services
Lignite Vision 21 Program

SUBJECT: Contract No. FY00-XXXVI-100 ("Evaluation of Potential SCR Catalyst Blinding During Coal Combustion"; Contractor: Energy & Environmental Research Center (EERC); Recommendation for Payment of $22,500 for Fifth of Seven Quarterly Reports (10/1/01- 12/31/02)

Pursuant to the above-referenced contract, I have received and reviewed the fifth of seven quarterly reports required from the contractor (EERC) under the terms of Contract No. FY00-XXXVI-100. It is my determination that the contractor has met the terms of the contract for receiving the $22,500 payment for the fifth of seven quarterly reports. Therefore, I recommend the payment of $22,500.

Jeff Burgess

JB/vg:24.S.30.A

Energy &
Environmental
Research
Center

UNIVERSITY OF NORTH DAKOTA

15 North 23rd Street — PO Box 9018 / Grand Forks, ND 58202-9018 / Phone: (701) 777-5000 Fax: 777-5181
Web Site: www.undeerc.org

S let me know if this triggers a payment? J

February 12, 2002

Ms. Karlene Fine
Executive Director
Industrial Commission of North Dakota
10th Floor
600 East Boulevard Avenue
Bismarck, ND 58505-0310

Dear Ms. Fine:

Subject: JV Task 31 – Evaluation of Potential SCR Catalyst Blinding During Coal Combustion
Contract FY00-XXXVI-100

Please find enclosed the October 1 – December 31, 2001 Quarterly Status Report for the subject task. This work was performed at the University of North Dakota Energy & Environmental Research Center under the subject contract.

If you have any questions, please call me at (701) 777-5177, fax at (701) 777-5181, or e-mail at sbenson@undeerc.org.

Sincerely,

Steven A. Benson
Senior Research Manager

SAB/tab

Enclosure

c/enc: Clifford Porter, Lignite Energy Council

EVALUATION OF POTENTIAL SCR CATALYST BLINDING DURING COAL COMBUSTION
Quarterly Report
October 1 – December 31, 2001

Installation at Baldwin Station

The first catalyst sample has been extracted and is being analyzed by the EERC and Haldor Topsoe. The sample was extracted after 2 months of operating time. The major changes in pressure drop were still observed during this test period. When the reactor chamber was opened up, it was determined that both of the sootblowers were plugged slightly and the air supply to the nozzles was only 50 psi instead of the requested 80 psi. Both contributed to the change and pressure drop and have been corrected and should not be an issue in the future. Photos from the catalyst extraction follow.

Installation at Columbia Station

The Columbia station is scheduled for an outage in February. The nozzle and door assembly will be installed at that time and the reactor installation will follow shortly.

Installation at Coyote Station

EERC personnel have been in contact with the people at Otter Tail Power to arrange for the installation of the nozzle at this plant. The reactor installation will be completed when the testing at the Baldwin station is complete.

Catalyst Sampling Activities

The first catalyst sample has been extracted and is being analyzed by the EERC and Haldor Topsoe. The sample was extracted after 2 months of operating time. The major changes in pressure drop were still observed during this test period. When the reactor chamber was opened up, it was determined that both of the sootblowers were plugged slightly and the air supply to the nozzles was only 50 psi instead of the requested 80 psi. Both contributed to the change and pressure drop and have been corrected and should not be an issue in the future. Figures 1 through 3 contain photos of reactor during the catalyst extraction process.

Figure 1 is a photograph of the top of the catalyst section. There was a small amount of plugging on one side of the reactor, likely due to poor sootblower performance or wall effects and easily removed with a small amount of effort.

Figure 2 is a photograph of the flow straightener leading into the top of the catalyst section. There was also an amount of this section that contained ash deposits. These deposits were also easily removed.

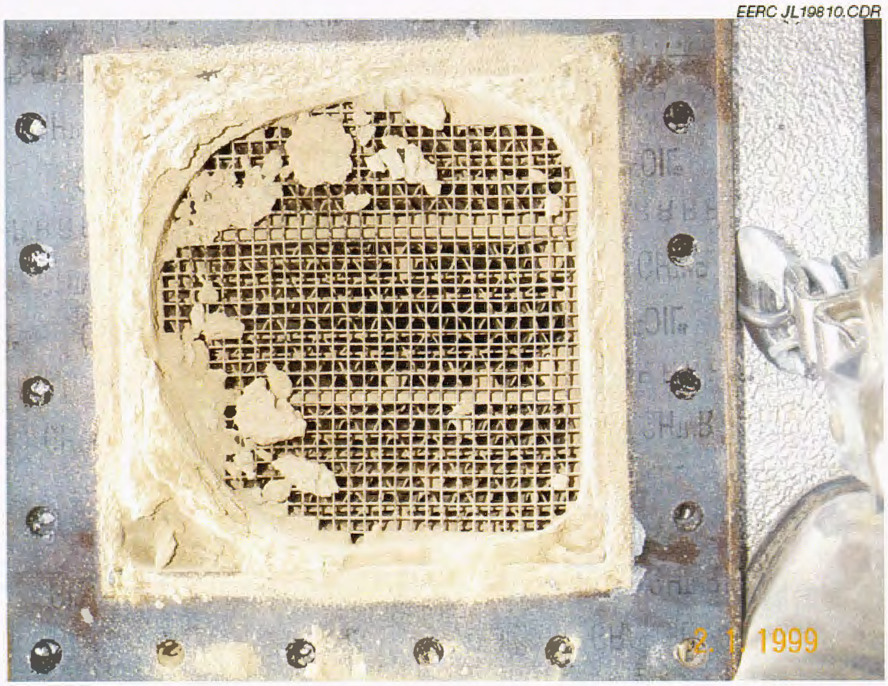


Figure 1. Photograph of the top of the catalyst section.

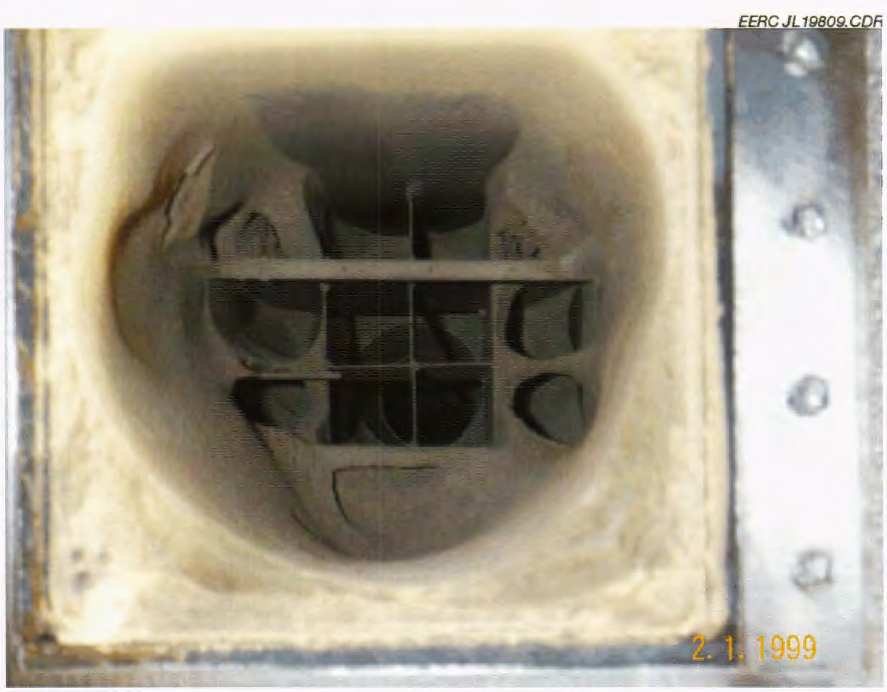


Figure 2. Photograph showing plugging in the flow straightener.

Figure 3 is a photograph of the bottom of the catalyst section. The same degree of pluggage was noted on the bottom half of the section.

One of the catalyst sections was removed and replaced with fresh catalyst. The removed catalyst is currently being analyzed at the EERC and Haldor Topsoe for catalyst blinding. All deposits in the flow straightener and other portions of the reactor were cleaned out. The deposits on top of the catalyst sections were left as they were.

EERC JL19811.CDR

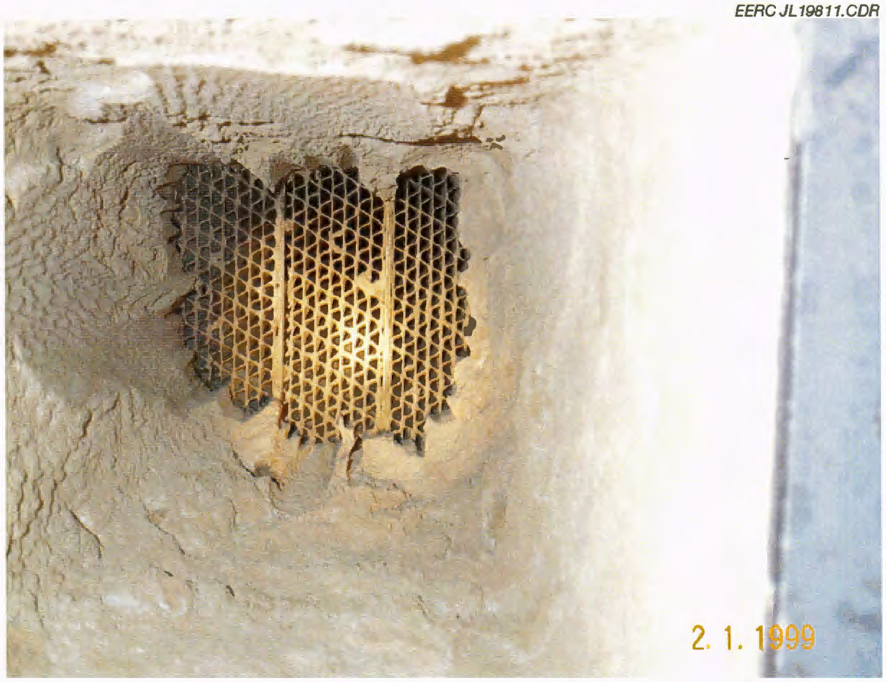


Figure 3. Photograph showing the bottom of the catalyst section.

INDUSTRIAL COMMISSION OF NORTH DAKOTA

John Hoeven
Governor

Wayne Stenehjem
Attorney General

Roger Johnson
Commissioner of Agriculture

Memorandum

TO: Karen Gutenkunst

FR: Karlene Fine
Executive Director and Secretary

DT: March 21, 2002

RE: GRANT PAYMENT

Please have a check(s) prepared in the following amount to the entity(s) listed below as per their contract.

UND - EERC $22,500
ATTN: GRANTS & CONTRACTS OFFICE
FY00-XXXVI-100 EVLUATION POTENTIAL SCR CATALYST BLINDING
PO BOX 9018
GRAND FORKS, ND 58202-9018 (Sixth Payment)

Please pay from the 2001-2003 biennium. If you have any questions, please call. Please forward the check(s) to the appropriate person(s) and make a copy for my files.

Thanks. KF

Karlene K. Fine, Executive Director and Secretary
State Capitol, 10th Floor - 600 E Boulevard Ave Dept 405 - Bismarck, ND 58505-0840
E-Mail: kfine@state.nd.us
Phone: (701) 328-3722 FAX: (701) 328-2820
"Your Gateway to North Dakota": discovernd.com

INDUSTRIAL COMMISSION OF NORTH DAKOTA

LIGNITE RESEARCH, DEVELOPMENT AND MARKETING PROGRAM

http://www.state.nd.us/ndic

MEMORANDUM

March 19, 2002

TO: Karlene Fine, Executive Director and Secretary
North Dakota Industrial Commission

FROM: John W. Dwyer, Acting Director
Lignite Research, Development and Marketing Program

SUBJECT: FY00-XXXVI-100: "Evaluation of Potential SCR Catalyst Blinding During Coal Combustion"; Contractor: Energy & Environmental Research Center; Recommendation for Payment of $22,500 for Fifth of Seven Quarterly Reports (10/1/01 – 12/31/01).

I have reviewed the fifth quarterly report (October 1, 2001 – December 31, 2001) from the contractor (Energy & Environmental Research Center) regarding Contract No. FY00-XXXVI-100 for the project titled "Evaluation of Potential SCR Catalyst Blinding During Coal Combustion".

This fifth of seven quarterly reports is adequate to determine that the contractor has complied with the statement of work.

The contractor has met the terms of contract FY00-XXXVI-100 required for receiving the $22,500 payment for the fifth quarterly report. I recommend payment of the $22,500.

JWD/vg: 24.S.30.A

LIGNITE RESEARCH COUNCIL

John Dwyer, Chairman
jdwyer@lignite.com
Lignite Research Council
P.O. Box 2277
Bismarck, ND 58502

Phone: (701) 258-7117 FAX: (701) 258-2755

INDUSTRIAL COMMISSION OF NORTH DAKOTA

Karlene Fine
Executive Director & Secretary
kfine@state.nd.us
Industrial Commission of North Dakota
State Capitol
600 East Boulevard Avenue
Bismarck, ND 58505

Phone: (701) 328-3722 FAX: (701) 328-2820

INDUSTRIAL COMMISSION OF NORTH DAKOTA

John Hoeven
Governor

Wayne Stenehjem
Attorney General

Roger Johnson
Commissioner of Agriculture

Memorandum

TO: Karen Gutenkunst

FR: Karlene Fine
Executive Director and Secretary

DT: June 10, 2002

RE: GRANT PAYMENT

Please have a check(s) prepared in the following amount to the entity(s) listed below as per their contract.

UND - EERC $22,500
ATTN: GRANTS & CONTRACTS OFFICE
FY00-XXXVI-100 EVLUATION POTENTIAL SCR CATALYST BLINDING
PO BOX 9018
GRAND FORKS, ND 58202-9018 (Seventh Payment)

Please pay from the 2001-2003 biennium. If you have any questions, please call. Please forward the check(s) to the appropriate person(s) and make a copy for my files.

Thanks. KF

Karlene K. Fine, Executive Director and Secretary
State Capitol, 14th Floor - 600 E Boulevard Ave Dept 405 - Bismarck, ND 58505-0840
E-Mail: kfine@state.nd.us
Phone: (701) 328-3722 FAX: (701) 328-2820
"Your Gateway to North Dakota": discovernd.com

INDUSTRIAL COMMISSION OF NORTH DAKOTA

LIGNITE RESEARCH, DEVELOPMENT AND MARKETING PROGRAM

Governor,
John Hoeven
Attorney General,
Wayne Stenehjem
Commissioner of Agriculture,
Roger Johnson

MEMORANDUM

June 6, 2002

TO: Karlene Fine, Executive Director and Secretary
North Dakota Industrial Commission

FROM: Harvey M. Ness, Director and Technical Advisor
Lignite Research, Development and Marketing Program HMN 6/6/02

cc: John W. Dwyer, Chairman
Lignite Research Council

SUBJECT: FY00-XXXVI-100: "Evaluation of Potential SCR Catalyst Blinding During Coal Combustion"; Contractor: Energy & Environmental Research Center; Recommendation for Payment of $22,500 for Sixth of Seven Quarterly Reports (1/1/02 – 3/31/02).

I have reviewed the fifth quarterly report (January 1, 2002 – March 31, 2002) from the contractor (Energy & Environmental Research Center) regarding Contract No. FY00-XXXVI-100 for the project titled "Evaluation of Potential SCR Catalyst Blinding During Coal Combustion".

This sixth of seven quarterly reports is adequate to determine that the contractor has complied with the statement of work.

The contractor has met the terms of contract FY00-XXXVI-100 required for receiving the $22,500 payment for the sixth quarterly report. I recommend payment of the $22,500.

HMN/vg: 24.S.30.A

LIGNITE RESEARCH COUNCIL
John Dwyer, Chairman
Harvey Ness, Director & Technical Advisor
P.O. Box 2277
Bismarck, N.D. 58502
(701) 258-7117 (701) 258-2755 Fax

INDUSTRIAL COMMISSION OF NORTH DAKOTA
Karlene Fine
Executive Director
600 East Boulevard, State Capitol
Bismarck, N.D. 58505
(701) 328-3722 (701) 328-2820 Fax

EERC
Energy & Environmental Research Center
UNIVERSITY OF NORTH DAKOTA
15 North 23rd Street — PO Box 9018 / Grand Forks, ND 58202-9018 / Phone: (701) 777-5000 Fax: 777-5181
Web Site: www.undeerc.org

May 13, 2002

Post-it® Fax Note 7671		Date 6-6	# of pages ▶ 3
To Harvey		From Shirley	
Co./Dept.		Co.	
Phone #		Phone #	
Fax #		Fax #	

Ms. Karlene Fine
Executive Director
Industrial Commission of North Dakota
10th Floor
600 East Boulevard Avenue
Bismarck, ND 58505-0310

Dear Ms. Fine:

Subject: JV Task 31 – Evaluation of Potential SCR Catalyst Blinding During Coal Combustion
Contract FY00-XXXVI-100

Please find enclosed the January 1 – March 31, 2002 Quarterly Status Report for the subject task. This work was performed at the University of North Dakota Energy & Environmental Research Center under the subject contract.

If you have any questions, please call me at (701) 777-5177, fax at (701) 777-5181, or e-mail at sbenson@undeerc.org.

Sincerely,

Steven A. Benson
Senior Research Manager

SAB/kal

Enclosure

c/enc: Harvey Ness, Lignite Energy Council

EVALUATION OF POTENTIAL SCR CATALYST BLINDING DURING COAL COMBUSTION
Quarterly Report
January 1 – March 31, 2002

Installation at Baldwin Station

The first catalyst sample has been analyzed by SEM EDS and x-ray diffraction. Both analyses showed the presence of calcium sulfate in the ash that was plugging the catalyst section. Haldor Topsoe is in the process of doing advanced analysis on the catalyst. The 4-month sample will be extracted the end of April.

Installation at Columbia Station

All of the reactor parts have been delivered and are approximately 60% installed. We are awaiting a permit from the Wisconsin DNR to finish the project. The permit should take about 30 days to obtain.

Installation at Coyote Station

EERC personnel have been in contact with the people at Otter Tail Power to arrange for the installation of the nozzle at this plant. Bland flanges have been installed at the reactor inlet and outlet. The nozzle will be inserted when the reactor is ready to be installed. The reactor installation will be completed when the testing at the Baldwin Station is complete.

Catalyst Sampling Activities

The first catalyst sample has been extracted and is being analyzed by the EERC and Haldor Topsoe. The sample was extracted after 2 months of operating time. The change in sootblowing frequency has resulted in a much lower pressure drop across the catalyst section.

Figure 1 is an SEM micrograph of fly ash removed from the catalyst. The chemical analysis for Figure 1 is found in Table 1. The small beads found on the ash particles contain calcium sulfate.

Figure 2 is an SEM micrograph showing a cross section of the ash particles. The same calcium sulfate phase is found as a coating on the particles. An x-ray diffraction analysis on the same fly ash sample confirmed the presence of calcium sulfate (anhydrite).

EERC JL20098.CDR

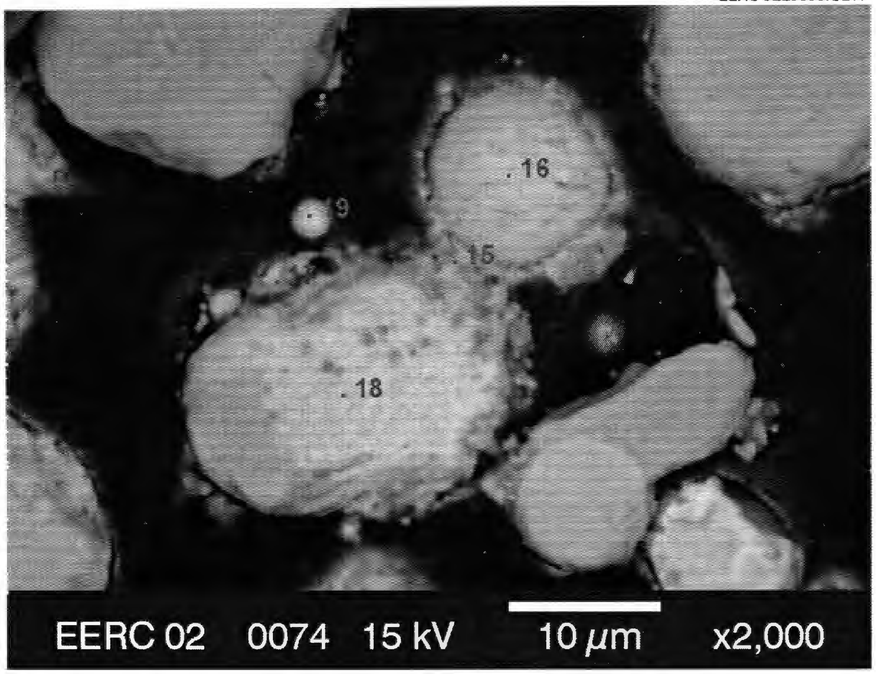


Figure 2. SEM micrograph of cross-sectioned fly ash containing analysis points 15–19.

Table 1. Chemical Analysis for Figure 1, wt%

Point	Na	Mg	Al	Si	P	S	Cl	K	Ca	Fe	O
24	2.63	2.57	6.29	2.23	1.13	29.37	0.27	0.46	16.59	12.22	23.99
25	2.91	1.03	3.86	32.81	0.00	9.57	0.04	0.57	13.74	3.51	30.85
26	3.22	1.20	2.84	8.89	0.79	25.49	0.00	0.66	11.27	6.04	38.30

Table 2. Chemical Analysis for Figure 2, wt%

Point	Na	Mg	Al	Si	P	S	Cl	K	Ca	Fe	O
15	0.69	1.96	3.76	2.10	0.18	27.84	0.19	0.20	26.97	5.21	30.70
16	0.49	3.23	14.36	9.00	0.24	0.02	0.10	0.00	35.56	11.94	23.39
17	1.56	2.35	8.42	0.59	1.29	24.30	0.36	0.09	25.29	5.91	27.12
18	0.31	2.52	12.99	4.42	0.00	0.00	0.00	0.00	42.38	12.68	20.63
19	0.81	2.54	9.08	1.31	2.46	9.55	0.97	0.04	34.00	13.20	23.21

INDUSTRIAL COMMISSION OF NORTH DAKOTA

John Hoeven Governor	Wayne Stenehjem Attorney General	Roger Johnson Commissioner of Agriculture

Memorandum

TO: Karen Gutenkunst

FR: Karlene Fine
Executive Director and Secretary

DT: August 15, 2002

RE: GRANT PAYMENT

Please have a check(s) prepared in the following amount to the entity(s) listed below as per their contract.

UND - EERC $22,500
ATTN: GRANTS & CONTRACTS OFFICE
FY00-XXXVI-100 EVLUATION POTENTIAL SCR CATALYST BLINDING
PO BOX 9018
GRAND FORKS, ND 58202-9018 (Eighth Payment)

UND - EERC $40,000
ATTN: GRANTS & CONTRACTS OFFICE
FY02-XLII-108 LOW-TEMP NO_X REDUCTION USING HIGH-SODIUM LIGNITE
PO BOX 9018
GRAND FORKS, ND 58202-9018 (First & Second Payments)

Please pay from the 2001-2003 biennium. If you have any questions, please call. Please forward the check(s) to the appropriate person(s) and make a copy for my files.

Thanks. KF

Karlene K. Fine, Executive Director and Secretary
State Capitol, 14th Floor - 600 E Boulevard Ave Dept 405 - Bismarck, ND 58505-0840
E-Mail: kfine@state.nd.us
Phone: (701) 328-3722 FAX: (701) 328-2820
"Your Gateway to North Dakota": discovernd.com

INDUSTRIAL COMMISSION OF NORTH DAKOTA

LIGNITE RESEARCH, DEVELOPMENT AND MARKETING PROGRAM

Governor,
John Hoeven
Attorney General,
Wayne Stenehjem
Commissioner of Agriculture,
Roger Johnson

MEMORANDUM
August 13, 2002

TO: Karlene Fine, Executive Director and Secretary
North Dakota Industrial Commission

FROM: Harvey M. Ness, Director and Technical Advisor
Lignite Research, Development and Marketing Program hmn 8.13.02

cc: John W. Dwyer, Chairman
Lignite Research Council

SUBJECT: FY00-XXXVI-100: "Evaluation of Potential SCR Catalyst Blinding During Coal Combustion"; Contractor: Energy & Environmental Research Center; Recommendation for Payment of $22,500 for Seventh Quarterly Report (4/1/02 – 6/30/02).

I have reviewed the seventh of seven quarterly reports (April 1, 2002 – June 30, 2002) from the contractor (Energy & Environmental Research Center) regarding Contract No. FY00-XXXVI-100 for the project titled "Evaluation of Potential SCR Catalyst Blinding During Coal Combustion".

This seventh quarterly report is adequate to determine that the contractor has complied with the statement of work.

The contractor has met the terms of contract FY00-XXXVI-100 required for receiving the $22,500 payment for the seventh quarterly report. I recommend payment of the $22,500.

HMN/vg: 24.S.30.A

LIGNITE RESEARCH COUNCIL
John Dwyer, Chairman
Harvey Ness, Director & Technical Advisor
P.O. Box 2277
Bismarck, N.D. 58502
(701) 258-7117 (701) 258-2755 Fax

INDUSTRIAL COMMISSION OF NORTH DAKOTA
Karlene Fine
Executive Director
600 East Boulevard, State Capitol
Bismarck, N.D. 58505
(701) 328-3722 (701) 328-2820 Fax

EERC
Energy & Environmental Research Center
UNIVERSITY OF NORTH DAKOTA
15 North 23rd Street — PO Box 9018 / Grand Forks, ND 58202-9018 / Phone: (701) 777-5000 Fax: 777-5181
Web Site: www.undeerc.org

August 5, 2002

Karlene Fine
Executive Director
Industrial Commission of North Dakota
10th Floor
600 East Boulevard
Bismarck, ND 58505-0310

Dear Ms. Fine:

Subject: JV Task 31 – Evaluation of Potential SCR Catalyst Blinding During Coal Combustion
Contract FY00-XXXVI-100

Please find enclosed the April 1 – June 30, 2002, Quarterly Status Report for the subject task. This work was performed at the University of North Dakota Energy & Environmental Research Center under the subject contract.

If you have any questions, please call me at (701) 777-5177, fax at (701) 777-5181, or e-mail at sbenson@undeerc.org.

Sincerely,

Steven A. Benson
Senior Research Manager

SAB/kal

Enclosure

c/enc: Clifford Porter, Lignite Energy Council

Shirley —
Check to see if this generates a payment. Then hold for Harvey's action (if needed).

If no payment to be made, then file
K

DOE F4600.6
(09-92)
Replaces EIA-459F
All Other Editions Are Obsolete

OMB Control No.
1910-0400

U.S. DEPARTMENT OF ENERGY
FEDERAL ASSISTANCE PROGRAM/PROJECT STATUS REPORT

1. Program/Project Identification No.	2. Program/Project Title	3. Reporting Period
DE-FC26-98FT40321	JV Task 31 – Evaluation of Potential SCR Catalyst Blinding During Coal Combustion	4-1-02 through 6-30-02

4. Name and Address
Energy & Environmental Research Center
University of North Dakota
PO Box 9018, Grand Forks, ND 58202-9018

5. Program/Project Start Date
4-15-98

6. Completion Date
3-31-03

7. Approach Changes

■ None

8. Performance Variances, Accomplishments, or Problems

Installation at Baldwin Station

The report from Haldor Topsoe on the reactivity of the 2- month sample from Baldwin was received. The analysis showed no loss of activity. The 4-month sample was also removed. Similar sulfate-rich materials were observed as in the previous sample. The sample has been submitted to Haldor Topsoe for the same analysis. The report from Haldor Topsoe is attached.

Installation at Columbia Station

All of the reactor parts have been delivered and are approximately 60% installed. We are awaiting a permit from the Wisconsin DNR to finish the project. The DNR is well beyond the 45-day period in which they were supposed to respond to the request from Alliant Energy. We expect the DNR to act very soon.

Installation at Coyote Station

EERC personnel have been in contact with the people at Otter Tail Power to arrange for the installation of the nozzle at this plant. Bland flanges have been installed at the reactor inlet and outlet. The nozzle will be inserted when the reactor is ready to be installed. The reactor installation will be completed when the testing at the Baldwin station is complete. The testing at Baldwin will be completed in mid July.

☐ None

9. Open Items

■ None

10. Status Assessment and Forecast

The reactor at Baldwin will be moved to the Coyote station during the next quarter. The installation at Columbia will also be completed.

■ No Deviation from Plan is Expected

11. Description of Attachments

Performance Variances, Accomplishments, or Problems (continued)

☐ None

12. Signature of Recipient and Date	13. Signature of U.S. Department of Energy (DOE) Reviewing Representative and Date
[signature] 8/8/02	

cc: TrS, HaJH, TNW, FGH, PLI, SSE, JMJ, MaT, Lab.file

HALDOR TOPSØE A/S
DK-2800 LYNGBY
DENMARK

Lyngby, 24 May 2002
MaT/MaT

File 35019

Confidential

Activity test DNX-664

EERC Baldwin 1440h

This report summarizes the results from the test of DNX-664 after 1440 hours of exposure on Dynegy Baldwin. The test did not show any deactivation.

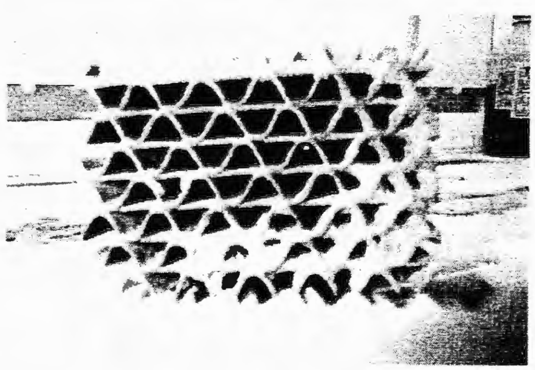
1. Test conditions:

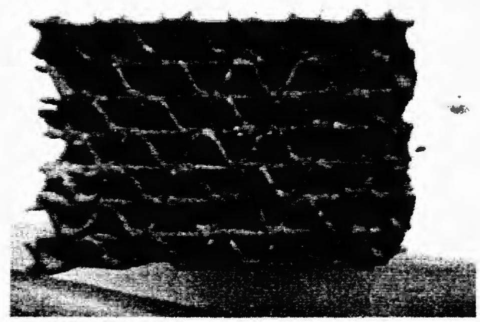
Catalyst: The tested catalyst was a DNX-664 (#8053/00) cut to following dimensions: 7.6"x2.6", length 19.7". **Reactor:** A 9"x9"slip-stream reactor that holds three test catalysts in each of the two catalyst layers. The reactor is equipped with a soot blowing device, a flow straightener, and a 1.5" dummy layer between the test catalyst and the reactor wall. **Test location:** Dynegy Balwin station, IL, a 600MW cyclone boiler, firing PRB coal (Antelope and Rochelle, and 2% tires). **Test conditions:** 730°F-750°F, Gas velocity 4.5m/s. a Fly ash analysis performed by EERC is given in attachment A. The catalysts have been soot blown twice every day.

Energy and Environmental Research Center (EERC), University of North Dakota has performed the catalyst testing.

2. Catalyst inspection:

The following two pictures show the front and the bottom of the 1440h sample upon arrival:





Keywords: EERC, PRB, DNX-664, SCR, Deactivation

Some surface clogging is observed on one corner the catalyst front edge. The clogging picture does not indicate that an oblique entrance angle should be responsible; a lower soot blowing pressure in that corner is more likely the reason.

3. Catalyst activity:

After 1440 hours of operation the test catalyst was returned to Haldor Topsoe. The catalyst and a reference sample from the original catalyst were tested in a SCR reactor (1.81"x1.81"). The test conditions where as follows: T=662°F, 3% O_2, 6% H_2O, 500 ppm SO_2, 350 ppm NOx, N_2 balance, superficial gas velocity $1.87 Nm^3/m^2/s$. The activity was measured with an NH_3/NOx ratio of 1.10. The activity is given as SCFH/ft^3 and is defined as:

K-NOx = Gas flow/Catalyst volume * Log (NOx inlet/NOx outlet)

The measured activities are given in the following table. The uncertainty on each activity measurement is typically 3%.

	Reference	EERC 1440h	K/K0
K-NOx 662°F SCFH/ft^3	22808	23400	1.026

As seen from the table, the activity of the reference catalyst and the 1440h sample are almost identical. The difference between the catalysts is within the uncertainty of this test. From the activity test we may conclude that no deactivation could be observed after 1440h.

4. Chemical analysis:

Samples was taken from the center of the catalysts, and analyzed for catalyst poisons.

Catalyst		Reference	EERC 1440h
K(soluble)	ppmw	120	505
K(total)	ppmw	<840	945
Na(soluble)	ppmw	500	2040
Na(total)	ppmw	900	2730
As	ppmw	20	<5
P	ppmw	2500	1650
Ca	w%	2,0	1.94
Mg	w%	<0.08	0.22
Fe	w%	<0.08	0.25
S	w%	0,01	0,48

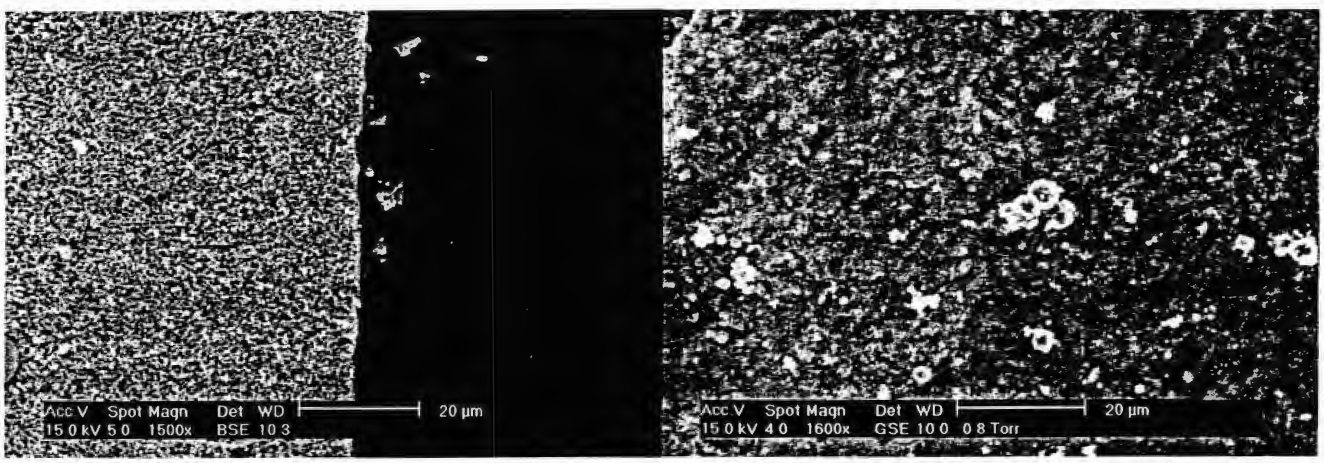
Actually only soluble K and Na are strong poisons. As, P, Ca and Mg are weak poisons, and the rest of the elements are without chemical effect. Compared with a fresh reference, only Na and S have accumulated significantly. The S accumulation is quite typical, and is due to equilibrium-determined uptake of the Titania carrier. The As accumulation is low compared with bituminous coal firing.

5. BET surface area:

The tested catalyst has been analyzed internal surface area. The BET analysis showed 48m2/g for the 1440h sample compared with 68m2/g for the reference catalyst. This is quite typical, and is due to an initial thermal sintering the first 500-1000 operating hours. After 1000 hours the catalyst surface area will be in equilibrium with the given operating temperature, and no further sintering takes place. The initial sintering observed on the 1440h has insignificant effect on the observed activity.

7. Scanning Electron Microscopy:

The 1440h catalyst sample has been examined with E-SEM. The following two pictures show a wall profile and the catalyst surface



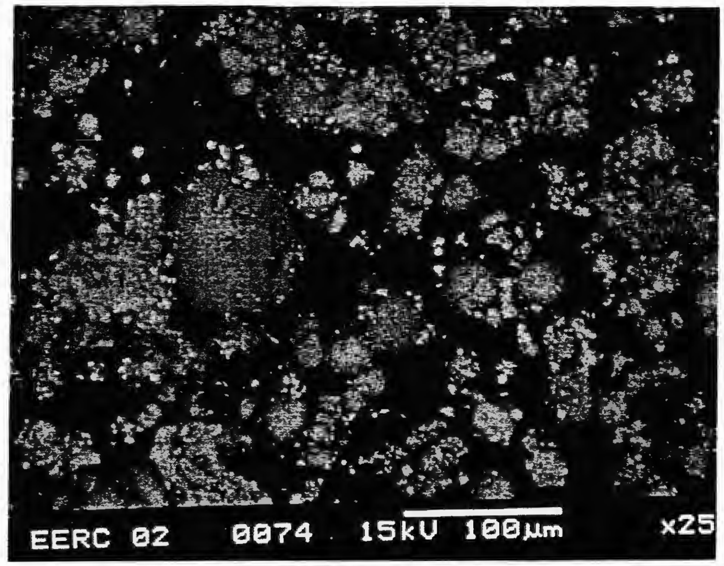
Only small amounts of fly ash are observed on the catalyst surface, some fly ash particulate can be observed on the right picture (white color). A submicron fouling layer could not be observed, which otherwise is typical for PRB deactivation.

8. Conclusion:

From the activity measurements, and the chemical analysis we may conclude:

After 1440 hours of operation of DNX-664 at Dynegy Baldwin, no significant deactivation, poisoning, or fouling could be observed.

Max Thorhauge

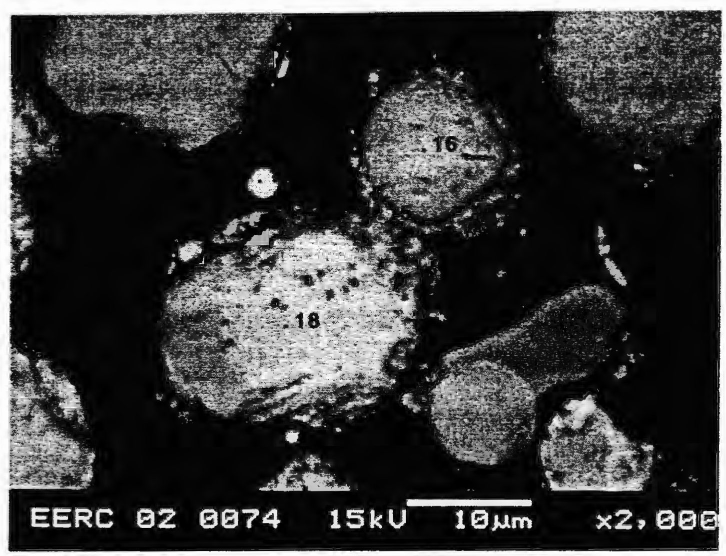


Attachment A:

Surface Analysis of Fly ash from the Baldwin Station:

Point	Na (wt %)	Mg (wt %)	Al (wt %)	Si (wt %)	P (wt %)	S (wt %)	Cl (wt %)	K (wt %)	Ca (wt %)	Fe (wt %)	O (wt %)
1	3.82	2.13	6.37	10.18	0.97	21.39	0.74	1.31	22.00	6.57	23.19
2	2.47	1.16	23.91	27.69	0.08	4.00	0.00	0.14	8.33	2.22	26.47
3	3.20	0.57	16.23	20.88	0.36	12.25	0.33	0.00	19.99	4.37	20.89
4	0.34	0.03	0.48	1.11	0.00	33.46	0.00	0.00	41.10	0.91	22.56
5	7.50	3.69	2.31	4.41	0.61	28.74	0.00	0.80	24.93	0.00	23.03

Cross Section Analysis of Fly Ash from the Baldwin Station:



Point	Na (wt %)	Mg (wt %)	Al (wt %)	Si (wt %)	P (wt %)	S (wt %)	Cl (wt %)	K (wt %)	Ca (wt %)	Fe (wt %)	O (wt %)
15	0.69	1.96	3.76	2.10	0.18	27.84	0.19	0.20	26.97	5.21	30.70
16	0.49	3.23	14.36	9.00	0.24	0.02	0.10	0.00	35.56	11.94	23.39
17	1.56	2.35	8.42	0.59	1.29	24.30	0.36	0.09	25.29	5.91	27.12
18	0.31	2.52	12.99	4.42	0.00	0.00	0.00	0.00	42.38	12.68	20.63
19	0.81	2.54	9.08	1.31	2.46	9.55	0.97	0.04	34.00	13.20	23.21

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November 6, 2002

Mr. Harvey Ness
Director
Lignite Energy Council
1016 East Owens Avenue Suite 200
PO Box 2277
Bismarck, ND 58502

Dear Mr. Ness:

Subject: JV Task 31 – Evaluation of Potential SCR Catalyst Blinding During Coal Combustion

Please find enclosed the July 1 – September 30, 2002, Quarterly Status Report for the subject task. This work was performed at the University of North Dakota Energy & Environmental Research Center.

If you have any questions, please call me at (701) 777-5177, fax at (701) 777-5181, or e-mail at sbenson@undeerc.org.

Sincerely,

Steven A. Benson
Senior Research Manager

SAB/tab

Enclosure

11/11/02 – No payment due –
2-pg summaries disagree –
Final report is due (apparently)
& final payment 22,500 will be last expenditure.
Will continue to send qrt'ly updates.
Project will be extended 9 months –
EERC will request an extension

EVALUATION OF POTENTIAL SCR CATALYST BLINDING DURING COAL COMBUSTION
Quarterly Report
July 1 – September 30, 2002

Installation at Baldwin Station

The testing at the Baldwin Station was completed this quarter. The sample from this testing will be retrieved when the reactor is dismantled. Plans are being made to dismantle the reactor and move it to the Coyote Station in the next month. The reactivity testing on the 4-month sample should be received soon from Haldor Topsoe.

Installation at Columbia Station

The permit from the Wisconsin Department of Natural Resources was finally received late this quarter. Upon receipt of the permit, the reactor installation was completed. The reactor will be started up as soon as the staff at the Columbia Station replace a stuck valve from a previous project.

Installation at Coyote Station

EERC personnel have been in contact with Otter Tail Power to arrange for the installation of the nozzle at this plant. Blank flanges have been installed at the reactor inlet and outlet. The nozzle will be inserted when the reactor is ready to be installed. The reactor installation will be completed within the next month.

The reactor at Baldwin will be moved to the Coyote Station during the next quarter. The reactor installed at the Columbia Station will be started.

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UNIVERSITY OF NORTH DAKOTA
15 North 23rd Street — PO Box 9018 / Grand Forks, ND 58202-9018 / Phone: (701) 777-5000 Fax: 777-5181
Web Site: www.undeerc.org

January 30, 2003

Mr. Harvey Ness
Director
Lignite Energy Council
1016 East Owens Avenue Suite 200
PO Box 2277
Bismarck, ND 58502

Dear Mr. Ness:

Subject: JV Task 31 – Evaluation of Potential SCR Catalyst Blinding During Coal Combustion

Please find enclosed the October 1 – December 31, 2002, Quarterly Status Report for the subject task. This work was performed at the University of North Dakota Energy & Environmental Research Center.

If you have any questions, please call me at (701) 777-5177, fax at (701) 777-5181, or e-mail at sbenson@undeerc.org.

Sincerely,

Steven A. Benson
Senior Research Manager

SAB/tab

Enclosure

EVALUATION OF POTENTIAL SCR CATALYST BLINDING DURING COAL COMBUSTION
Quarterly Report
October 1 – December 31, 2002

Installation at Baldwin Station

The reactor at the Baldwin Station is being removed. The reactor will then be shipped to the EERC for some general maintenance before going to the Coyote Station. The catalyst is being examined by scanning electron microscopy (SEM), and a sample will be sent to Haldor Topsoe for reactivity testing.

Installation at Columbia Station

The reactor is installed at the Columbia Station. The testing has begun.

Installation at Coyote Station

EERC personnel have been in contact with Otter Tail Power Company to arrange for the installation of the nozzle at this plant. The nozzle has been successfully installed. The Coyote installation is scheduled to take place in February or March after the reactor has been properly serviced at the EERC.

The reactor at Baldwin will be moved to the Coyote Station during the next quarter. The reactor installed at the Columbia Station will be monitored. The samples from the Baldwin Station will be analyzed by SEM.

EERC
Energy & Environmental Research Center
UNIVERSITY OF NORTH DAKOTA
15 North 23rd Street — PO Box 9018 / Grand Forks, ND 58202-9018 / Phone: (701) 777-5000 Fax: 777-5181
Web Site: www.undeerc.org

April 25, 2003

Ms. Karlene Fine
Executive Director
Industrial Commission of North Dakota
10th Floor
600 East Boulevard
Bismarck, ND 58505-0310

No paym. required – time extension – this report is for info only. - KMW

Dear Ms. Fine:

Subject: JV Task 31 – Evaluation of Potential SCR Catalyst Blinding During Coal Combustion
Contract FY00-XXXVI-101

Enclosed is the January 1 – March 31, 2003, Quarterly Status Report for the subject task. If you have any questions, please call me at (701) 777-5177, fax at (701) 777-5181, or e-mail at sbenson@undeerc.org.

Sincerely,

for Steven A. Benson
Senior Research Manager

SAB/cs

Enclosure

EVALUATION OF POTENTIAL SCR CATALYST BLINDING DURING COAL COMBUSTION
Quarterly Report
January 1 – March 31, 2003

Installation at Baldwin Station

The reactor at the Baldwin Station has been removed and shipped back to the Energy & Environmental Research Center. The unit is undergoing some routine maintenance before being shipped to the Coyote Station. No reactivity test results are available at this time.

Installation at Columbia Station

The reactor is now fully operational and has logged 477 hours of time. No major indications of plugging have been observed at this time.

Installation at Coyote Station

The Coyote Station has had a new control system installed. We are giving them time to work the problems out of this system before installing the reactor. This should take place in May. The catalyst from Haldor Topsoe was received for this test.

The reactor at Columbia will continue operation and be sampled at 2-months' time. The second reactor will be moved to the Coyote Station in May.

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Evaluation of Potential SCR Catalyst Blinding During Coal Combustion

Project Sponsors Meeting

May 13, 2003

Energy & Environmental Research Center
PO Box 9018, Grand Forks, ND 58202-9018
www.underc.org

AGENDA

Tuesday, May 13, 2003 **State Conference Room**

Howard Franklin, Hitachi America Ltd., Tarrytown, NY
Isato Morita, Hitachi, Japan (guest of Howard Franklin)
Terry Graumann, Otter Tail Power Company, Fergus Falls, MN
Flemming Hansen, Haldor Topsoe, Inc., Houston, TX (unavailable)
Tom Hastings, Cormetech, Inc., Durham, NC
Zia Karim, Dynegy Midwest Generation, Baldwin, IL
Susan Maley, U.S. DOE National Energy Technology Laboratory, Morgantown, WV (by phone)
Rene Mangal, Kinectrics, Inc., Toronto, Ontario, Canada
Harvey Ness, Lignite Research Council; Industrial Commission of North Dakota, Bismarck, ND (unavailable)
Dave O'Connor, EPRI, Palo Alto, CA (unavailable)
Blair Seckington, Ontario Power Generation, Toronto, Ontario, Canada
Kenneth Stuckmeyer, Ameren Union Electric, St. Louis, MO
Edmundo Vasquez, Alliant Energy/RMT, Madison, WI (by Net Conference)

Purpose

Annual Sponsors Meeting for the "Evaluation of Potential SCR Catalyst Blinding During Coal Combustion" Project

TIME	ACTIVITY	PRESENTER(S)
8:30 a.m.	Welcome/Introductions	Gerald Groenewold Tom Erickson
9:00 a.m.	Project Background and Overview	Steve Benson
9:30 a.m.	Accomplishments: ❖ Task 1 – Identification of Test Coals, Utility Host Sites, and Final Work Plan ❖ Task 2 – Bench-Scale Testing and Screening	 Steve Benson Steve Benson
10:30 a.m.	BREAK	
10:45 a.m.	❖ Task 3 – Design and Construction of SCR Slipstream Test Chamber ❖ Task 4 – SCR Test Chamber Installation and Data Collection at Utility Host Sites	Jason Laumb Jason Laumb Bob Jensen
12:00 noon	LUNCH *[Second-Floor Lunchroom]*	
1:00 p.m.	❖ Task 5 – Determination of SCR Blinding Mechanisms ❖ Task 6 – Final Interpretation, Recommendations, and Reporting	Steve Benson Steve Benson
	Future Directions	Steve Benson
	Tour	Steve Benson
3:15 p.m.	Depart for Airport	

EERC Contact Person: Connie Wixo, 701.777.5161

Distribution:
Gerald Groenewold, Director
Tom Erickson, Associate Director for Research
Steve Benson, Senior Research Manager
Jason Laumb, Research Manager
Jay Gunderson, Research Engineer
Bob Jensen, Research Associate
Jill Zola, Research Specialist
Bruce Folkedahl, Research Manager
Lindsay Dvorak, Research Technician

FYI:
Everett Sondreal, Principal Research Advisor
Deb Haley, Associate Director, Marketing, Outreach, and Administrative Resources
John Harju, Associate Director for Research
John Hendrikson, Associate Director, Business and Operations
Michael Jones, Associate Director, Industrial Relations and Technology Commercialization

c: Linda Quamme, Administrative Assistant
Patti Reimer, Administrative Assistant
Front Desk

EERC
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Evaluation of Potential SCR Catalyst Blinding During Coal Combustion

Project Review Meeting
May 13, 2003

Meeting Agenda

• Introductions	GHG, TAE
• Project Overview and Background	SAB
• Accomplishments	
– Task 1 – Identification of Test Coals, Utility Host Sites, and Final Work Plan	SAB
– Task 2 – Bench-Scale Testing and Screening	SAB
– Task 3 – Design and Construction of SCR Slipstream Test Chamber	JL
– Task 4 – SCR Test Chamber Installation and Data Collection at Utility Host Sites	JL/RJ
– Task 5 – Determination of SCR Blinding Mechanisms	JL
– Task 6 – Final Interpretation, Recommendations, & Reporting	SAB
• Future Directions	SAB
• Tour	SAB
• Leave for airport – etc.	

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Presentation Overview

- Background Information
- Project Goals and Objectives
- Task Structure
- Accomplishments
- Future Directions

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Background

- High levels of alkali and alkaline-earth elements present in low-rank coals fired are prone to form sulfates that can blind the catalyst.
- Sulfate formation is also enhanced by the presence of an SCR catalyst; this has the potential to accelerate the sulfation reactions, causing blinding of the catalyst.
- The high levels of sodium in lignites coals combined with calcium can produce low-melting-point eutectic compounds that will melt on the surface.

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Background (continued)

- German experience – the ash components found to impact SCR performance in European installations include alkali and alkaline-earth elements that result in sulfate formation.
- The total calcium content and the sum of the calcium, magnesium, potassium, and sodium were used in Europe to provide an indication of the problems that occur.
- The levels of calcium in U.S. low-rank coals are 2 to 4 times higher than the problematic coals in Europe where SCR blinding has been reported.
- The sum of the alkali and alkaline-earth elements is at least twice the levels found to be problematic in the European experience.

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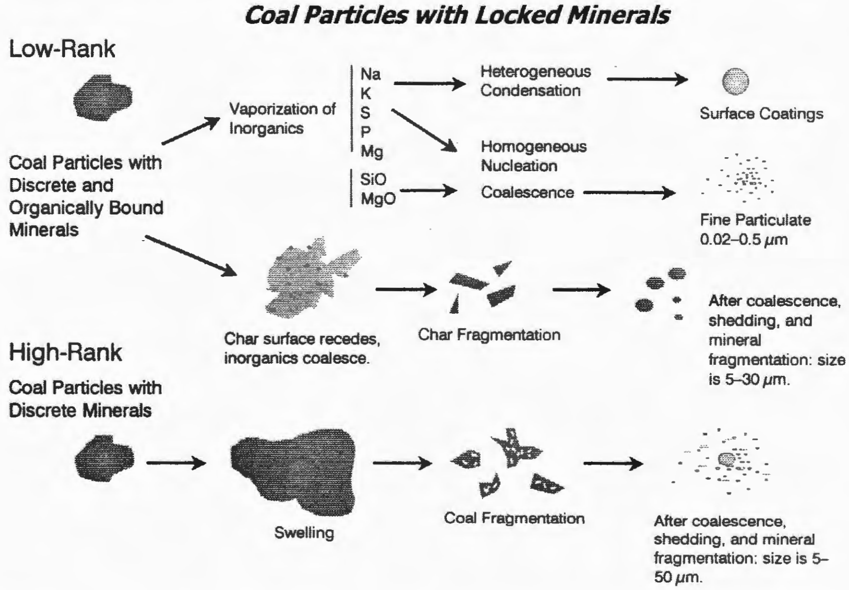
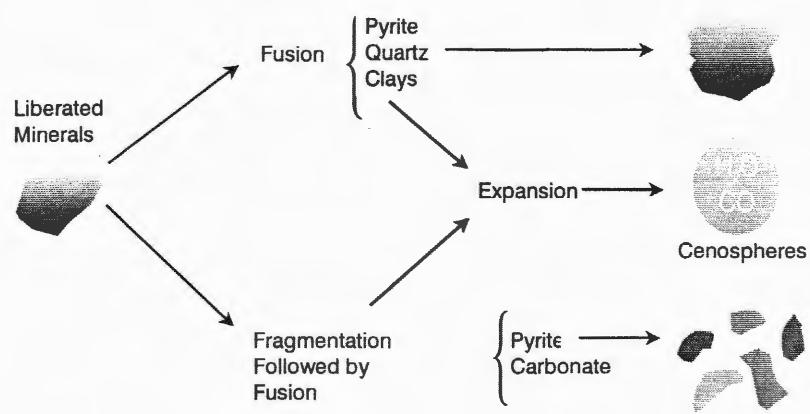
Mechanisms for Fly Ash Formation During Combustion

Coal Particles with Locked Minerals

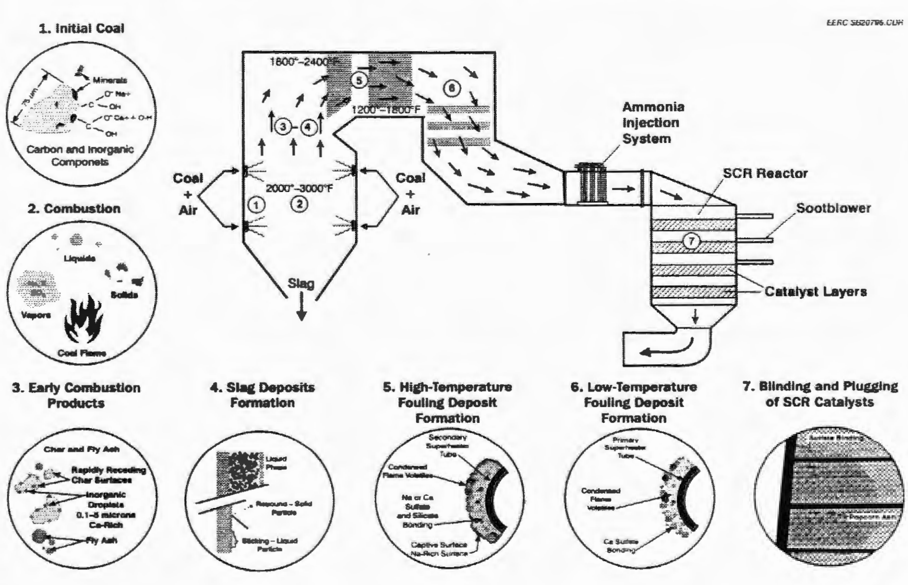


Mechanisms for Fly Ash Formation During Combustion

Liberated Minerals



Background – Ash-Related Issues



Justification

- Utilities, SCR vendors, and regulating agencies need sound scientific information on SCR performance for low-rank coals.
  - Knowledge of blinding mechanisms is critical.
- Potential to challenge EPA or other state rulings (i.e., SCR may not be "best" system for control due to blinding or poisoning issues).
- SCR may convert mercury to a form more likely to be captured – initiating new project to examine the oxidation of mercury.

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Objectives

- Determine potential for low-rank coal ash to cause blinding of selective catalytic reduction (SCR) catalysts.
- Determine mechanisms of SCR blinding.

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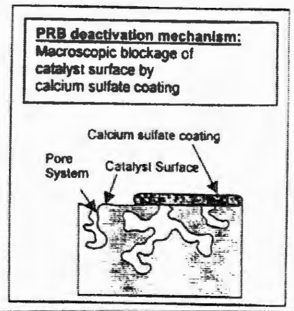
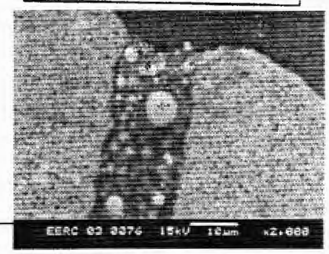
Issues Involving Low-Rank Coals and SCR

- Research by Germans, Cormetech, EPRI, and other utilities showed that physical blinding is caused by alkali sulfates (Na, K, Ca).
- Siemens work ASME IJPGC (2000) describes small calcium sulfate crystals/particles blocking catalyst pores with 50% catalyst deactivation after 3000 hours for PRB coal.





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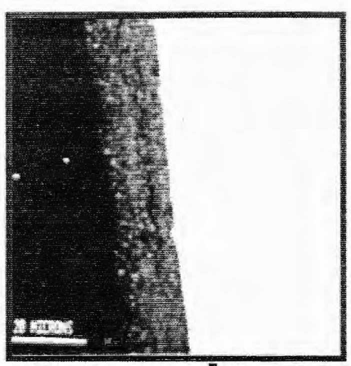
Issues Involving Low-Rank Coals and SCR

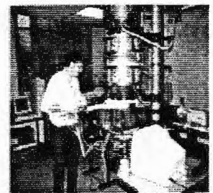
Fine particulate deposits at low temperature (full-scale boiler)

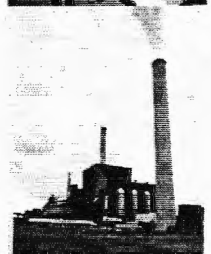


Ca-sulfate-rich deposit, particles <3 μm | Steel deposition probe

- Fine particle production more prevalent with North Dakota lignite and Powder River Basin (PRB) coal-type lower-rank coals compared to bituminous coals.
- PRB and lignites produce large concentrations of reactive Ca (for sulfation).
- Catalytic activity of metals in SCR may enhance deposition (sulfation).
- Certain phosphate compounds are stable in SCR regime.

Project Work Plan





- Task 1 – Identification of Test Coals, Utility Host Sites, and Final Work Plan
- Task 2 – Bench-Scale Testing and Screening
- Task 3 – Design and Construction of SCR Slipstream Test Chamber
- Task 4 – SCR Test Chamber Installation and Data Collection at Utility Host Sites
- Task 5 – Determination of SCR Blinding Mechanisms
- Task 6 – Final Interpretation, Recommendations, and Reporting

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Deliverables

- Utilities gain mechanistic information on SCR catalyst blinding to aid in:
  - Identifying NO_x control technology best for low-rank coals.
  - Selection of SCR vendors.
  - Negotiating guarantees on SCR performance.
- Additional scientific data to challenge EPA.
- SCR industry improves its products for low-rank coals.
- Continued positive promotion of North Dakota lignite.

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Project Participants

- Electric Utilities:
  - Ontario Power Technologies – Kinectrics
  - Otter Tail Power Company
  - Alliant Energy
  - AmerenUE
- EPRI
- North Dakota Industrial Commission
- U.S. Department of Energy – National Energy Technology Laboratory
- Catalyst Vendors: Hitachi, Haldor-Topsoe, Cormetech

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Project Personnel

- Manager: Steve Benson
- Principal Investigator: Jason Laumb
- Key Technical Staff: Jay Gunderson, Bob Jensen, Jill Zola, and Nathan Kadrmas
- Administrative: Connie Wixo

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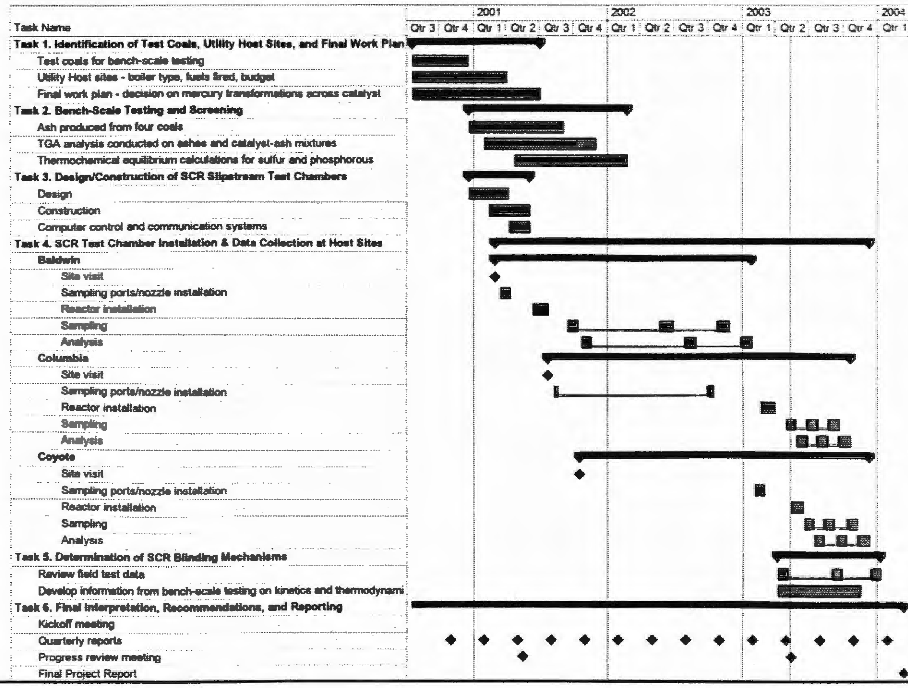
Schedule



Task 1 – Identification of Test Coals, Utility Host Sites, and Final Work Plan

- Task 1 – Identification of Test Coals, Utility Host Sites, and Final Work Plan
  - Test coals for bench-scale testing – range of calcium, phosphorus contents, represents sponsor's/field test coals
  - Utility host sites – boiler type, fuels fired, budget

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Task 1 – Selection of Test Coals

- Coals Selected for Bench-Scale Testing
  - Beulah
  - Antelope
  - Antelope/Rend Lake blend
  - PRB(various)/low-sulfur bituminous blend
  - North Rochelle
  - Caballo ??

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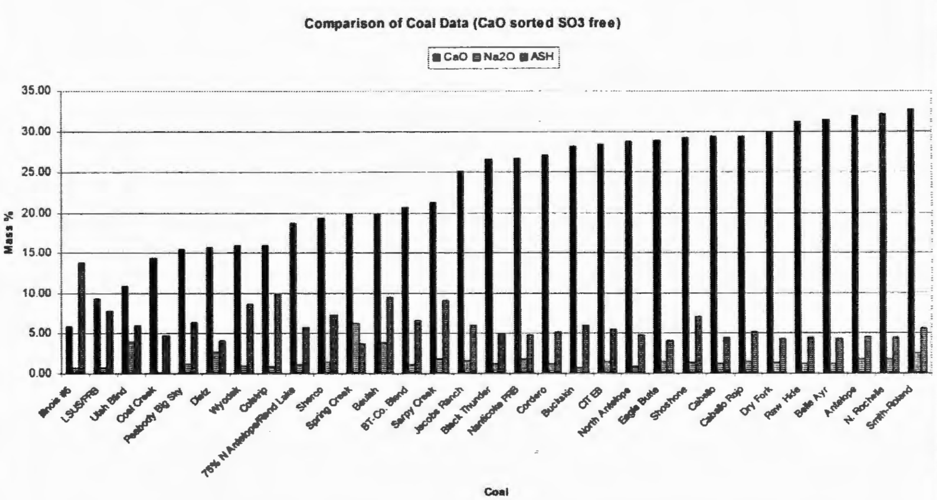
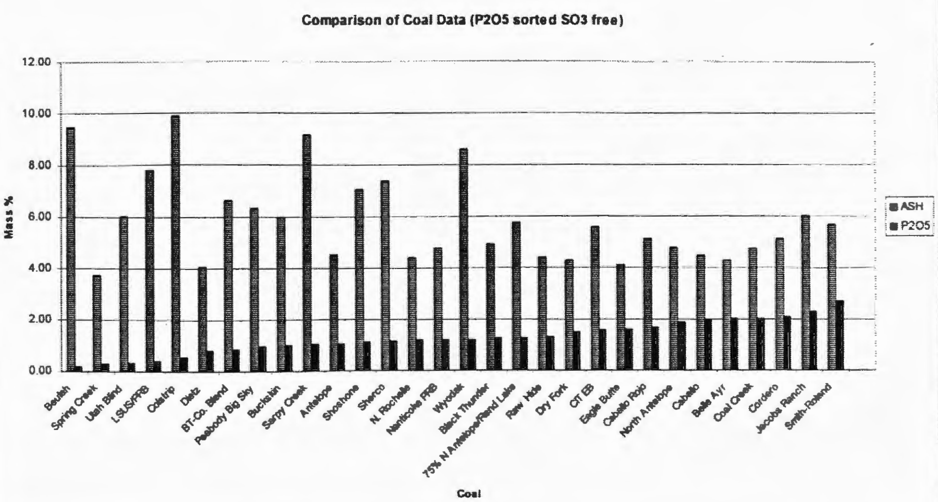
Fuels Analysis



Fuels Analysis



Task 1 (continued) – Utility Host Selection

Prioritized picks for test sites for the SCR Blinding project

Field Test #1 – Columbia

– P.C.-fired which may be important for partitioning differences compared to cyclone
– High potential blinding coal in Caballo, which can be burned nearly 100% for the entire test
– Good fit operationally, we've tested their before an know the unit; NH4, hookups, electrical, plant personnel assi
– Proximity; 1200 miles with only 16-20 hours travel time round trip (pulling a trailer).

Field Test #2 – Baldwin Plant

– cyclone fired
– Units already are equipped to do slip stream testing
– Plant currently fires a blend of antelope and tires – plant is willing to fire 100%
– Good high potential blinding coal in Antelope, which should run moderately close to 100%
– Good fit operationally with codes, hookups, Plant personnel assistance, NH4, etc.
– Proximity: 2100 miles with 60-70 travel hours round trip (just southeast of St. Louis about 30 miles).

Field Test #3 – Coyote

– cyclone fired
– High potential blinding with high alkali (Ca-Na-Mg), plus fairly high S.
– Excellent fit operationally with exact numbers on piping, etc.; all hookups, electrical, NH4, codes, plant personr
– Experience working there before.
– Very close proximity: 500 miles and 8-10 hours travel time round trip.
– the cheapest to do, which means if we run into problems like cost overruns on the other field tests, we can no d

Task 2 – Bench-Scale Testing and Screening

- Ash produced from 4 coals.
- TGA analysis conducted on ashes and catalyst/ash mixtures.
- Thermochemical equilibrium calculations conducted for sulfur and phosphorus containing species.

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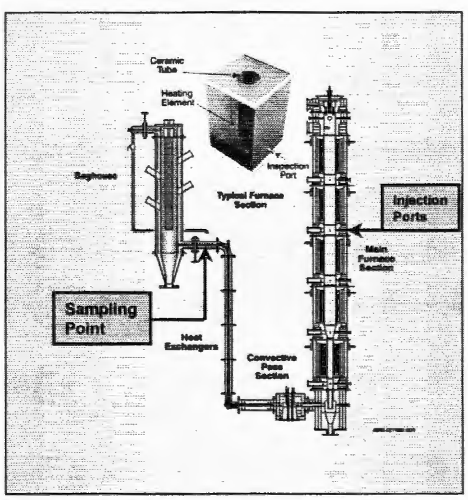
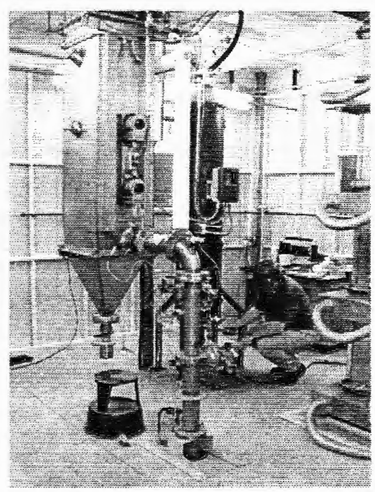
Conversion and Environmental Process Simulator





4.4 lb/hr (2 kg/hr) pf and 40,000 Btu/hr
8 scfm flue gas flow
Refractory lined
ESP, baghouse, and cyclone

Preheat air – 950°C
Main furnace flue gas – <1600°C
Convective section – 760°–1200°C
Gas-sampling location – 250°C

TGA Testing

- Isothermal testing to develop reaction rate as a function of temperature
  - This testing will provide key information on the rate of blinding that will occur as a function of temperature and gas composition.
  - 74% N_2
  - 8% H_2O
  - 14% CO_2
  - 4% O_2
  - 100–300 ppm NH_3
  - 0.04% SO_2
  - 1–1000 ppm P

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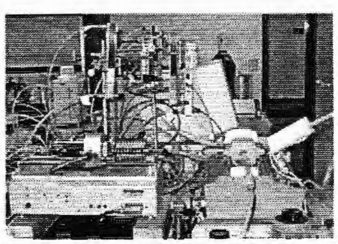
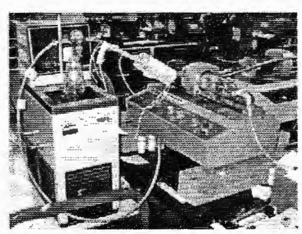
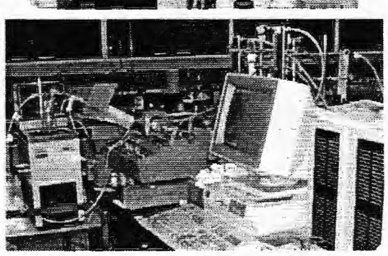
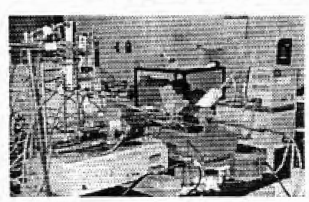
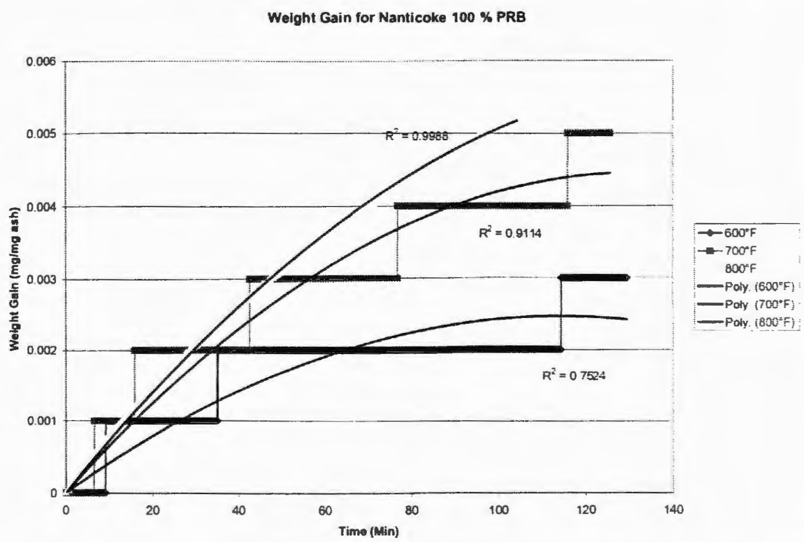
TGA System

Weight Gain Curves – Baseline



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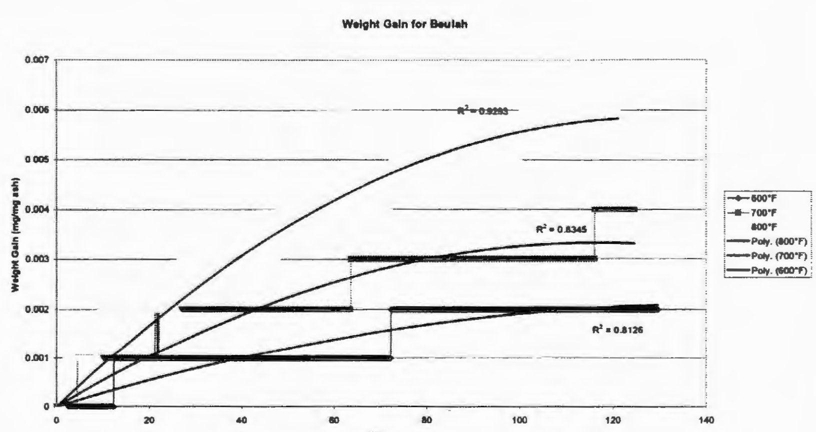
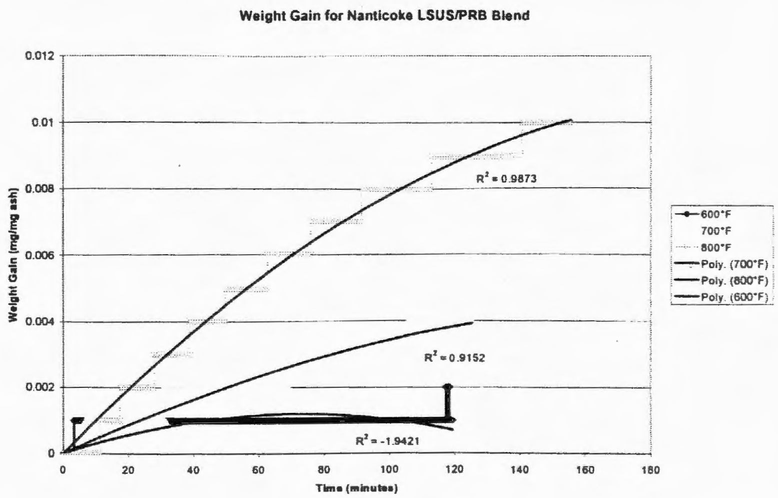
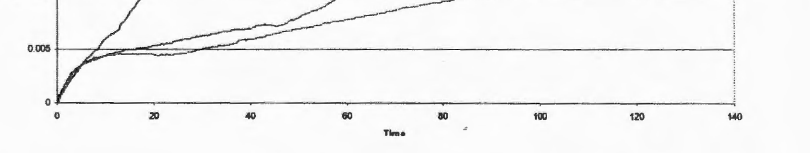


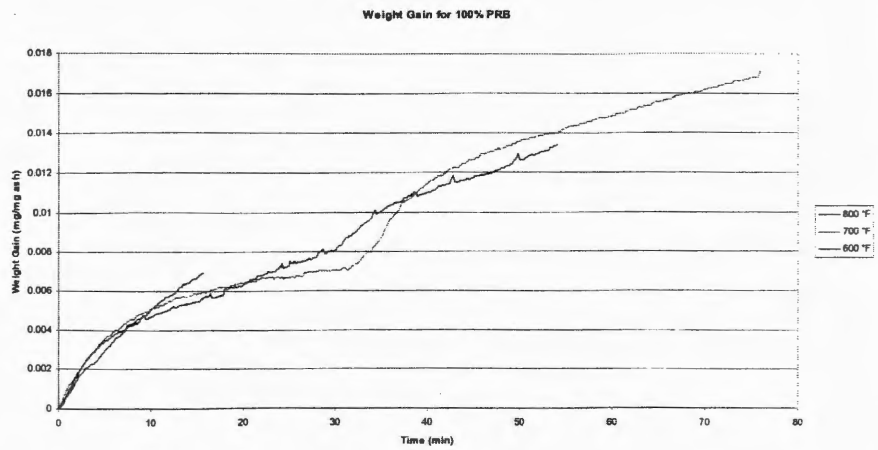
Weight Gain Curves – Baseline



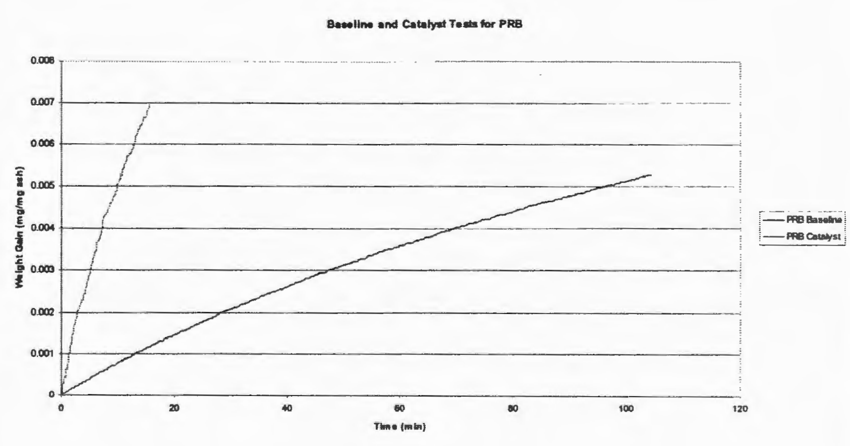
Weight Gain Curves – With NH_3, P



Weight Gain Curves – With NH_3, P



Catalyst Tests – Comparisons



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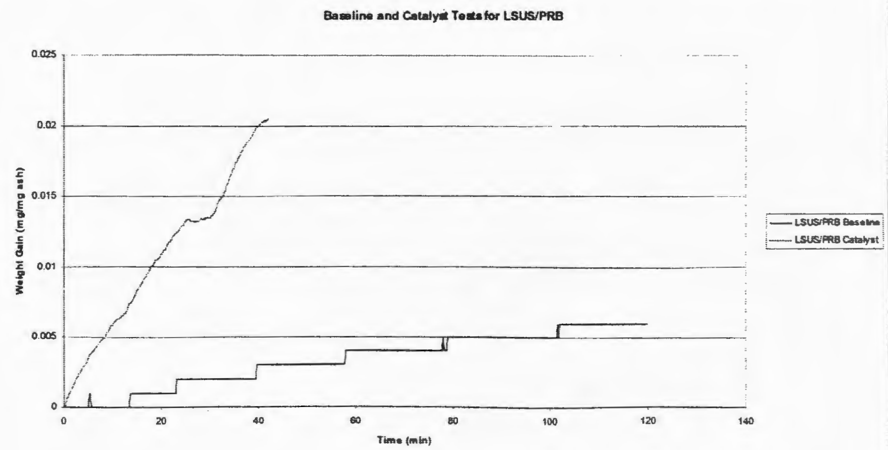
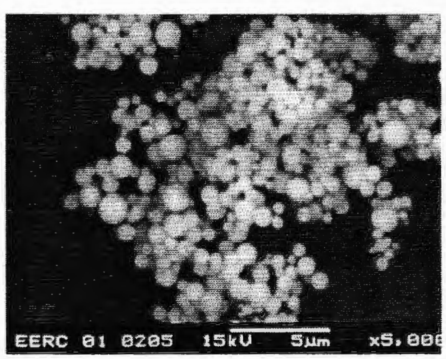


Characterization of Reaction Products, 100% PRB



100 % PRB 800°F		
Element	Percent	
Na	0.50	0.00
Mg	5.60	5.00
Al	9.22	11.30
Si	9.00	8.30
P	1.80	1.30
S	0.70	2.10
Cl	0.00	0.00
K	0.30	0.00
Ca	32.40	31.00
Ti	0.00	1.40
Cr	0.00	0.00
Fe	11.60	7.70
Ba	1.50	1.10
O	27.00	30.60

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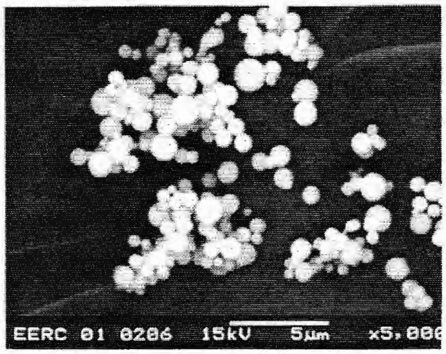
Characterization of Reaction Products, LSUS/PRB



LSUS/PRB 800°F		
Element	Percent	
Na	0.40	0.50
Mg	2.10	3.10
Al	15.90	12.60
Si	14.50	21.80
P	2.00	4.00
S	1.00	0.00
Cl	0.10	0.00
K	1.70	1.00
Ca	20.00	10.60
Ti	0.90	3.00
Cr	0.00	0.00
Fe	4.90	5.60
Ba	0.00	1.00
O	36.40	36.50

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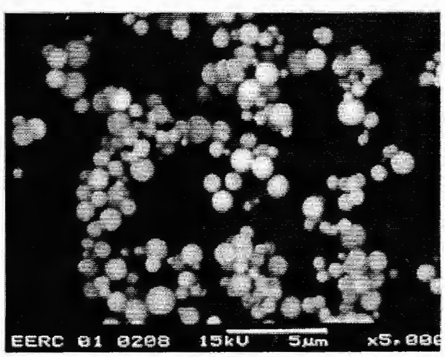
Characterization of Reaction Products, Beulah



Beulah 800°F		
Element	Percent	
Na	1.60	1.00
Mg	4.00	5.30
Al	7.10	9.00
Si	22.70	18.10
P	0.00	0.00
S	1.60	2.80
Cl	0.00	0.00
K	1.40	0.50
Ca	17.10	25.00
Ti	0.00	1.50
Cr	0.10	0.00
Fe	5.40	4.00
Ba	5.90	4.60
O	33.00	28.00

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FACT Calculations

- Operating principle
  - Based on minimization of Gibb's free energy.
  - Predicts gas, liquid, and solid species as a function of temperature.
- Limitations
  - Complete equilibrium is assumed.
  - Only considers species in database.
  - Each calculation is independent of the others.

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FACT Calculations – Conditions

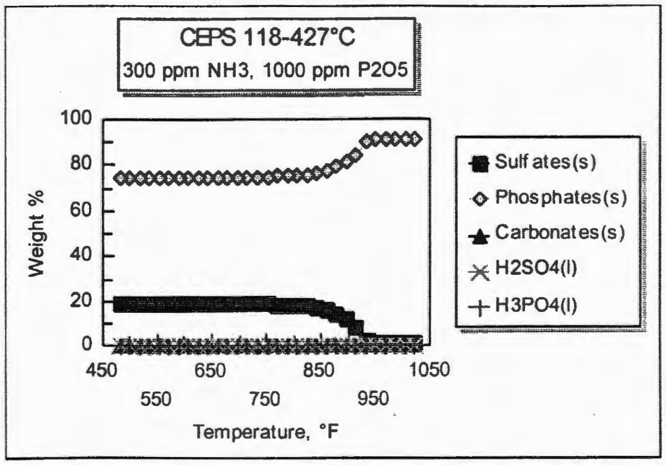
Gas Composition, %

N_2	74.00
O_2	4.00
CO_2	14.00
H_2O	8.00
SO_2	0.04
NH_3	100, 300 ppm
P_2O_5	1, 1000 ppm

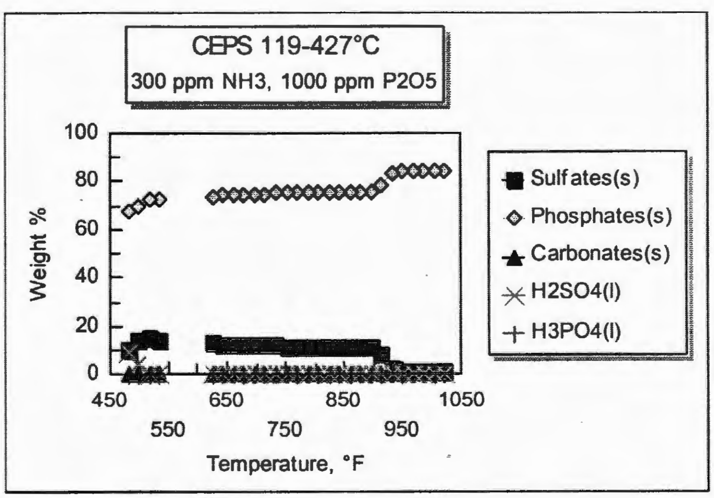
Particle Loading
1.5 grains/scf (3.4 g/m³)

Temperature: 1022°–482°F

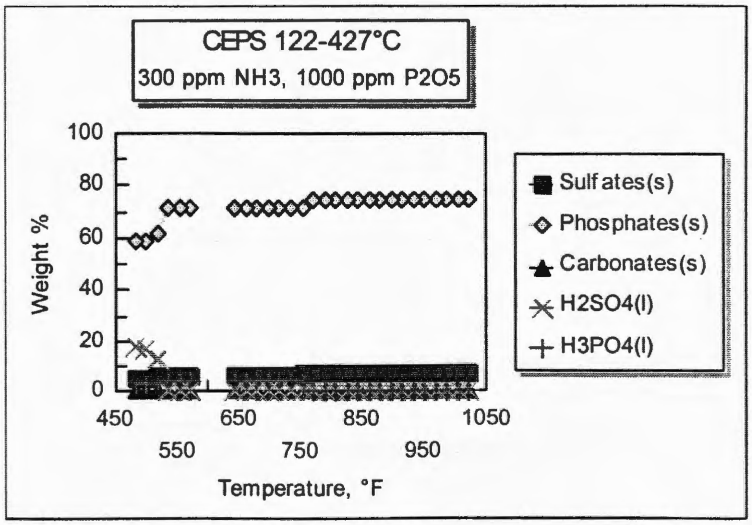
FACT Calculations



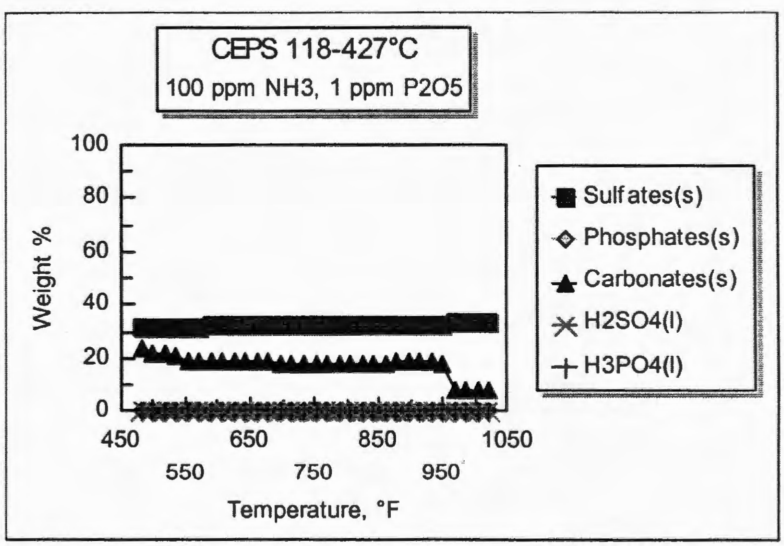
FACT Calculations



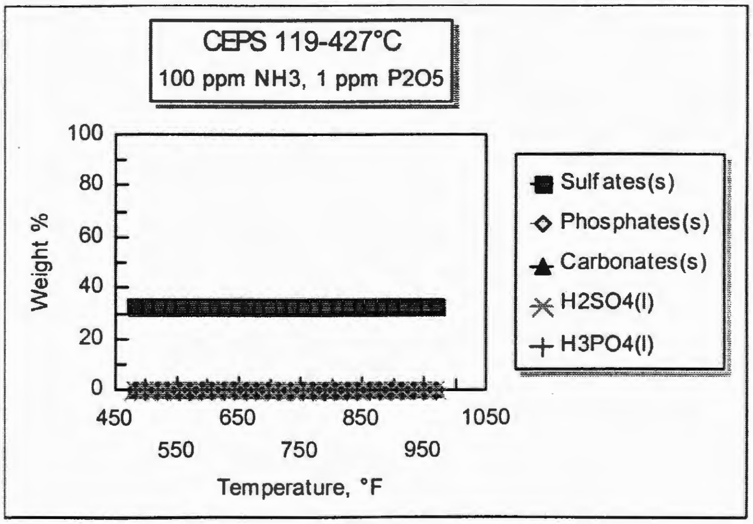
FACT Calculations



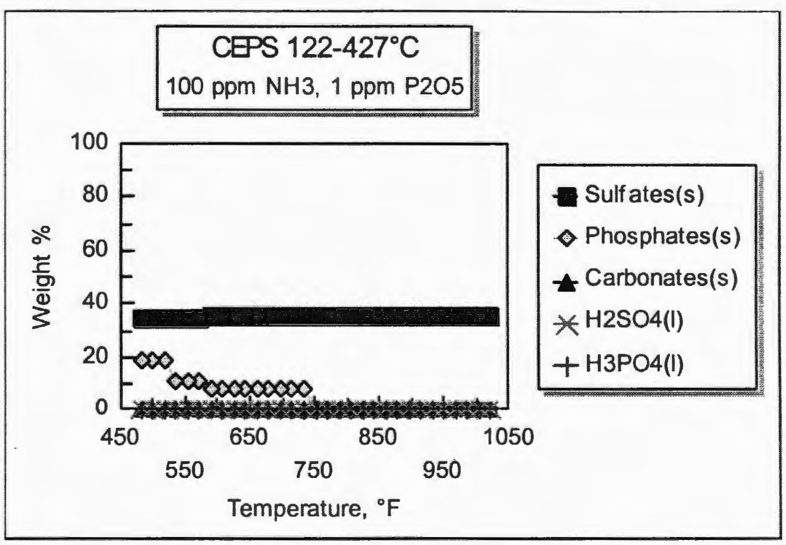
FACT Calculations



FACT Calculations



FACT Calculations



Conclusions

- PRB and lignite coals have the potential to blind SCR catalysts.
- The addition of ammonia, phosphorus, and catalyst enhances the formation of phosphates and sulfates.
- A high blinding potential exists for LSUS/PRB blends.

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Conclusions (continued)

- FACT modeling also predicts the formation of sulfates and phosphates as well as carbonates.
- Morphology analysis of exposed fly ash shows sulfates and phosphates are present.

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Task 3:

Design and Construction of SCR Slipstream Test Chamber

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Task 3: Design and Construction of Slipstream Reactor

- Goals and objectives
- Overview of slipstream SCR test system
- Reactor design
- Operating conditions
- Control scheme
- Sampling methodology
- Plant requirements
- Site visits

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Goals and Objectives

- Determine potential for low-rank coal ash to cause blinding of selective catalytic reduction (SCR) catalysts.
- Determine mechanisms of SCR blinding through testing at full-scale installations.
- Portable design with modular components.
- Maintain consistent operating conditions.
- Minimal plant personnel requirements.
- Off-site monitoring and control w/remote access.

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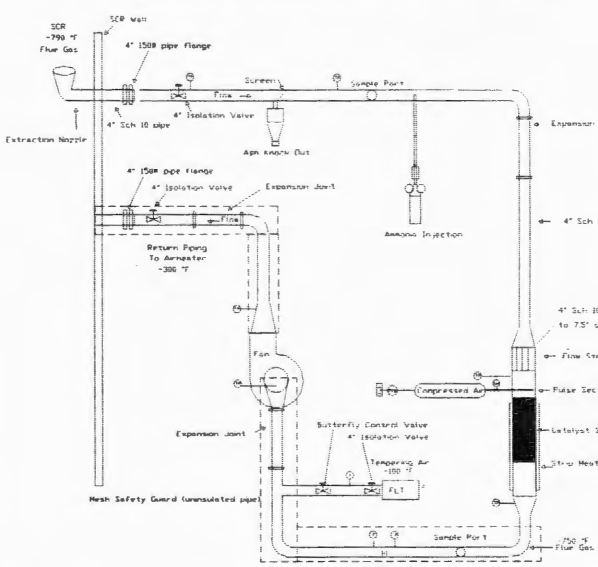
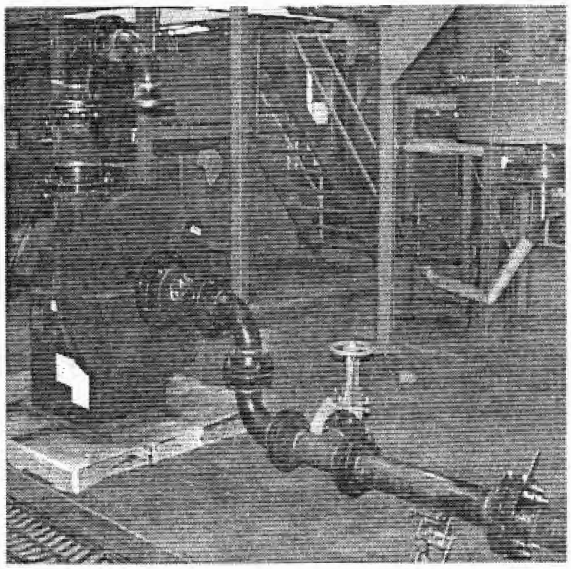
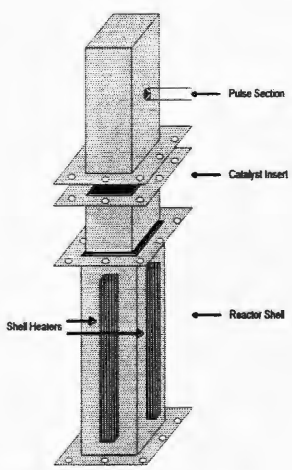
Conceptual Drawing



Induced Draft Fan



Reactor Design



- Transition from 4" pipe to ~7.5" square
- Flow conditioner: 16-gauge c.s. (4x4 matrix by 12" length)
- Pulse cleaning of catalyst surface
- Catalyst supported between flanges
- Reactor shell: ~8.5' square 10-gauge c.s. plate
  - Strip heaters for start-up/shutdown
- On-line measurements
  - Temperature at inlet and exit
  - Catalyst dP
  - Flow rate (calculated face velocity)
- Insulated to minimize heat loss

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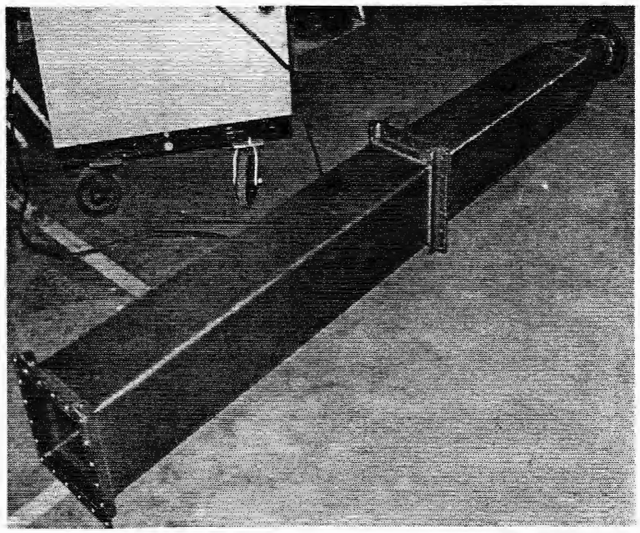
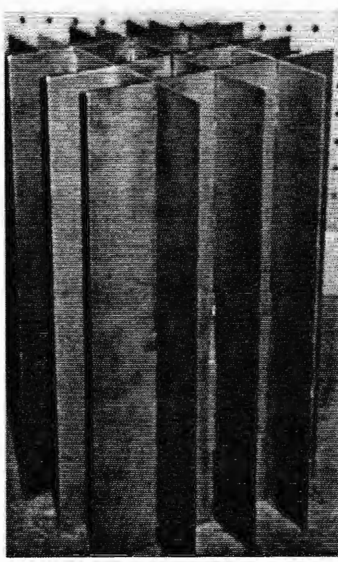
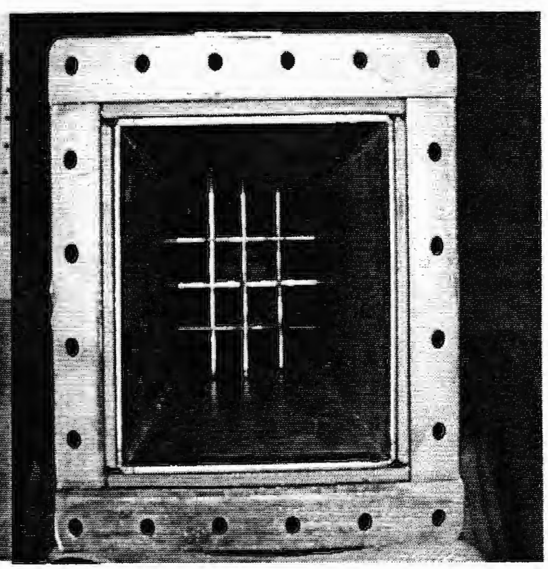
Transition and Reactor Shell



Flow Conditioner





Operating Conditions

- Gas temperature ~ 700°–800°F
- Gas flow rate – 400–500 acfm
- Approach velocity range: 5.0–5.5 m/sec
- Ammonia injection rate – 0.5:1 with NO_x level
- Tempering air for fan ~ 150–200 scfm
- Catalyst dP 0.5–1.0 inches water column
- Fan sized for up to –30 inches water column

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Control Scheme

- Isokinetic sampling
- Orifice meter for flow measurement
- VFD to control flow rate through reactor
- Tempering air to protect fan <350 °F
- Data acquisition – LabTech software
- Heaters to maintain reactor temperature above dew point during start-up and shutdown
- Periodic (as needed) cleaning of catalyst surface by air pulse

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Control Room

- Modular design
  - Compact (crammed tight)
  - Controlled environment
    - ♦ Air-conditioned space
    - ♦ Dust/water protection
  - Detachable walls
  - Lifting supports
  - Wheels
  - Skid-mounted
- 480-V, 3-phase power for fan
- 240-V electrical supply
  - Breaker panel
- Pressure transmitters
  - Orifice meter
  - Catalyst dP
  - System pressure
- Ammonia injection control system
- Data acquisition hardware and software
  - Fan speed, heaters, cleaning, and tempering air controls
  - UPS

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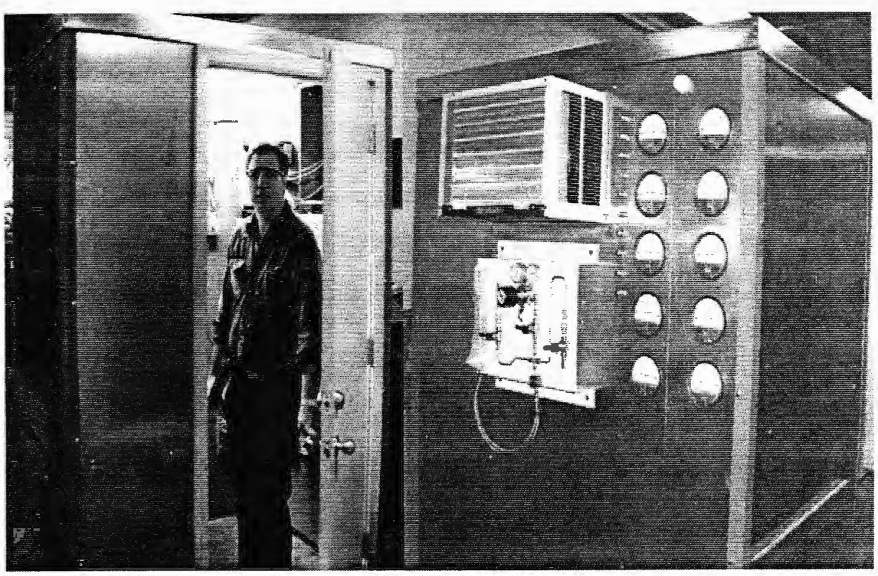
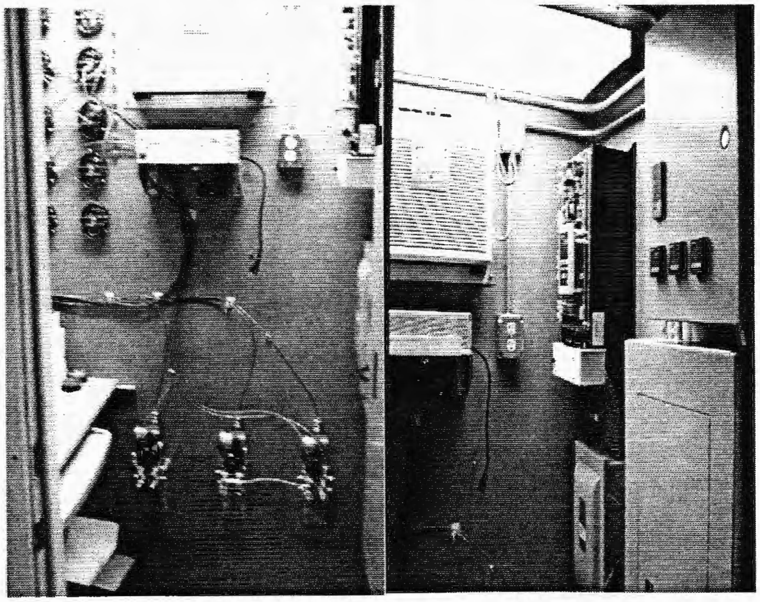
Control Room



Control Room



Sampling Methodology

- Initial reactivity testing of catalyst
- Catalyst samples taken at 2, 4, and 6 months duration
- Analyses:
  - Morphology – scanning electron microscopy and x-ray microanalysis
    - Images
    - Area and point analyses to determine bonding mechanisms
  - Reactivity testing: catalyst vendor
- On-site sampling
  - SASS train at reactor inlet for size distribution and composition of entrained ash
  - Direct comparison with bench-scale results

Plant Requirements

- T1/DSL line for remote access
- 60 amps, 480-V, 3-phase power for fan
- 60 amps, 240-V, 60 hertz, single-phase power to control room
- Electrician to provide hookup to control room
- Crane/elevator access to sampling area
- Compressed air for control valve and pulse
- Welder for system supports and field fitting
- 5" inlet port w/150# flange, 4" flanged exhaust port
- Personnel to check system daily
  - Ammonia tank monitoring (changing when empty)
  - System dPs
  - System isolation during outage

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Task 4:

SCR Test Chamber Installation and Data Collection at Utility Host

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SCR Test Chamber Installation and Data Collection at Utility Host

- Review reactor installations
- Baldwin
  - Reactor conditions
  - Chemical analysis
- Columbia
  - Reactor conditions
  - Chemical analysis
- Work with Sargent and Lundy
- Conclusions
- Acknowledgements

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SCR Reactor Installations

- Cyclone-fired boiler burning PRB (Baldwin Station) – Testing completed (6 months). Awaiting reactivity results for months 4 and 6 from the catalyst vendor.
- PC-fired boiler burning PRB (Columbia Station) – Reactor installed and operating. Logged over 800 hours of time.
- Cyclone-fired burning lignite (Coyote Station) – Reactor to be installed in June. Plant is in an outage until then.

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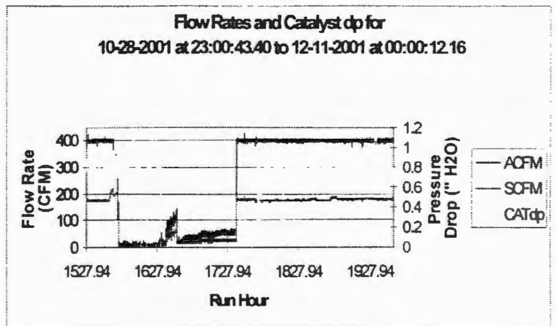
SCR Reactor Flows at Baldwin (2-Month)

- The testing has been completed on a cyclone-fired boiler burning a PRB coal.
- An increase in pressure drop across the reactor has been observed as the testing progressed. Sootblowing cycles were adjusted and the dp stabilized.



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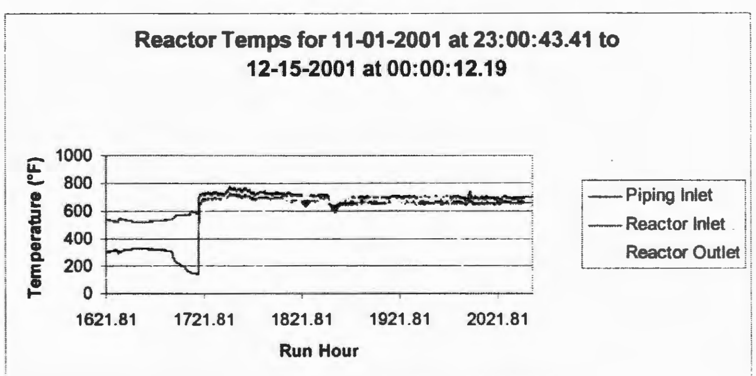
SCR Reactor Temperatures (2 Month)



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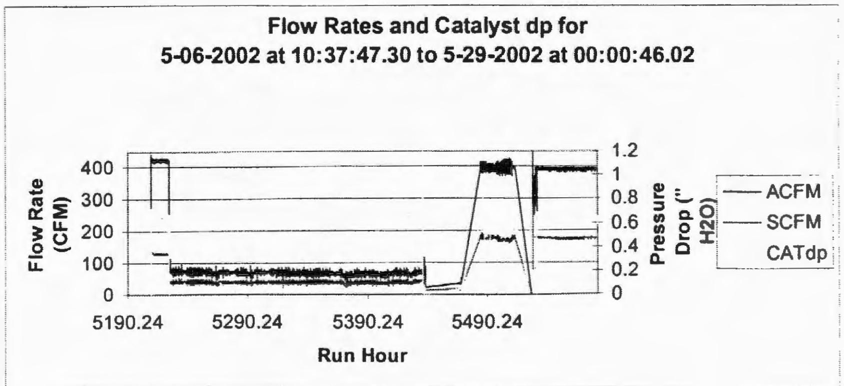
SCR Reactor Flows at Baldwin (4 Month)



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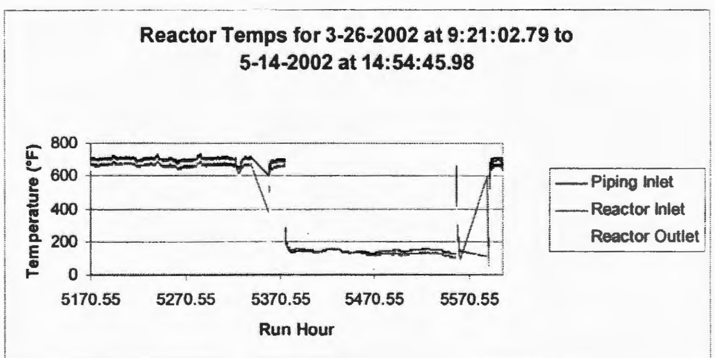
SCR Reactor Temperatures (4 Month)



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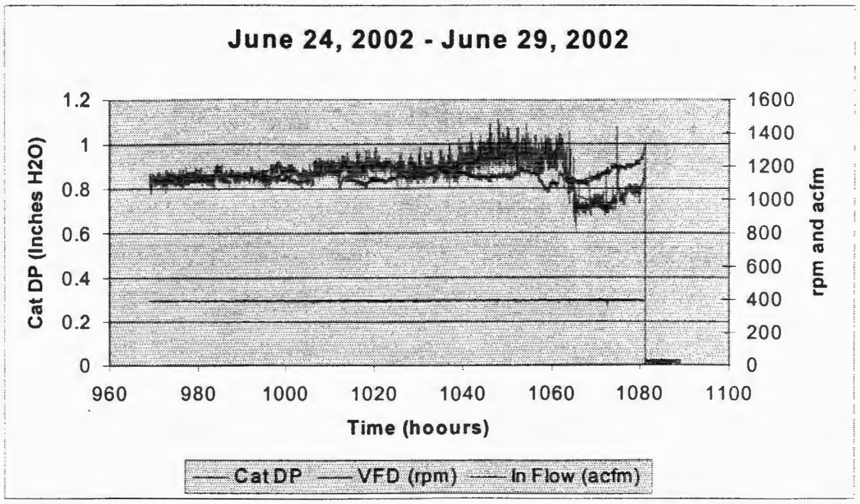
Baldwin SCR Reactor



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Baldwin SCR Reactor

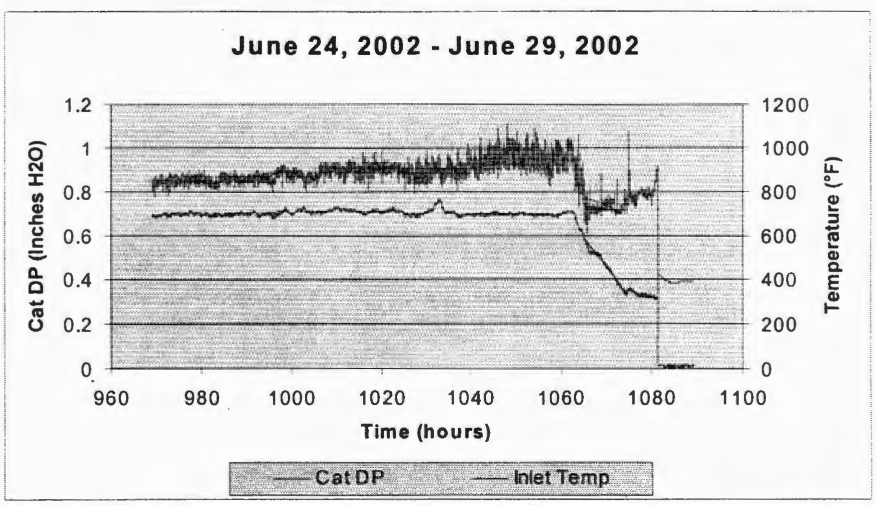

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Photo of Top of Catalyst Section (2 Month)

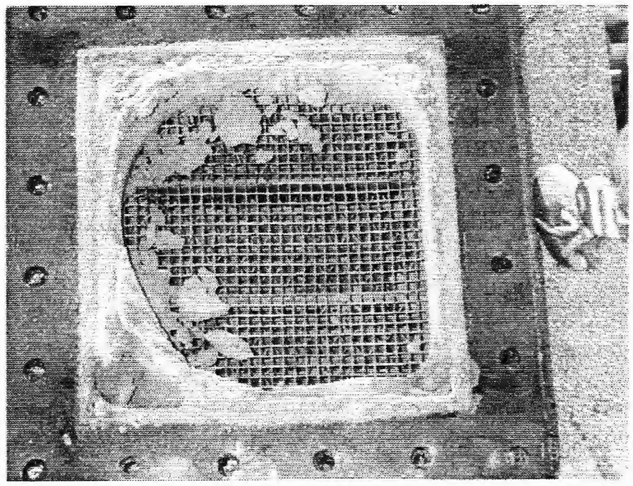
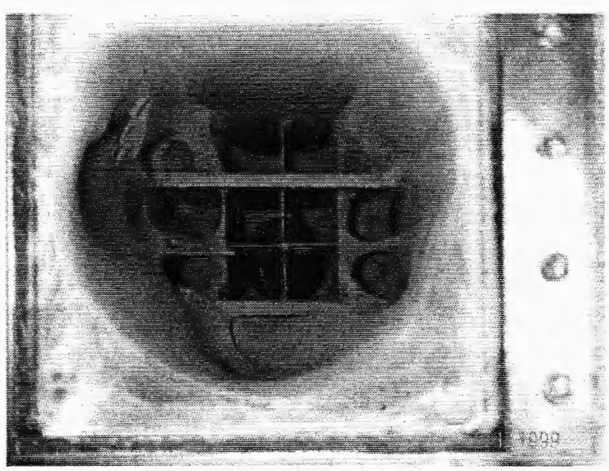
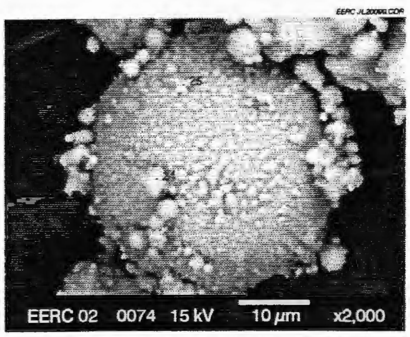


Photo of Flow Straightener – Look Up 2 Month



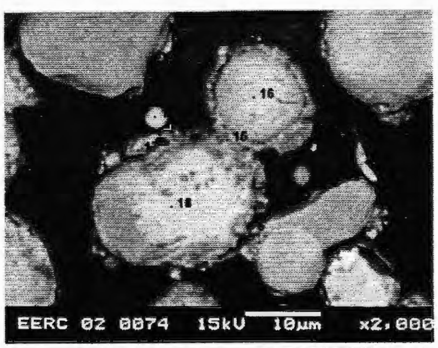
Chemical Analysis Results (2 Month)



- Small beads of calcium sulfate-rich material can be found on the surface of the fly ash particles after two months.
- The presence of calcium sulfate was confirmed by x-ray diffraction analysis.

Point	Na (wt %)	Mg (wt %)	Al (wt %)	Si (wt %)	P (wt %)	S (wt %)	Cl (wt %)	K (wt %)	Ca (wt %)	Fe (wt %)	O (wt %)
24	2.63	2.57	6.29	2.23	1.13	29.37	0.27	0.46	16.59	12.22	23.99
25	2.91	1.03	3.86	32.81	0.00	9.57	0.04	0.57	13.74	3.51	30.85
26	3.22	1.20	2.84	8.89	0.79	25.49	0.00	0.66	11.27	6.04	38.30

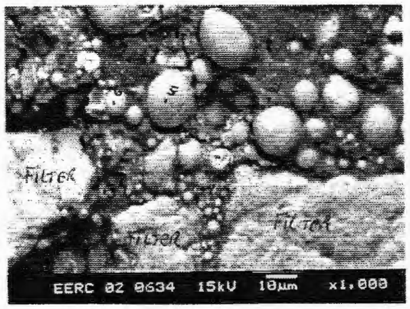
Chemical Analysis Results (2 Month)



- Calcium sulfate can be found at or near the catalyst surface, as evidenced by point 17.

Point	Na (wt %)	Mg (wt %)	Al (wt %)	Si (wt %)	P (wt %)	S (wt %)	Cl (wt %)	K (wt %)	Ca (wt %)	Fe (wt %)	O (wt %)
15	0.69	1.96	3.76	2.10	0.18	27.84	0.19	0.20	26.97	5.21	30.70
16	0.49	3.23	14.36	9.00	0.24	0.02	0.10	0.00	35.56	11.94	23.39
17	1.56	2.35	8.42	0.59	1.29	24.30	0.36	0.09	25.29	5.91	27.12
18	0.31	2.52	12.99	4.42	0.00	0.00	0.00	0.00	42.38	12.68	20.63
19	0.81	2.54	9.08	1.31	2.46	9.55	0.97	0.04	34.00	13.20	23.21

Chemical Analysis Results (4 Month)



- Calcium sulfate can now be found in the pores of the catalyst surface.

Point	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	Cr	Fe	Ba	O
1	1.73	4.79	2.63	6.10	1.80	25.92	1.37	0.51	21.12	1.43	0.63	1.96	1.73	28.27
2	2.03	2.16	1.56	17.46	1.38	14.69	3.77	0.69	7.48	7.69	0.00	5.48	0.00	35.59
3	1.07	nd	0.85	11.42	1.27	5.67	7.31	0.00	2.15	31.21	0.00	nd	nd	34.15
4	nd	1.09	2.51	8.96	0.53	20.74	0.78	nd	39.32	3.58	0.00	3.43	0.00	18.49
5	0.28	1.38	3.84	41.41	nd	nd	0.30	1.54	12.60	1.24	0.00	3.76	0.99	32.17
6	0.89	2.69	3.96	10.28	1.37	15.28	4.79	nd	12.46	10.74	0.00	4.94	nd	30.75

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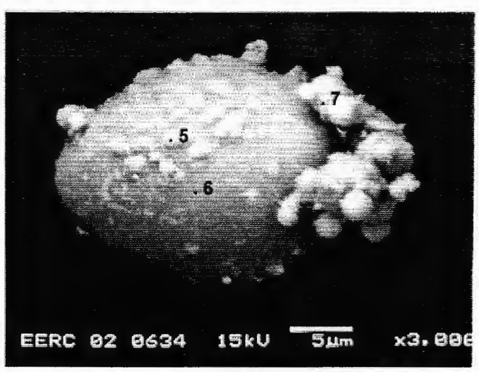
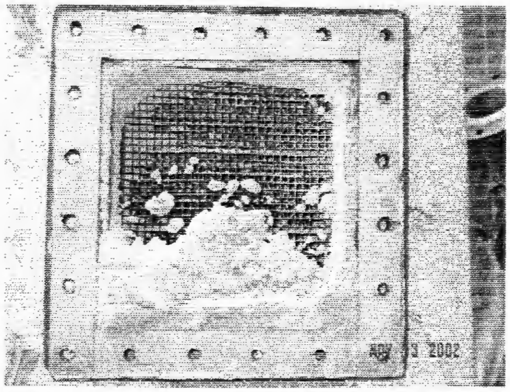
Chemical Analysis Results (4 Month) (continued)



- Calcium sulfate deposition is similar to the 2-month sample.

Point	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	Cr	Fe	Ba	O
5	5.80	1.21	1.24	40.50	0.00	2.43	0.00	0.50	6.96	nd	0.00	3.79	nd	36.67
6	1.10	1.03	0.23	51.68	0.00	nd	nd	0.72	3.35	nd	nd	2.59	0.00	38.73
7	11.02	2.18	4.22	1.34	0.71	21.40	0.34	nd	10.66	1.05	0.00	3.00	nd	43.22

Photo of Top of Catalyst Section (4 Month)



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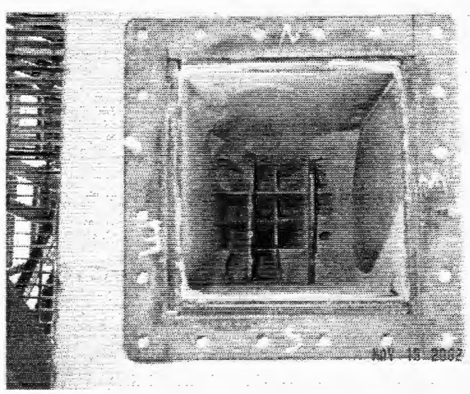
Flow Straightener



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Flow Straightener (continued)

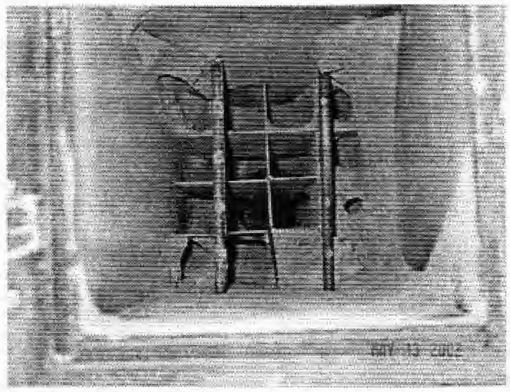

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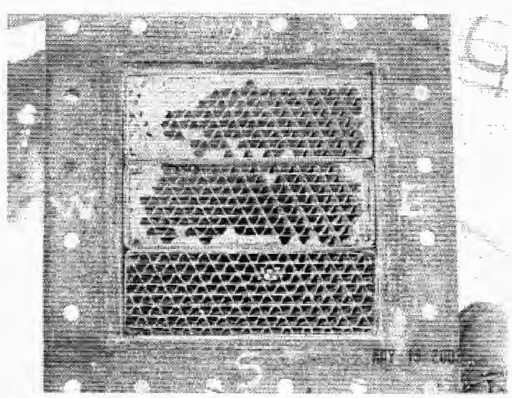
Photo After 4-Month Sample Has Been Removed



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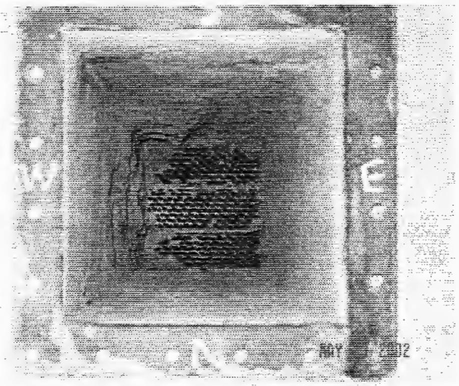
Reactor Exit



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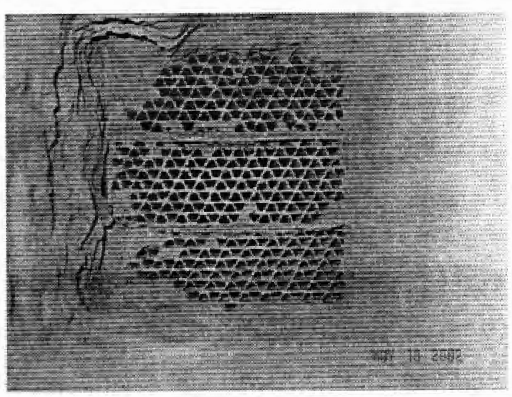
Reactor Exit (continued)



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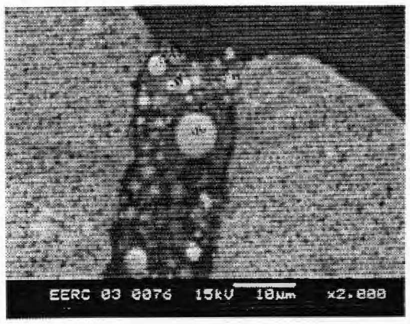
Chemical Analysis Results (6 Month)

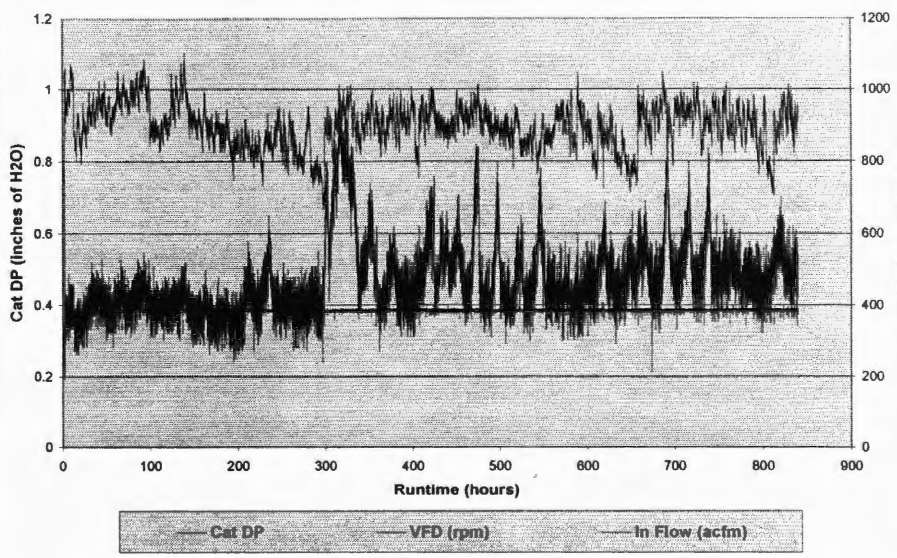


- Calcium sulfate can now be found in catalyst pores.

Point	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	Cr	Fe	Ba
12	2.49	5.71	0.57	27.75	nd	0.39	0.21	0.90	25.44	0.85	0.00	6.91	2.84
13	1.24	3.28	3.66	6.18	1.33	27.87	0.87	0.30	23.05	1.38	0.00	5.18	nd
14	0.33	5.04	1.93	14.53	0.74	1.31	0.38	0.00	41.49	5.44	nd	4.46	3.65
15	0.35	4.48	2.28	14.15	0.77	4.04	0.38	nd	37.54	5.66	0.00	4.58	2.67
16	1.63	3.62	14.05	22.85	0.00	0.00	0.32	0.69	21.10	1.72	0.00	4.59	3.08
17	0.86	2.52	7.89	13.11	1.26	16.47	1.09	0.59	22.38	1.48	nd	4.45	2.11
18	1.24	4.77	2.86	12.53	0.87	10.39	0.52	nd	34.00	0.85	0.00	4.90	2.47

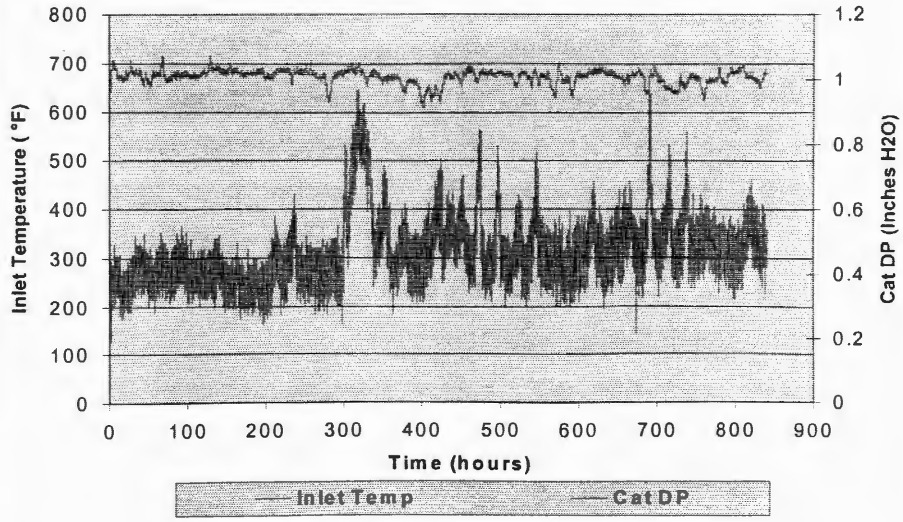
Columbia SCR Reactor

April 3, 2003 – May 8, 2003



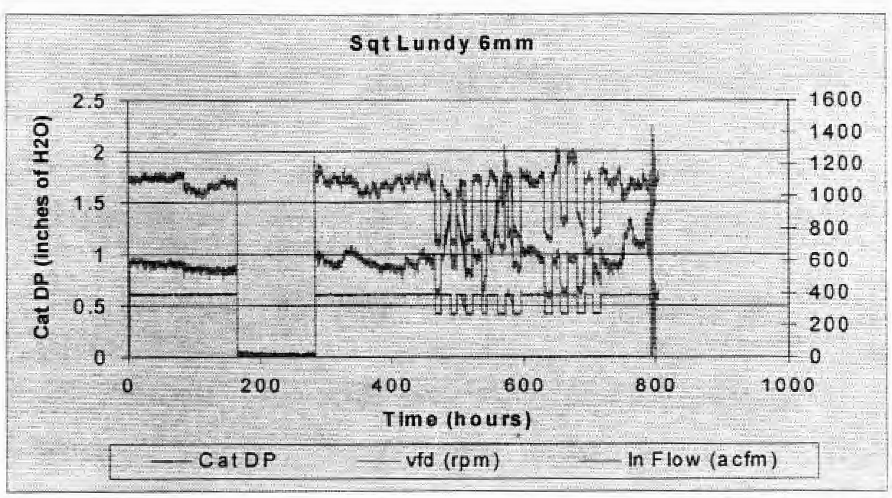
Columbia SCR Reactor Temperatures

April 3, 2003 – May 8, 2003



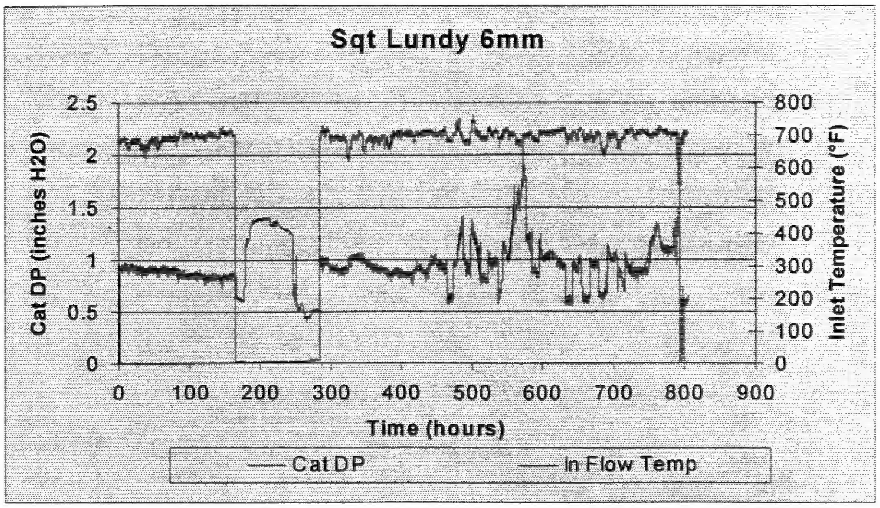
Baldwin SCR Reactor

Nov. 1, 2002 – Dec. 6, 2002



Baldwin SCR Reactor

Nov. 1, 2002 – Dec. 6, 2002



Conclusions

- PRB and lignite coals have the potential to blind SCR catalysts.
- There is evidence of sulfation both on the fly ash and catalyst surface.
- Future tests will be conducted on a tangentially fired unit burning a PRB and a cyclone unit burning a lignite.
- Wall effects contributed to the formation of deposits near the walls of the reactor.
- There was no loss of catalyst reactivity after two months of operation at Baldwin.
  - No data for 4 and 6 months of operation.

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Acknowledgments

- Thank you to the personnel from the Columbia and Baldwin stations for their efforts in helping with the installation and sampling activities.

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Mechanisms of Catalyst Blinding

Partitioning of Inorganic Components During Combustion

- Partitioning in utility boilers
  - Phase partitioning: vapors, liquids, and solids
  - Entrained particulate: size and chemical partitioning
- Partitioning in deposits
- Fly ash particle-size evolution
  - Coal characteristics
  - System conditions

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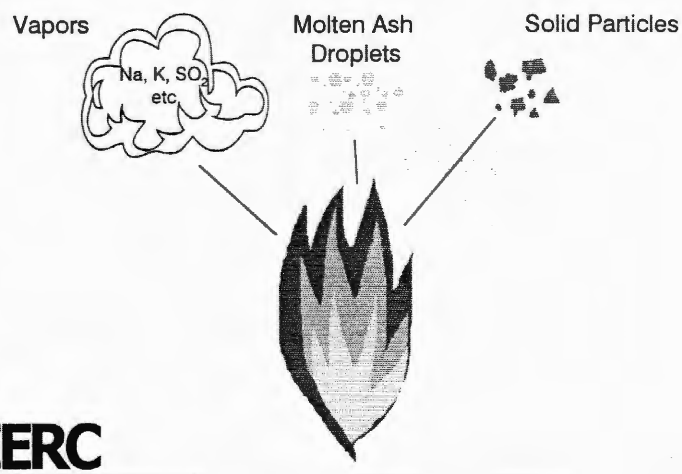
Partitioning of Inorganic Constituents in a Coal Flame



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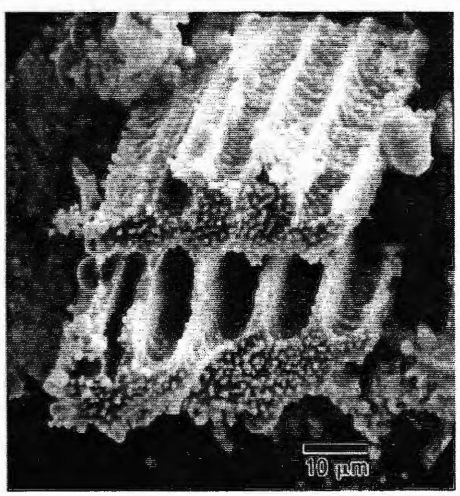
Ash Particle Formation in Pores

- PRB coal
- 0.5-sec char
- CaO droplets forming in pores and on surface
- SEI image



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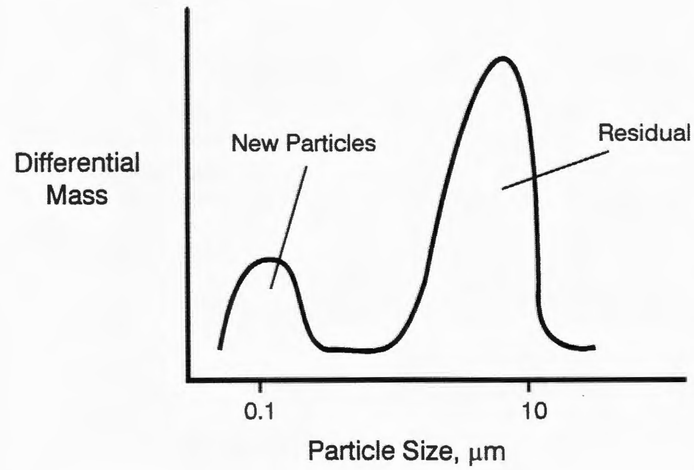
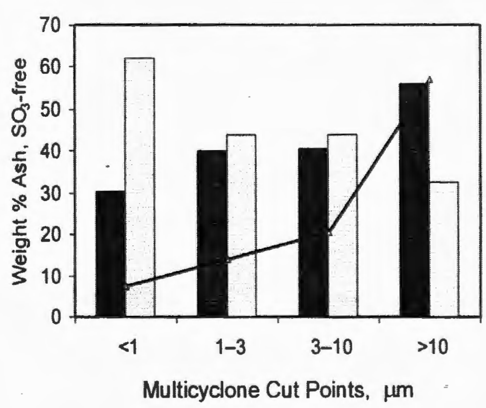
Size Distribution of Fly Ash Produced During Combustion



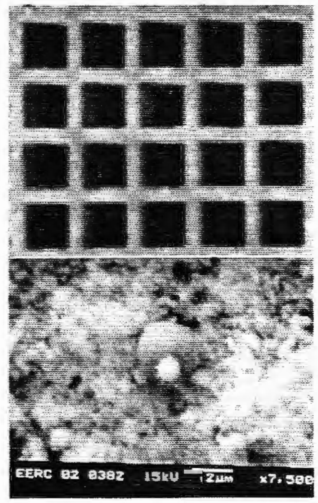
Partitioning of Elemental Oxides



- Data are from a Powder River Basin coal.
- Particles are entrained ash from a full-scale utility boiler.

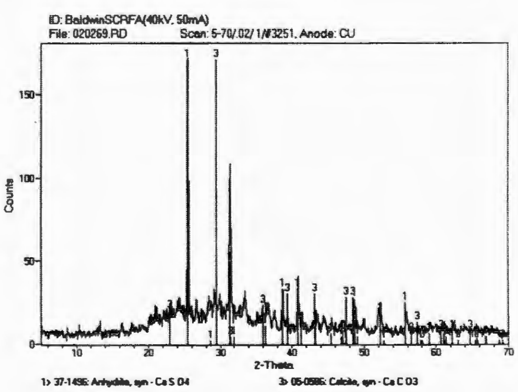
Formation of Initial Layers

- Key processes
  - Vapor-phase and small-particle diffusion and electrophoresis dominate transport mechanisms.
  - Ash particles are held in place possibly by van der Waals and electrostatic forces.
  - Particles rich in CaO, MgO, Na-species, and sulfur deposit.
  - Deposited particles react with SO_2 and SO_3 from gas phase.



Phase Identification – XRD

- Dominant Phase
  - $CaSO_4$
- Minor Phases
  - $Ca_3Mg(SiO_4)_2$
  - $CaCO_3$



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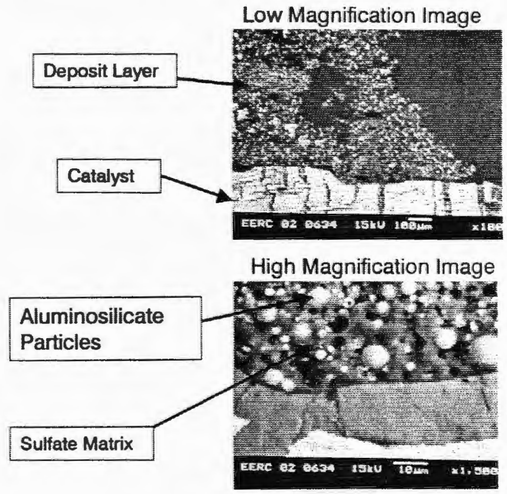
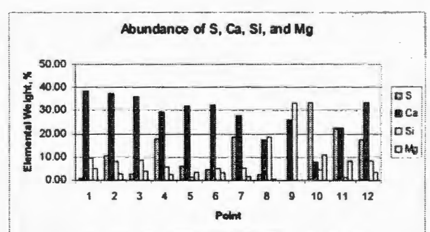
Formation of Sulfate-Bonded Deposits

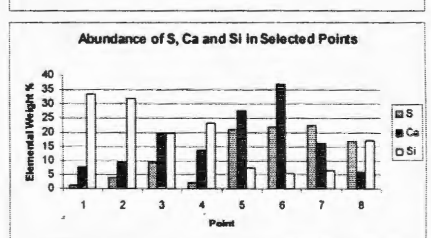
- Key processes
  - Inertial impaction and incorporation of larger particles
  - Vapor-phase SO_2 and SO_3 reaction, possibly CO_2
  - Pore filling and densification
  - Surface tension forces
  - Reactivity of deposited material



Chemical Composition of Selected Points – Morphological Analysis

- Top chart is from a sample from 2 months
  - CaO-rich materials with some sulfation
- Bottom chart is from a sample from 6 months
  - Sulfated materials combined with silicate particles





Future Directions

- Columbia Testing – complete within 6 months
- Installation at Coyote and complete testing within 8 months
- Data interpretation and reporting – within 10 months
- Other activities
  - Mercury oxidation – Coyote Station

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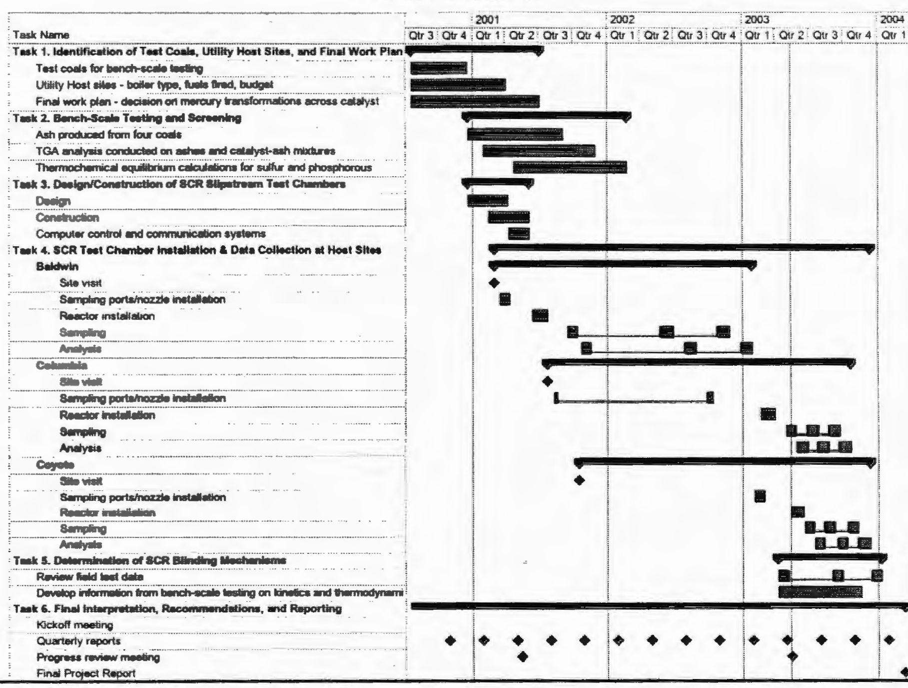
Schedule



10D

EERC
Energy & Environmental Research Center
UNIVERSITY OF NORTH DAKOTA
15 North 23rd Street — PO Box 9018 / Grand Forks, ND 58202-9018 / Phone: (701) 777-5000 Fax: 777-5181
Web Site: www.undeerc.org

June 30, 2003

Ms. Karlene Fine
Executive Director
Industrial Commission of North Dakota
10th Floor
600 East Boulevard
Bismarck, ND 58505-0310

Dear Ms. Fine:

Subject: JV Task 31 – Evaluation of Potential SCR Catalyst Blinding During Coal Combustion
Contract FY00-XXXVI-100

Enclosed is the April 1 – June 30, 2003, Quarterly Status Report for the subject task. If you have any questions, please call me at (701) 777-5177, fax at (701) 777-5181, or e-mail at sbenson@undeerc.org.

Sincerely,

Steven A. Benson
Senior Research Manager

SAB/drh

Enclosure

If this generates a paymt + they OK
plan process

EVALUATION OF POTENTIAL SCR CATALYST BLINDING DURING COAL COMBUSTION
Quarterly Report
April 1 – June 30, 2003

Installation at Baldwin Station

Reactivity tests have not been received from the catalyst vendor. More analysis was completed on the 2-, 4-, and 6-month catalyst samples. More details of the specific analyses are attached.

Installation at Columbia Station

The reactor is up and operating well. The 2-month sample was extracted in June, and scanning electron microscopy (SEM) and reactivity tests are pending.

Installation at Coyote Station and Mercury Add-On work

We are making the final arrangements to get the reactor installed at Coyote. All of the funding is now secured for the mercury oxidation work.

More detailed SEM analyses of the samples from the Baldwin station were completed this quarter. Figure 1 shows the results of plotting the S/Ca ratio as one progresses down the length of the catalyst section. The values after 2 months range from 0.8 to 1.0 with little variability. This indicates sulfating is taking place after 2 months, however, not to a great degree.

The results of a similar analysis on the 4-month sample can be found in Figure 2. After 4 months, the S/Ca has increased and is now over 1.0. However, little variability can be seen as one moves down the catalyst length.

A more detailed analysis was completed on the 6-month sample, with samples being taken every 2 inches. Figure 3 contains some of the results from this analysis. The abundance of sulfur and calcium is the greatest at the inlet, with the concentration leveling off in the midsection of the catalyst. A small increase is also seen at the catalyst outlet.

The reactor at Columbia will continue operation and will be sampled at 4 month's time. The second reactor will be moved to the Coyote station, and the mercury tests will be started directly after installation.

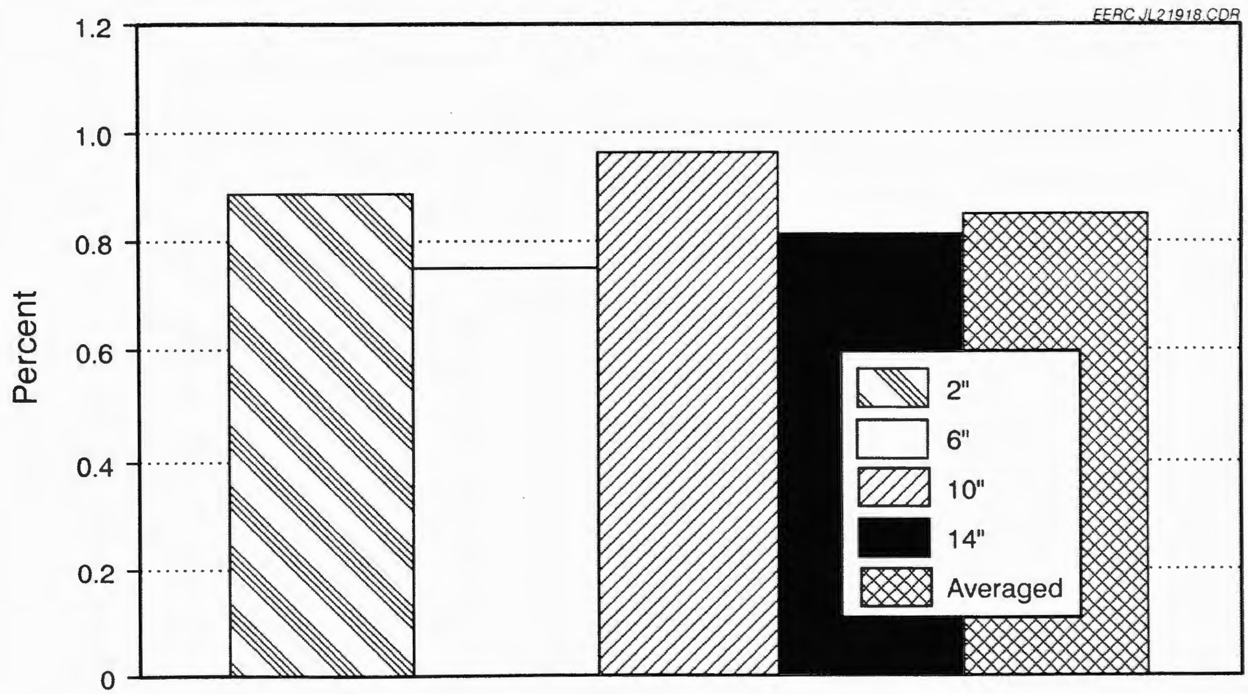


Figure 1. Ratio of sulfur to calcium, 2-month sample.

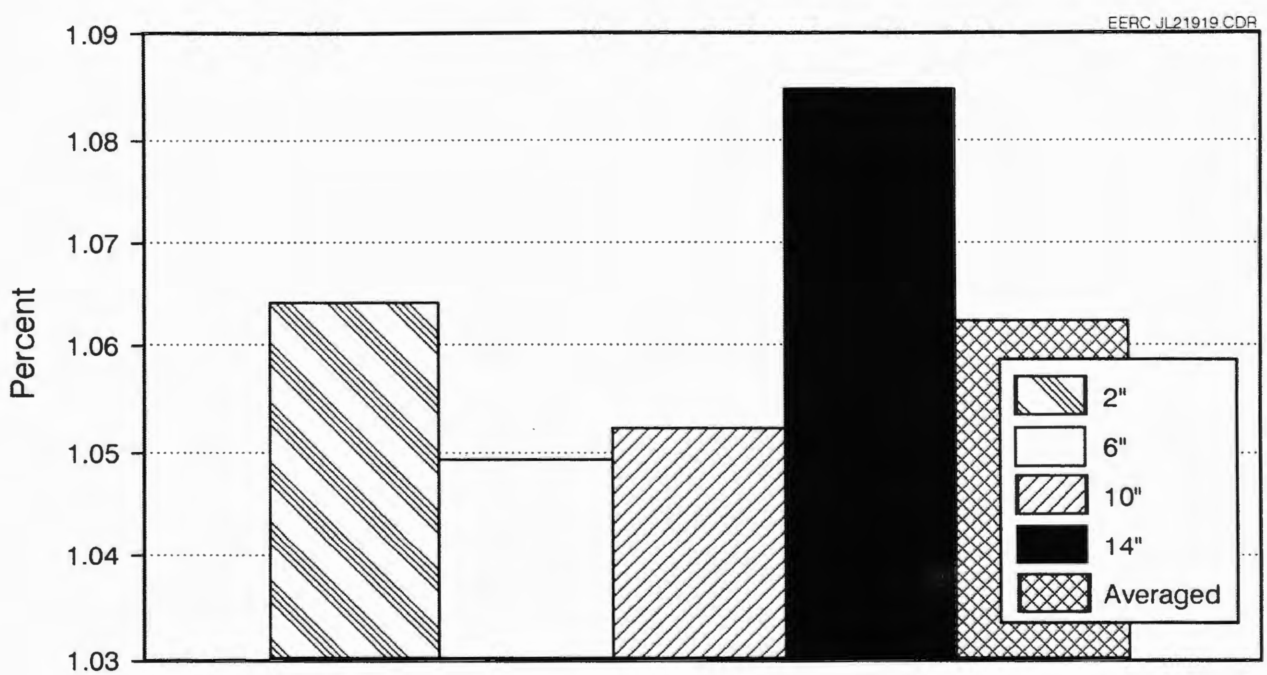


Figure 2. Sulfur to calcium ratio, 4-month sample.

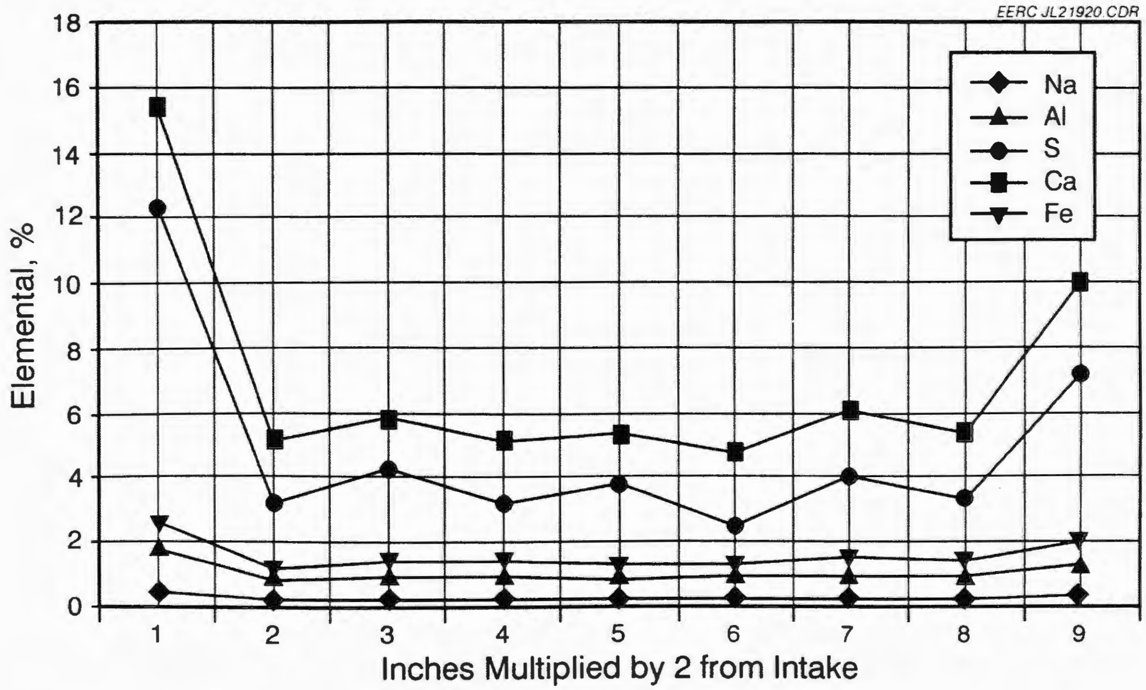


Figure 3. Six-month sample of alkali elements.

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Web Site: www.undeerc.org

December 2, 2003

Ms. Karlene Fine
Executive Director
Industrial Commission of North Dakota
600 East Boulevard Avenue
State Capitol, 10th Floor
Bismarck, ND 58505-0310

Dear Ms. Fine:

Subject: Evaluation of Potential SCR Catalyst Blinding During Coal Combustion
Contract No. FY-00-XXXVI-100

Enclosed is the July 1–September 30, 2003, Quarterly Status Report for the subject project. If you have any questions, please call me at (701) 777-5177, fax at (701) 777-5181, or e-mail at sbenson@undeerc.org.

Sincerely,

Steven A. Benson
Senior Research Manager

SAB/bak

Enclosure

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EVALUATION OF POTENTIAL SCR CATALYST BLINDING DURING COAL COMBUSTION

Quarterly Report

(For the Period July 1 – September 30, 2003)

Prepared for:

Ms. Karlene Fine

Executive Director
Industrial Commission of North Dakota
600 East Boulevard Avenue
State Capitol, 10th Floor
Bismarck, ND 58505-0310

Contract No. FY-00-XXXVI-100

Prepared by:

Steven A. Benson

Energy & Environmental Research Center
University of North Dakota
PO Box 9018
Grand Forks, ND 58202

December 2003

EERC DISCLAIMER

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Quarterly Technical Progress Report
July 1 – September 30, 2003

INTRODUCTION

The U.S. Environmental Protection Agency (EPA) rule of New Source Performance Standards, under the authority of the 1990 Clean Air Act Amendments, established new NO_x emission standards and defines selective catalytic reduction (SCR) as a "best demonstrated system" for NO_x control in utility and industry boilers, which may not be true for lower-rank coal boilers. Recent studies on German coals show an impact of sodium, calcium, sulfur, and phosphorus on the performance of SCR catalysts. Over a period of time, blinding of the SCR catalyst occurred, resulting in decreased conversion efficiency. Extrapolation of the German experience to U.S. applications reveals that catalyst deactivation may occur because of the high alkaline metals, sulfur, arsenic, and SO_3 contents in some U.S. coals. SCR systems operate in flue gas ducts downstream of the economizer and just prior to the air heater where entrained ash or dust can deposit. The high alkali and alkaline-earth element contents (sodium and calcium) of entrained fly ash generated from combustion of low-rank coals react with gaseous SO_2 to form low-temperature sulfate-based ash deposits on catalyst surfaces. Deposit buildup of this type can effectively blind or mask the catalyst, diminishing its reactivity for converting NO_2 to N_2 and water and potentially creating increased ammonia slip.

The North Dakota challenge and petition of the NO_x ruling was denied by EPA with explanations that include insufficient evidence to show that catalyst poisoning from alkali metals occurs with low-rank coals. Thus research is needed to determine the true extent of potential SCR blinding for lower-rank coals. If indeed masking of SCR catalyst material is an issue, then SCR technology may not be the best available technology for NO_x control at North Dakota utility sites and the EPA ruling may need to be amended. Other options that may surface as result of such research include providing technological and fundamental science and engineering knowledge for manufacturing SCR catalysts that resist blinding from low-rank coal-type ash material or designing SCR systems that can be cleaned on-line.

The primary goal of this Energy & Environmental Research Center (EERC) project is to determine the potential of low-rank coal ash to cause blinding or masking of SCR catalysts. A secondary goal will be to determine the degree of elemental mercury conversion across the catalysts. Specific objectives include 1) identify candidate coals and blends for testing under bench-scale conditions; 2) conduct bench-scale testing to screen coals and identify key conditions for testing at the full scale; 3) design and construct a SCR slipstream test chamber for sampling at full-scale facilities; 4) conduct testing at full-scale facilities; 5) identify SCR blinding mechanisms, rates, and cleaning methods as well as mercury conversion efficiencies; and 6) interpret data, prepare a report, and attend sponsor meetings to develop recommendations related to expected catalyst life and degree of mercury conversion.

WORK PLAN

The work plan for this project consists of six tasks outlined as follows:

- Task 1 – Identification of Test Coals and Utility Host Sites
- Task 2 – Bench-Scale Testing and Screening
- Task 3 – Design and Construction of the SCR Slipstream Test Chamber
- Task 4 – SCR Test Chamber Installation and Data Collection at Utility Host Sites
- Task 5 – Determination of SCR Blinding Mechanisms
- Task 6 – Final Interpretation, Recommendations, and Reporting

BACKGROUND

Recent studies conducted by Hartenstein et al. (1) showed an impact of sodium, calcium, sulfur, and phosphorus on the performance of SCR catalysts when German coals were fired. Over a period of time, blinding of the SCR catalyst occurred, resulting in decreased conversion efficiency. Extrapolation of the German experience to U.S. applications reveals that catalyst deactivation may occur because of the high alkaline metals, sulfur, and SO_3 contents in some U.S. coals. SCR systems operate in flue gas ducts downstream of the economizer and just prior to the air heater where entrained ash or dust can deposit. The high alkali and alkaline-earth element contents (sodium and calcium) of entrained fly ash generated from combustion of low-rank coals react with gaseous SO_2 to form low-temperature sulfate-based ash deposits on catalyst surfaces.

The mechanisms for this type of low-temperature deposition have been examined and modeled in detail at the EERC in work termed Project Sodium and Project Calcium in the early 1990s; however, the focus of those projects was specific to primary superheater and economizer regions of boilers and not SCR systems (2–3). Deposit buildup of this type can effectively blind or mask the catalyst, diminishing its reactivity for converting NO_2 to N_2 and water and potentially creating increased ammonia slip (3). Arsenic and phosphates, which are not uncommon in low-rank coals, may also play a role in catalyst degeneration. Arsenic is a known catalyst poison (4) in applications such as catalytic oxidation for pollution control. Phosphates can occur in low-temperature ash deposits to create blinding effects, and they also occur with arsenic and can cause catalyst poisoning (5).

EXPERIMENTAL

Objective and Goals

The goals of this project are to determine the potential of low-rank coal ash to cause blinding or masking of SCR catalysts. Specific objectives include 1) identify candidate coals and blends for testing under bench-scale conditions; 2) conduct bench-scale testing to screen coals and identify key conditions for testing at the full scale; 3) design and construct a SCR slipstream test chamber for sampling at full-scale facilities; 4) conduct testing at full-scale facilities; 5) identify SCR blinding mechanisms, rates, and cleaning methods; and 6) interpret data, prepare a report, and attend sponsor meetings to develop recommendations related to expected catalyst life and degree of mercury conversion.

PLANNED SCOPE OF WORK

Task 1 – Identification of Test Coals and Utility Host Sites

This task includes a kickoff meeting between the multiclient consortium members to determine which utilities and boiler units will have the SCR slipstream test chamber installed in them and which coals should be tested. Three utility host sites were selected for long-duration tests using the SCR slipstream test chamber, including at least one lignite boiler and one PRB boiler. Baldwin Station in Baldwin, Illinois, has a cyclone-fired PRB boiler; Columbia Station in Portage, Wisconsin, burns Powder River Basin (PRB) coal; and Coyote Station in Beulah, North Dakota, burns Beulah lignite coal. The coals burned as part of the full-scale slipstream SCR testing are part of the test pool; in addition, other coals that sponsors may want to test at the bench scale, which would not be tested at a utility host site, will be selected and acquired. The time-consuming nature of the utility field testing precludes the testing of multiple coals at full-scale units. A maximum of six test coals will be selected and acquired for this program. A final objective of Task 1 will be to finalize the project work plan.

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Two portable test chambers were constructed under this task for testing SCR masking at two low-rank coal boilers (i.e., PRB and lignite boilers). Each chamber will maintain the correct temperature, surface area, and orientation of SCR catalyst material while passing an isokinetically drawn slipstream of the boiler flue gas through the chamber using a purchased induced-draft fan.

The slipstream system is presented in Figure 1. A purge section is installed ahead of the reactor to remove accumulated dust. Thermocouple and pressure taps are located in the purge sections for measurements before and after each section. The SCR reactor is an approximately

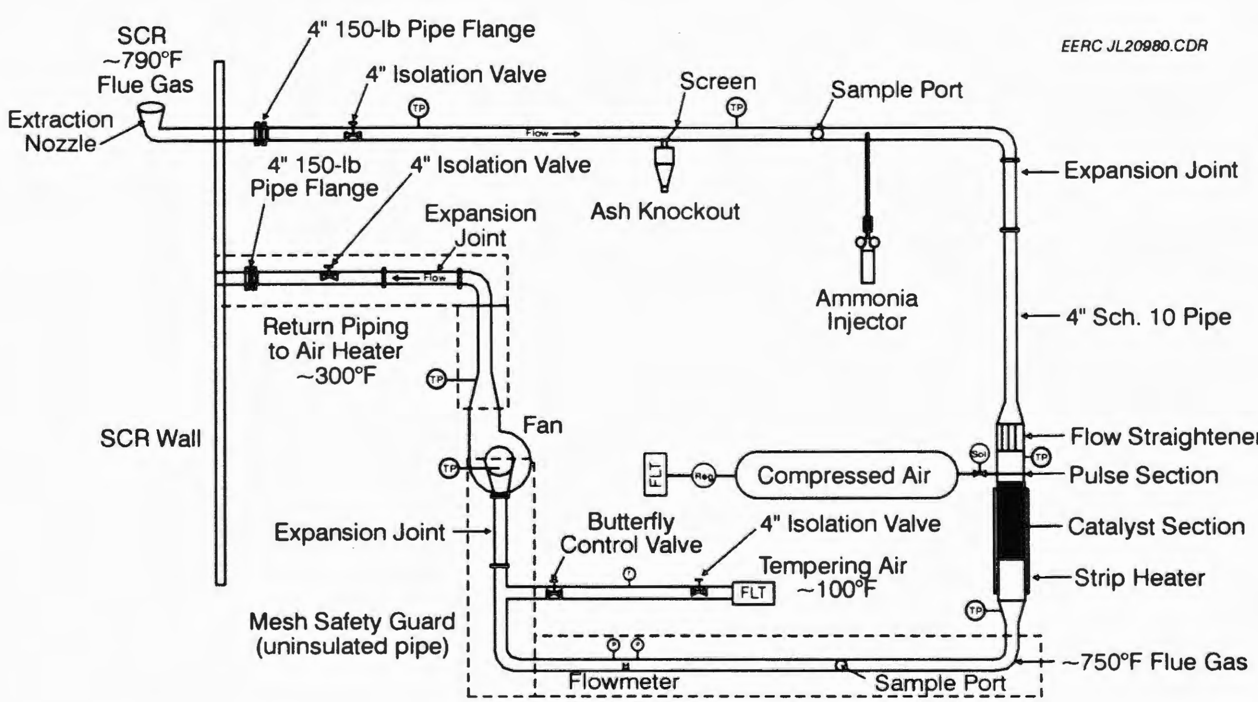

Figure 1. Conceptual schematic of the SCR reactor slipstream field test unit.

7.5-in.-square by 8-ft-long steel housing that consists of two sections: one flow straightener and a catalyst test section. Support brackets located on the piping entering and leaving the reactor will enable individual sections of the SCR to be removed. Strip heaters are installed on the catalyst section, and the entire housing is insulated for temperature control. A remote computer located at the EERC controls the reactor, with an on-site computer for monitoring purposes. Several reactor temperatures, pressure drop across the catalyst, and pressure drop across an orifice meter are monitored. Additional slots are available on the data acquisition boards for future equipment and monitors. To achieve an approach velocity of 5.2 m/s (17.0 ft/s), approximately 400 acfm (200 scfm) of flue gas is extracted from the convective pass of the utility boiler immediately downstream from the economizer at a temperature in the 700°F range. The total gas flow through the reactor represents a thermal load of approximately 300 kW.

The first section of the reactor is a short length (6-in.) used as a flow straightener. The catalyst test section is 3.28 ft (1 m) in length. The catalyst section consists of three 2.5 in. × 7.5 in. plate-type sections. A steel catalyst holder holds the catalyst pieces together inside the reactor (Figure 2). The catalyst holders are located on each end of the catalyst section. The holder consists of an angle iron welded together in a square with bars spanning between two of the flanged sides. One leg of the angle is sandwiched between the reactor shell flanges, and the other holds the catalyst sections tightly together in place. The holder keeps the catalyst away from the reactor shell, prevents flow around the catalyst, and allows for easy removal of the catalyst from the reactor.

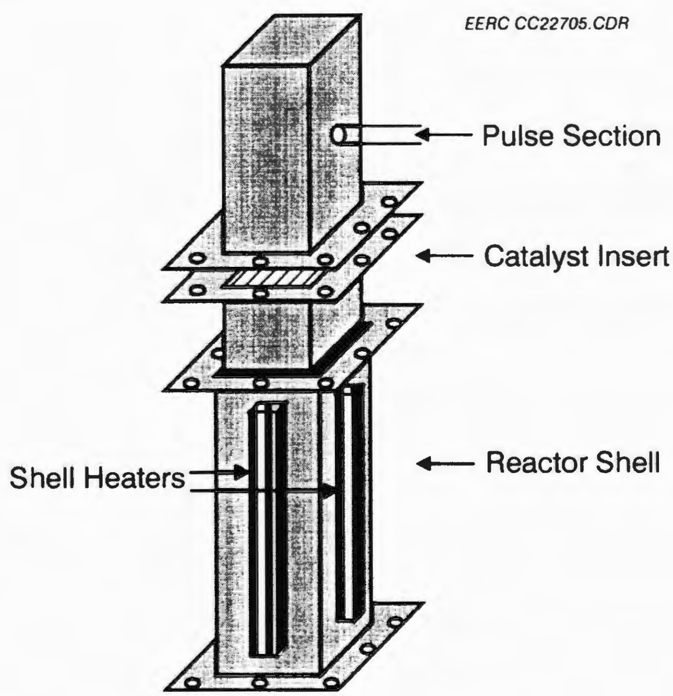

Figure 2. SCR catalyst section.

For catalyst inspection or replacement, the catalyst section can be unbolted and slid out from the reactor (support brackets hold the remaining reactor pieces in place). Once a catalyst reactor section is removed, the top catalyst holder can be removed and the section(s) of interest removed by pushing it up from the bottom and out the top. A new section is then inserted from the top to replace the piece removed.

Task 4 – SCR Test Chamber Installation and Data Collection at Utility Host Sites

SCR test chambers will be installed in a slipstream arrangement at three utility boilers. Since SCR masking or blinding phenomena occur over longer periods of time, the SCR test chamber will be kept in a slipstream arrangement in the region ahead of the air heater at each boiler for a period of 6 months. Upon installation of the test chamber at each boiler unit, measurements of flue gas temperature, composition, and velocity will be taken using portable equipment. Periodic checks of the chamber by a trained boiler technician will be made to ensure experimental quality. The test chamber will be constructed so that periodic samples of the catalyst can be removed to assess reactivity as a function of time. Testing was initiated at the Baldwin Station in July 2001 and completed in December 2002. Installation at the Columbia Station began in March 2002 using the second slipstream test chamber. After permitting delays were resolved, the field test was initiated in October 2002. That test is scheduled for termination in November 2003. The field test included shutdowns. The SCR slipstream test chamber used at the first utility boiler site test chamber will be installed at the third utility boiler at the Coyote Station with installation of fresh catalyst.

Task 5 – Determination of SCR Blinding Mechanisms

Upon completion of the SCR chamber experiments at each plant, the SCR catalyst section in the test chamber will be sent to Hitachi in Japan for measuring any degradation in catalyst reactivity. These are standard tests routinely performed by catalyst vendors.

The nature of any ash deposition or ash–catalyst reactions will be investigated by the EERC using SEM, x-ray diffraction, and other analytical techniques. These same techniques and other fine-particle SEM analytical techniques will be used to analyze the entrained ash samples collected at the field sites. Correlations between the physical and chemical characteristics of any ash deposits on the SCR test section and entrained ash sample collected at the chamber inlet, and the coal inorganic composition will be made to discern mechanisms of SCR blinding. Minor and trace element analyses of deposits and SCR catalyst material will be performed in order to evaluate the effects of As, Sr, and Ba, which may act as poisoning agents.

Task 6 – Final Interpretation, Recommendations, and Reporting

Task 6 will bring together all of the data interpretation on SCR-blinding mechanisms and mercury conversion efficiencies. Potential cleaning methods, if necessary, or other blinding remedial measures will be recommended. Project reporting, periodic meetings with all consortium members, and efficient transfer of information will be facilitated in this task. Quarterly interim reports and a final report will be submitted to project sponsors at the end of the project.

RESULTS AND DISCUSSION

Activities under Tasks 4 and 5 were continued during this quarter

Task 4 – SCR Test Chamber Installation and Data Collection at Utility Host Sites

SCR reactors were in operation at two sites during this quarter. The reactor at Columbia Station continues to operate well. The 2- and 4-month catalyst samples were removed and replaced with fresh catalyst in July and September, respectively. The field test is scheduled to terminate in early November. Additional operating data will be available for the next quarterly. The reactor retrieved from Baldwin Station was installed at the Coyote Station in August. The unit seems to be plugging at a higher rate than either of the two previous installations. Figure 3 shows the catalyst pressure drop from the Coyote and Baldwin reactors. Identical catalysts were tested at both stations. After approximately 421 hours, the pressure drop at the Coyote reactor increased at a much higher rate than the Baldwin reactor. Currently, the pressure drop at the Coyote station has increased to 1.7 in. of H_2O.

Figures 4–9 show the reactor and catalyst at Coyote Station after 2 months of field testing. Figure 4 shows the flue section just upstream of the SCR catalyst in the reactor. Some deposition is visible in the photograph. Additional fouling on the flow straighteners farther upstream of the SCR catalyst is visible in Figure 5. The SCR catalyst section after 2 months of operation is presented in Figure 6. The left side of the catalyst is indicative of the amount of fouling present,

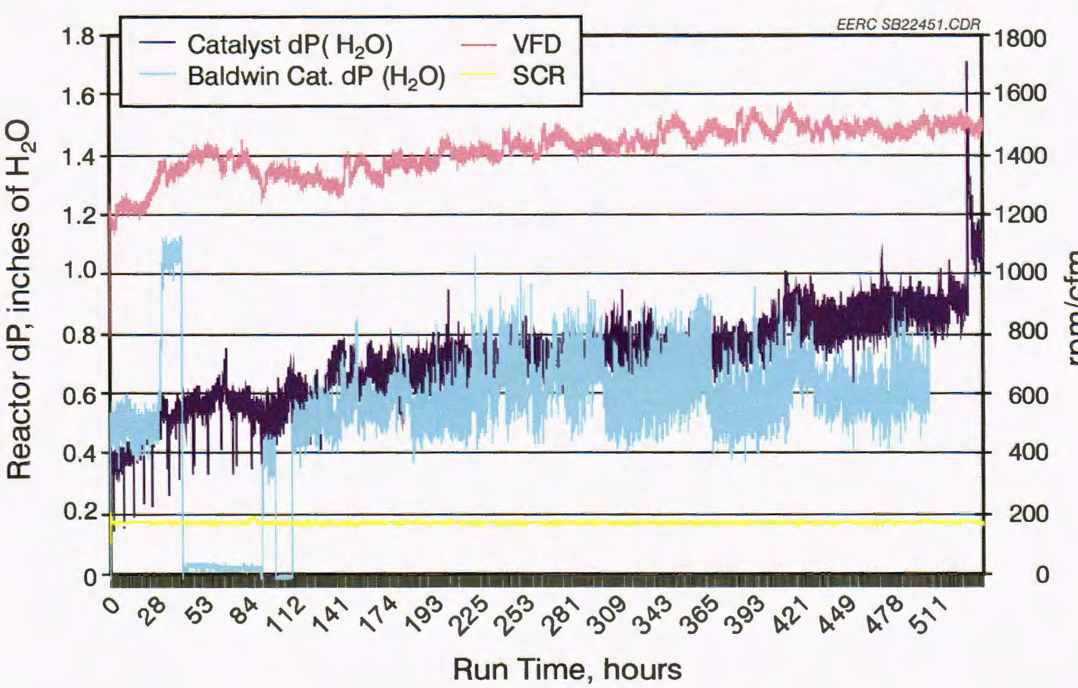

Figure 3. Coyote reactor flow information with Baldwin Station SCR reactor pressure drop.

EERC CC22582.CDR

Figure 4. Inlet to the catalyst section of the SCR reactor view looking upstream; Coyote Station at the 2-month test interval.

EERC CC22580.CDR

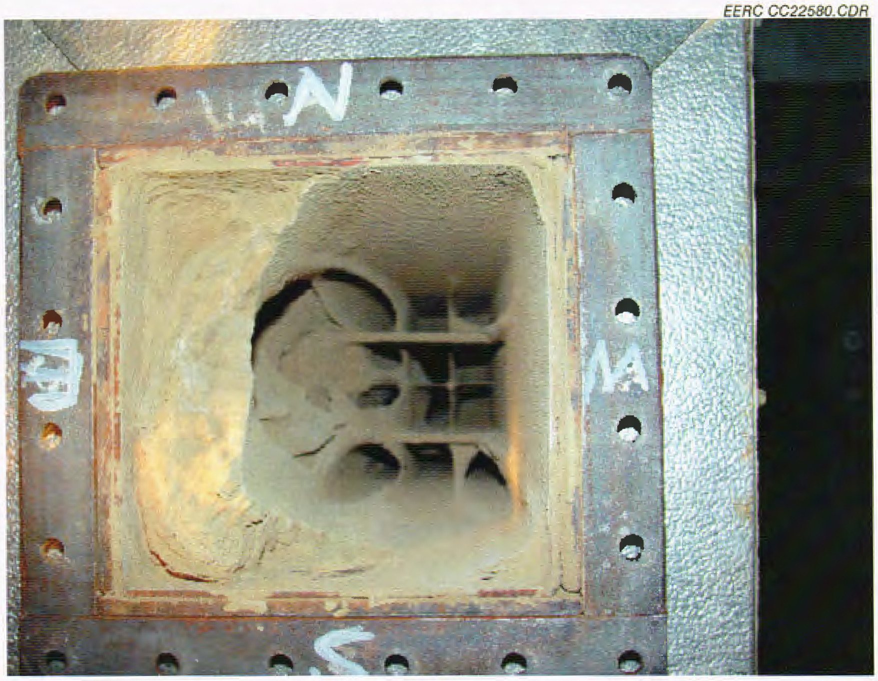

Figure 5. Ash deposition on the flow straighteners upstream of the catalyst section of the SCR reactor view looking upstream; Coyote Station at the 2-month test interval.

EERC CC22584.CDR

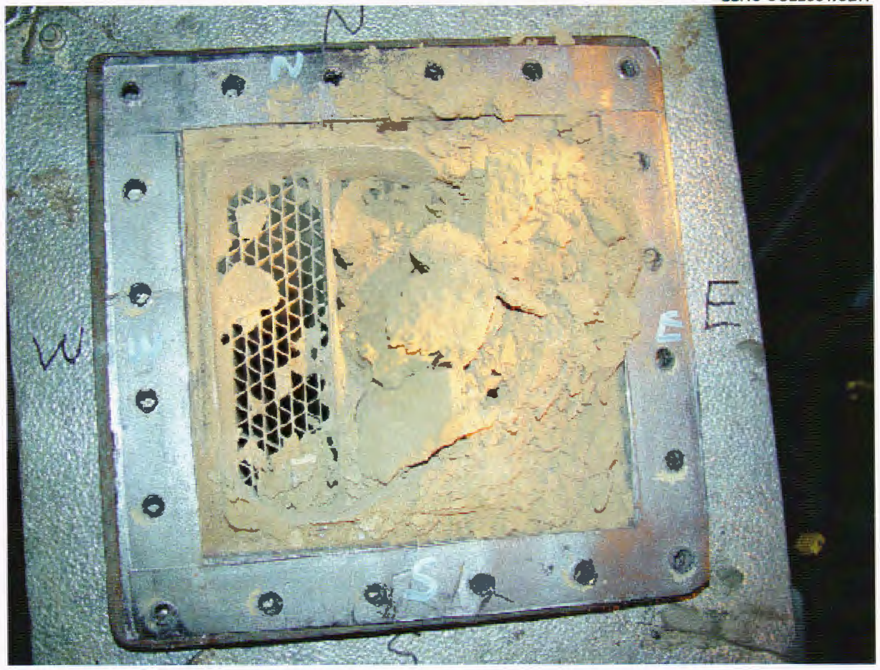

Figure 6. Inlet of the SCR catalyst section after 2 months of field testing at the Coyote Station.

EERC CC22581.CDR

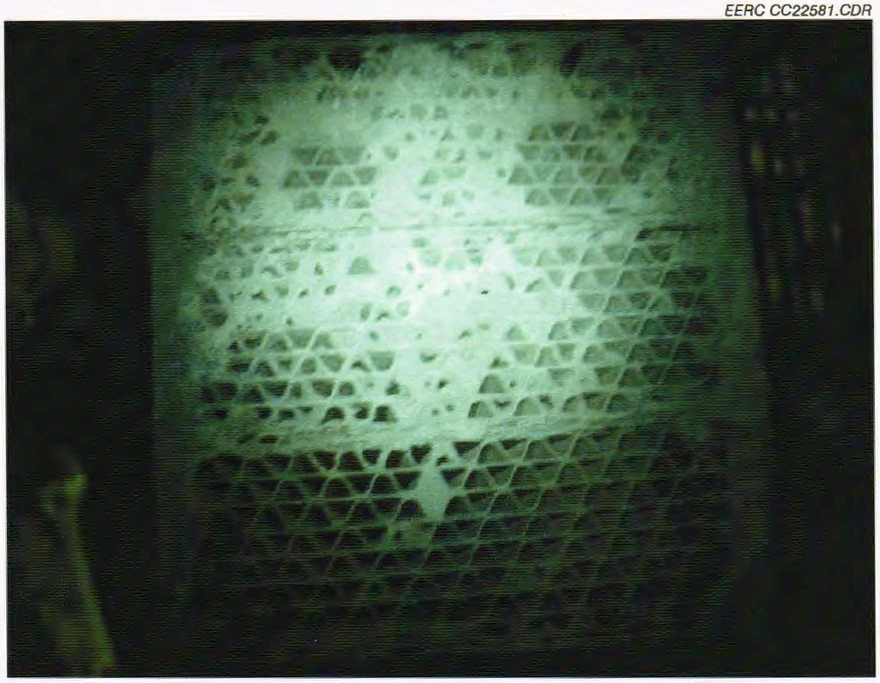

Figure 7. Outlet of the catalyst section of the SCR reactor view looking upstream; Coyote Station at the 2-month test interval.

EERC CC22583.CDR

Figure 8. Inlet of the catalyst section of the SCR reactor after catalysts have been removed; view looking downstream; Coyote Station at the 2-month test interval.

EERC CC22585.CDR

Figure 9. Catalyst ready for the SCR reactor assembly. Two physically cleaned, previously exposed catalysts at the top, new catalyst at the bottom; Coyote Station at the 2-month test interval.

whereas the ash present on the right side of the catalyst fell from the upstream flue section when the joint was separated. Nevertheless, the entire surface appears coated with ash deposits, and some of the catalyst channels were plugged. The catalyst exit, Figure 7, shows the plugged channels. Figure 8 shows the ash layer remaining after the catalyst was removed for cleaning and retrieval of the 2-month sample. The 4- and 6-month catalyst sections were hand cleaned with a brush as well as possible and reinserted into the SCR reactor with a new section of catalyst. Figure 9 shows the catalyst section of the SCR reactor ready for assembly with the previously exposed sections of catalyst above the new section of catalyst.

Task 5 – Determination of SCR Blinding Mechanisms

A database to house all of the SEM data is under construction. SEM analyses of the 2- and 4-month Columbia catalysts have been completed. These data will be compiled in the next quarter. Preliminary review of the morphology data indicates that sulfation of small calcium-oxide rich particles appears to be the dominant mechanism of particle bonding and pore filling on the catalyst surfaces. The presence of the catalyst appears to enhance the sulfation rates. Phosphates do not appear to be contributing to the particle bonding in the samples examined to date.

Reactivity tests results for the 4- and 6-month Baldwin Station samples have not been received from Hitachi. All three catalyst samples from the Columbia Station are being sent to Hitachi for reactivity testing in November following termination of that field test.

FUTURE WORK – NEXT QUARTER

Work in the upcoming quarter will involve site visits and data reduction. The Columbia Station site test will be terminated and equipment retrieved. The 2-month catalyst sample will be removed from the Coyote Station site. Flow data and catalyst morphology from the Baldwin and Columbia sites will be analyzed. Available flow data from Coyote will reduced. Portions of the 2-month catalyst sample from Coyote Station will be analyzed. Quarterly reports will be prepared. As the updated milestone chart presented in Figure 10 indicates, the Coyote Station field test will be terminated in March 2004.

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1. Hartenstein, H.U.; Gutberlet, H.; Licata, A. Utility Experience with SCR in Germany. In *Proceedings of the 16th Annual International Pittsburgh Coal Conference;* Pittsburgh, PA, Oct 11–15, 1999.

2. Benson, S.A.; Hurley, J.P.; Zygarlicke, C.J. Studies on Calcium-Based Deposition in Utility Boilers. In *Proceedings of the Conference on Effects of Coal Quality on Power Plants*; St. Louis, MO, Sept 1990.

3. Benson, S.A.; Hurley, J.P.; Zygarlicke, C.J.; Steadman, E.N.; Erickson, T.A. Predicting Ash Behavior in Utility Boilers. *Energy Fuels* **1993**, *7*, 746–754.

4. Harbison, G. Minimizing Operating Costs of VOC Control. *Pollution Engineering* [Online] **1998**, *Summer*, 6.

5. Swaine, D.J.; Taylor, G.F. Arsenic in Phosphatic Boiler Deposits. *J. Inst. Fuel* **1970**, *July,* 261.

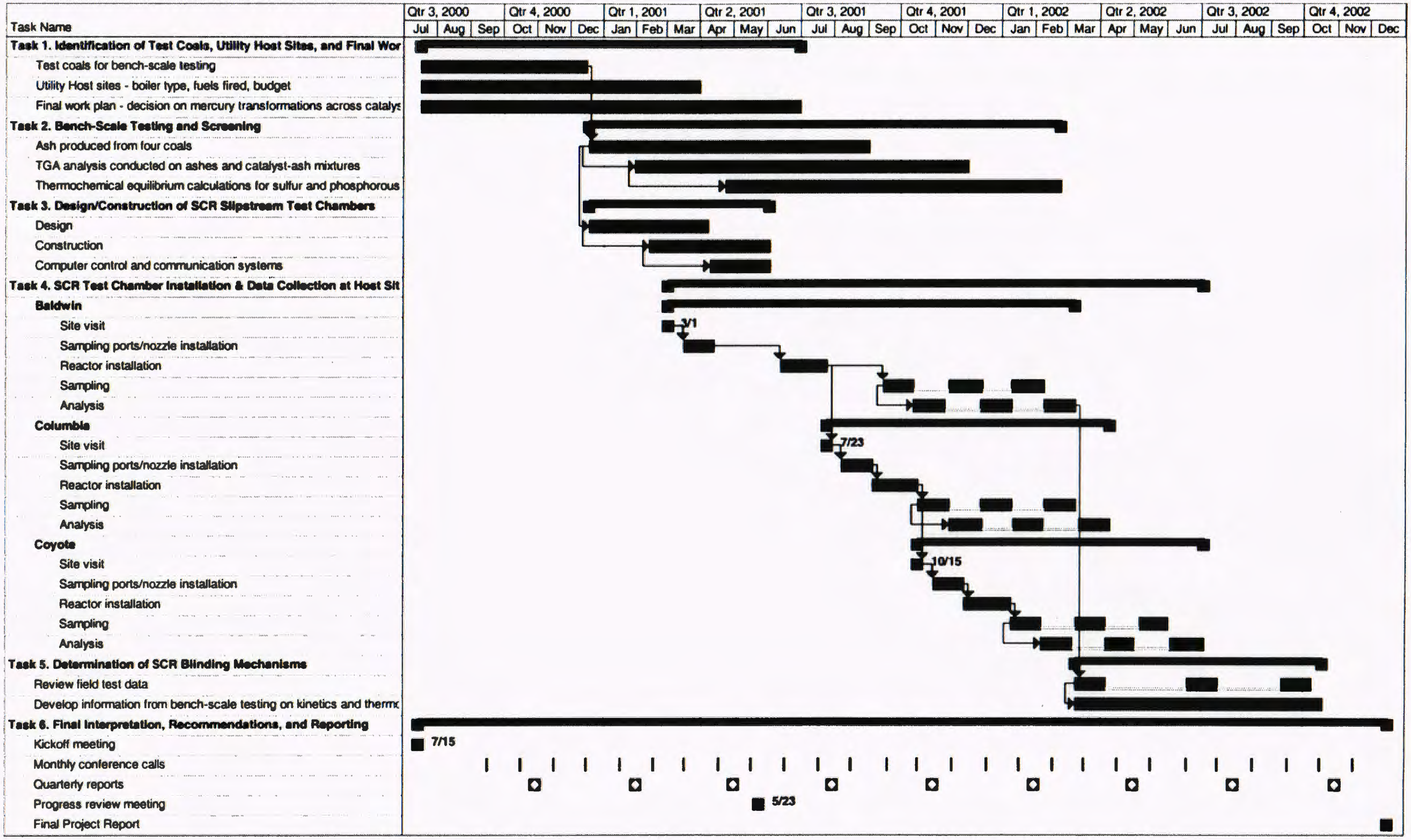

Figure 10. Updated milestone chart.

EERC
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October 30, 2003

Ms. Karlene Fine
Executive Director
Industrial Commission of North Dakota
10th Floor
600 East Boulevard
Bismarck, ND 58505-0310

Dear Ms. Fine:

Subject: JV Task 31 – Evaluation of Potential SCR Catalyst Blinding During Coal Combustion
Contract FY00-XXXVI-100

Enclosed is the July 1 – September 30, 2003, Quarterly Status Report for the subject task. If you have any questions, please call me at (701) 777-5177, fax at (701) 777-5181, or e-mail at sbenson@undeerc.org.

Sincerely,

Steven A. Benson
Senior Research Manager

SAB/cs

Enclosure

Post-it® Fax Note 7671	Date 11-10	# of pages ▶ 3
To Harvey	From Shirly	
Co./Dept.	Co.	
Phone #	Phone #	
Fax #	Fax #	

EVALUATION OF POTENTIAL SCR CATALYST BLINDING DURING COAL COMBUSTION
Quarterly Report
July 1 – September 30, 2003

Installation at Baldwin Station

Reactivity tests have not been received from the catalyst vendor. Data from the scanning electron microscopy (SEM) analysis of these samples are included in the attachment for comparison purposes.

Installation at Columbia Station

The reactor continues to operate well. The 4-month sample was extracted in August. SEM analyses of the 2- and 4-month samples have been completed. A database is currently under construction to house all of the SEM data. These data will be compiled in the next quarter. The testing is scheduled to be completed the first week in November, barring any unplanned outages.

The reactor at Columbia will continue operation and will be samples 6 months' time. The reactor at the Coyote Station will continue operation, and sampling activities will be completed at 2 and 4 months' time. The mercury sampling at Coyote will coincide with the catalyst sampling.

Installation at Coyote Station and Mercury Add-on Work

The reactor was successfully installed at the Coyote Station in August. The unit seems to be plugging at a higher rate than either of the two previous installations. Operating data and data from the first mercury measurements can be found in the attachments. The first round of mercury sampling was also conducted. Ontario Hydro mercury samples were collected before and after the reactor, with and without ammonia. Without ammonia, 56% of the mercury exiting the reactor was elemental; when the ammonia was turned on, 80% of the mercury was in the elemental form. The inlet mercury was on average 86% elemental.

Figure 1 shows the catalyst pressure drop from the Coyote and Baldwin reactors. Identical catalysts were tested at both stations. After approximately 421 hours, the pressure drop at the Coyote reactor increases at a much higher rate than the Baldwin reactor. Currently the pressure drop at the Coyote station has increased to 1.7" of H_2O. More information will be available about the blinding at Coyote when the first 2-month sample is extracted.

8. Performance Variances, Accomplishments, or Problems (continued)

Figure 1 shows the catalyst pressure drop from the Coyote and Baldwin reactors. Identical catalysts were tested at both stations. After approximately 421 hours, the pressure drop at the Coyote reactor increases at a much higher rate than the Baldwin reactor. Currently the pressure drop at the Coyote station has increased to 1.7" of H_2O. More information will be available about the blinding at Coyote when the first 2-month sample is extracted.

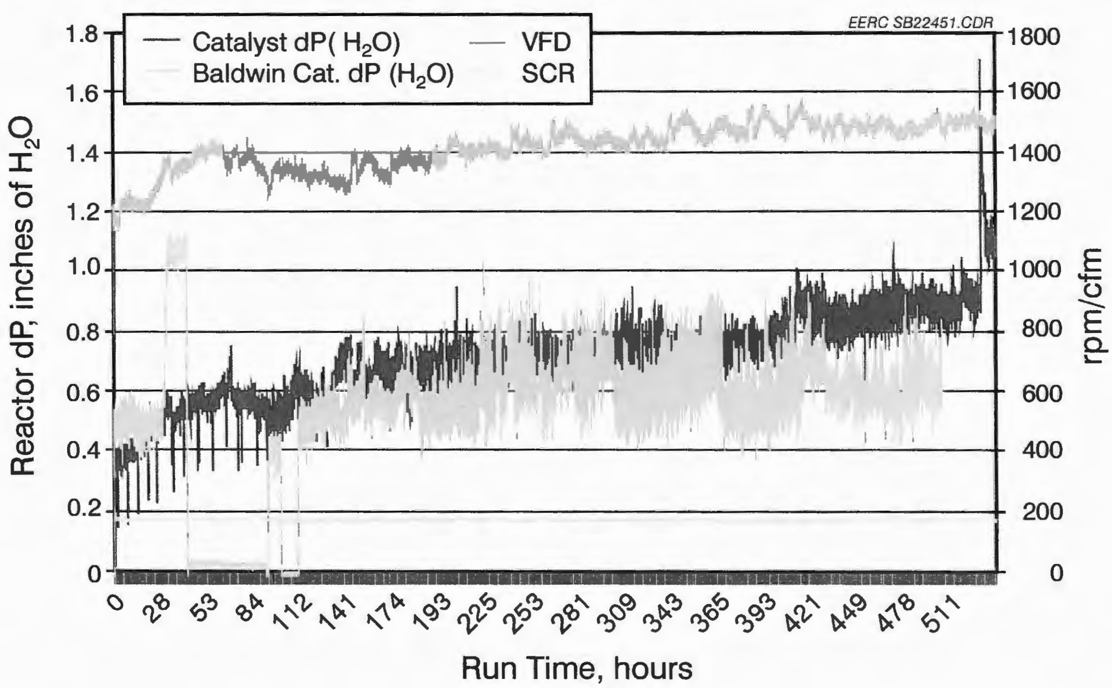

Figure 1. Coyote reactor flow information.

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February 19, 2004

Ms. Karlene Fine
Executive Director
North Dakota Industrial Commission
State Capitol, 10th Floor
600 East Boulevard Avenue
Bismarck, ND 58505-0310

Dear Ms. Fine:

Subject: Evaluation of Potential SCR Catalyst Blinding During Coal Combustion
Contract No. FY-00-XXXVI-100

Enclosed is the October 1 – December 31, 2003, Quarterly Status Report for the subject task. You may notice that the report includes some results reported in the quarterly report for the period ending September 30, 2003. Although they were produced since October 1, we wanted to provide the latest results available at the time the last quarterly report was written. If you have any questions, please call me at (701) 777-5177, fax at (701) 777-5181, or e-mail at sbenson@undeerc.org.

Sincerely,

Steven A. Benson
Senior Research Manager

SAB/bak

Enclosure

EERC

Energy & Environmental Research Center

EVALUATION OF POTENTIAL SCR CATALYST BLINDING DURING COAL COMBUSTION

Quarterly Report

(For the Period October 1 – December 31, 2003)

Prepared for:

Ms. Karlene Fine

North Dakota Industrial Commission
State Capitol, 10th Floor
600 East Boulevard Avenue
Bismarck, ND 58505-0310

Contract No. FY-00-XXXVI-100

Prepared by:

Steven A. Benson
Charlene R. Crocker
Jason D. Laumb
Robert R. Jensen

Energy & Environmental Research Center
University of North Dakota
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Grand Forks, ND 58202-9018

February 2004

University of North Dakota Grand Forks

EERC DISCLAIMER

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Quarterly Technical Progress Report
October 1 – December 31, 2003

INTRODUCTION

The U.S. Environmental Protection Agency (EPA) rule of New Source Performance Standards, under the authority of the 1990 Clean Air Act Amendments, established new NO_x emission standards and defines selective catalytic reduction (SCR) as a "best demonstrated system" for NO_x control in utility and industry boilers, which may not be true for lower-rank coal boilers. Recent studies on German coals show an impact of sodium, calcium, sulfur, and phosphorus on the performance of SCR catalysts. Over a period of time, blinding of the SCR catalyst occurred, resulting in decreased conversion efficiency. Extrapolation of the German experience to U.S. applications reveals that catalyst deactivation may occur because of the high alkaline metals, sulfur, arsenic, and SO_3 contents in some U.S. coals. SCR systems operate in flue gas ducts downstream of the economizer and just prior to the air heater where entrained ash or dust can deposit. The high alkali and alkaline-earth element contents (sodium and calcium) of entrained fly ash generated from combustion of low-rank coals react with gaseous SO_2 to form low-temperature sulfate-based ash deposits on catalyst surfaces. Deposit buildup of this type can effectively blind or mask the catalyst, diminishing its reactivity for converting NO_2 to N_2 and water and potentially creating increased ammonia slip.

The North Dakota challenge and petition of the NO_x ruling was denied by EPA with explanations that include insufficient evidence to show that catalyst poisoning from alkali metals occurs with low-rank coals. Thus research is needed to determine the true extent of potential SCR blinding for lower-rank coals. If masking of SCR catalyst material is indeed an issue, then SCR technology may not be the best available technology for NO_x control at North Dakota utility sites and the EPA ruling may need to be amended. Other options that may surface as results of such research include providing technological and fundamental science and engineering knowledge for manufacturing SCR catalysts that resist blinding from low-rank coal-type ash material or designing SCR systems that can be cleaned on-line.

The primary goal of this Energy & Environmental Research Center (EERC) project is to determine the potential of low-rank coal ash to cause blinding or masking of SCR catalysts. A secondary goal will be to determine the degree of elemental mercury conversion across the catalysts. Specific objectives include 1) identify candidate coals and blends for testing under bench-scale conditions; 2) conduct bench-scale testing to screen coals and identify key conditions for testing at the full scale; 3) design and construct a SCR slipstream test chamber for sampling at full-scale facilities; 4) conduct testing at full-scale facilities; 5) identify SCR blinding mechanisms, rates, and cleaning methods as well as mercury conversion efficiencies; and 6) interpret data, prepare a report, and attend sponsor meetings to develop recommendations related to expected catalyst life and degree of mercury conversion.

WORK PLAN

The work plan for this project consists of six tasks outlined as follows:

- Task 1 – Identification of Test Coals and Utility Host Sites
- Task 2 – Bench-Scale Testing and Screening
- Task 3 – Design and Construction of the SCR Slipstream Test Chamber
- Task 4 – SCR Test Chamber Installation and Data Collection at Utility Host Sites
- Task 5 – Determination of SCR Blinding Mechanisms
- Task 6 – Final Interpretation, Recommendations, and Reporting

BACKGROUND

Recent studies conducted by Hartenstein et al. (1) showed an impact of sodium, calcium, sulfur, and phosphorus on the performance of SCR catalysts when German coals were fired. Over a period of time, blinding of the SCR catalyst occurred, resulting in decreased conversion efficiency. Extrapolation of the German experience to U.S. applications reveals that catalyst deactivation may occur because of the high alkaline metals, sulfur, and SO_3 contents in some U.S. coals. SCR systems operate in flue gas ducts downstream of the economizer and just prior to the air heater where entrained ash or dust can deposit. The high alkali and alkaline-earth element contents (sodium and calcium) of entrained fly ash generated from combustion of low-rank coals react with gaseous SO_2 to form low-temperature sulfate-based ash deposits on catalyst surfaces.

The mechanisms for this type of low-temperature deposition have been examined and modeled in detail at the EERC in work termed Project Sodium and Project Calcium in the early 1990s; however, the focus of those projects was specific to primary superheater and economizer regions of boilers and not SCR systems (2–3). Deposit buildup of this type can effectively blind or mask the catalyst, diminishing its reactivity for converting NO_2 to N_2 and water and potentially creating increased ammonia slip (3). Arsenic and phosphates, which are not uncommon in low-rank coals, may also play a role in catalyst degeneration. Arsenic is a known catalyst poison (4) in applications such as catalytic oxidation for pollution control. Phosphates can occur in low-temperature ash deposits to create blinding effects, and they also occur with arsenic and can cause catalyst poisoning (5).

EXPERIMENTAL

Objective and Goals

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Bench-scale combustion testing accomplishes two main objectives. The first is to obtain potentially useful information on SCR blinding propensity for several coals other than those used in the field test. Three coals are being field-tested: a blend of PRB coals at Baldwin, Black Thunder PRB at Columbia, and Beulah lignite at Coyote. A bench-scale thermogravimetric analysis (TGA) test program will be able to test six coals for SCR catalyst blinding and reactivity degradation testing. These bench-scale tests may also lead to more time-efficient and economical means of testing SCR blinding potential in the future. These tests may be conducted in collaboration with a project funded through the EERC's Center for Air Toxic Metals®, which is focused on SCR catalyst impacts on mercury transformations.

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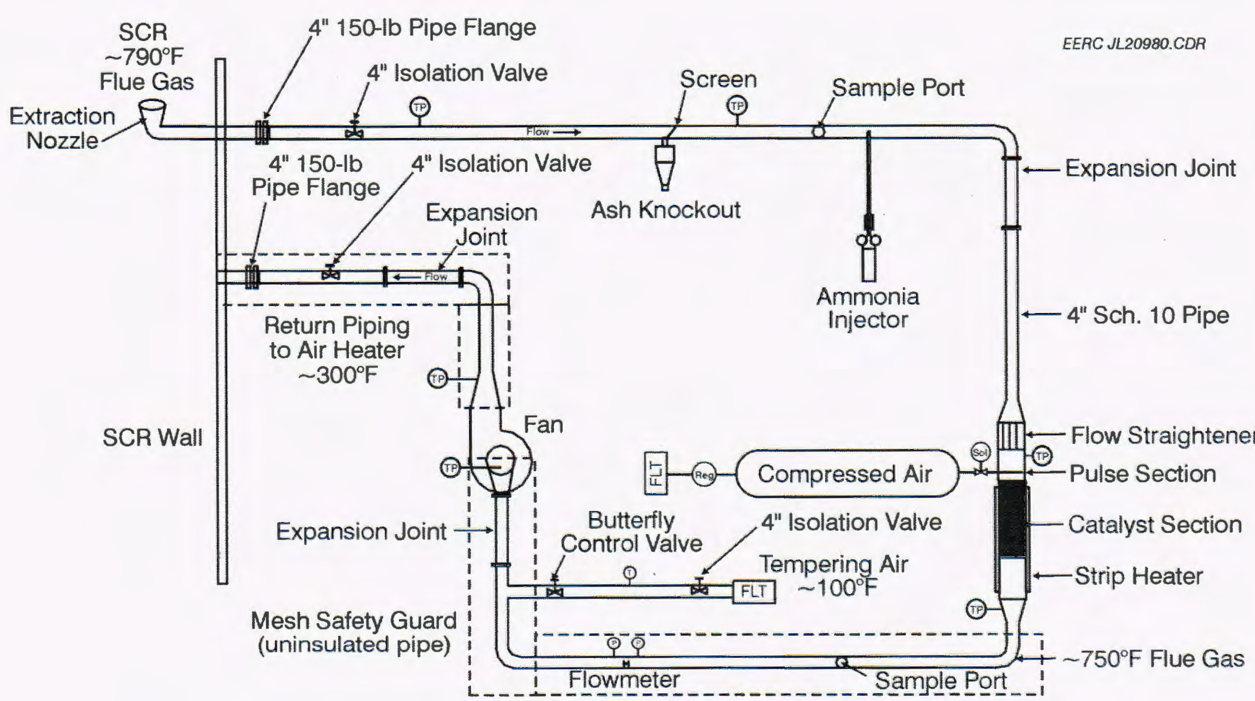

Figure 1. Conceptual schematic of the SCR reactor slipstream field test unit.

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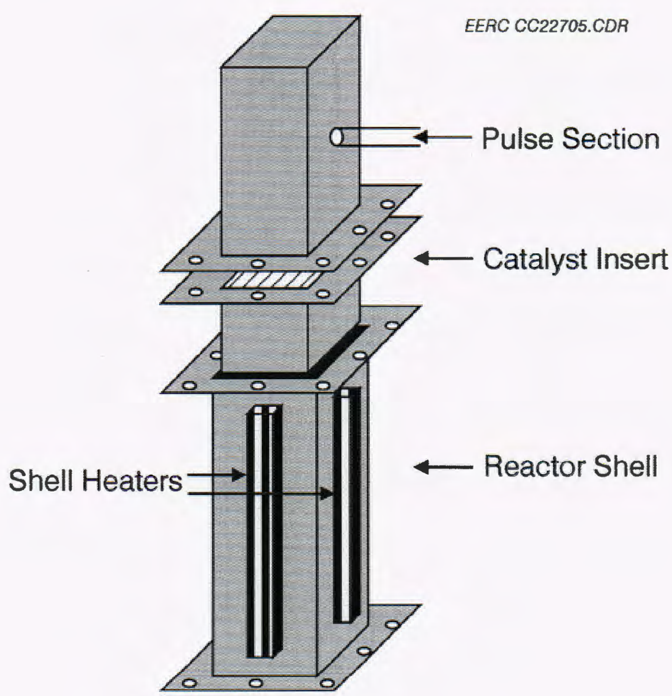

Figure 2. SCR catalyst section.

For catalyst inspection or replacement, the catalyst section can be unbolted and slid out from the reactor (support brackets hold the remaining reactor pieces in place). Once a catalyst reactor section is removed, the top catalyst holder can be removed and the section(s) of interest removed by pushing it up from the bottom and out the top. A new section is then inserted from the top to replace the piece removed.

Task 4 – SCR Test Chamber Installation and Data Collection at Utility Host Sites

SCR test chambers will be installed in a slipstream arrangement at three utility boilers. Since SCR masking or blinding phenomena occur over longer periods of time, the SCR test chamber will be kept in a slipstream arrangement in the region ahead of the air heater at each boiler for a period of 6 months. Upon installation of the test chamber at each boiler unit, measurements of flue gas temperature, composition, and velocity will be taken using portable equipment. Periodic checks of the chamber by a trained boiler technician will be made to ensure experimental quality. The test chamber will be constructed so that periodic samples of the catalyst can be removed to assess reactivity as a function of time. Testing was initiated at the Baldwin Station in July 2001 and completed in December 2002. Installation at the Columbia Station began in March 2002 using the second slipstream test chamber. After permitting delays were resolved, the field test was initiated in October 2002. That test is scheduled for termination in November 2003. The field test included shutdowns. The SCR slipstream test chamber used at the first utility boiler site test chamber will be installed at the third utility boiler at the Coyote Station with installation of fresh catalyst.

Task 5 – Determination of SCR Blinding Mechanisms

Upon completion of the SCR chamber experiments at each plant, the SCR catalyst section in the test chamber will be sent to Hitachi in Japan for measuring any degradation in catalyst reactivity. These are standard tests routinely performed by catalyst vendors.

The nature of any ash deposition or ash–catalyst reactions will be investigated by the EERC using SEM, x-ray diffraction, and other analytical techniques. These same techniques and other fine-particle SEM analytical techniques will be used to analyze the entrained ash samples collected at the field sites. Correlations between the physical and chemical characteristics of any ash deposits on the SCR test section and entrained ash sample collected at the chamber inlet, and the coal inorganic composition will be made to discern mechanisms of SCR blinding. Minor and trace element analyses of deposits and SCR catalyst material will be performed in order to evaluate the effects of As, Sr, and Ba, which may act as poisoning agents.

Task 6 – Final Interpretation, Recommendations, and Reporting

Task 6 will bring together all of the data interpretation on SCR-blinding mechanisms and mercury conversion efficiencies. Potential cleaning methods, if necessary, or other blinding remedial measures will be recommended. Project reporting, periodic meetings with all consortium members, and efficient transfer of information will be facilitated in this task. Quarterly interim reports and a final report will be submitted to project sponsors at the end of the project.

RESULTS AND DISCUSSION

Activities under Tasks 4 and 5 were continued during this quarter

Task 4 – SCR Test Chamber Installation and Data Collection at Utility Host Sites

SCR reactors were in operation at two sites during this quarter. The 6-month catalyst samples in the reactor at Columbia Station were removed in November when the field test was terminated. The trend over the 6-month test showed the dP across the catalyst increasing as deposits accumulate on the catalyst surfaces. Catalyst cleaning decreased the dP, but never to the rate of fresh catalyst. An in-depth analysis will be included in the final report. The reactor retrieved from Baldwin Station was installed at the Coyote Station in August. The unit seems to be plugging at a higher rate than either of the two previous installations. After approximately 2700 hours and a catalyst change, the pressure drop at the Coyote reactor increased at a much higher rate than the Baldwin or Columbia reactors. Currently, the pressure drop at the Coyote station has stabilized to 0.9 in. of H_2O.

Figures 3–8 show the reactor and catalyst at Coyote Station after 2 months of field testing. Figure 3 shows the flue section just upstream of the SCR catalyst in the reactor. Some deposition is visible in the photograph. Additional fouling on the flow straighteners farther upstream of the SCR catalyst is visible in Figure 4. The SCR catalyst section after 2 months of operation is presented in Figure 5. The left side of the catalyst is indicative of the amount of fouling present,

EERC CC22582.CDR

Figure 3. Inlet to the catalyst section of the SCR reactor view looking upstream; Coyote Station at the 2-month test interval.

EERC CC22580.CDR

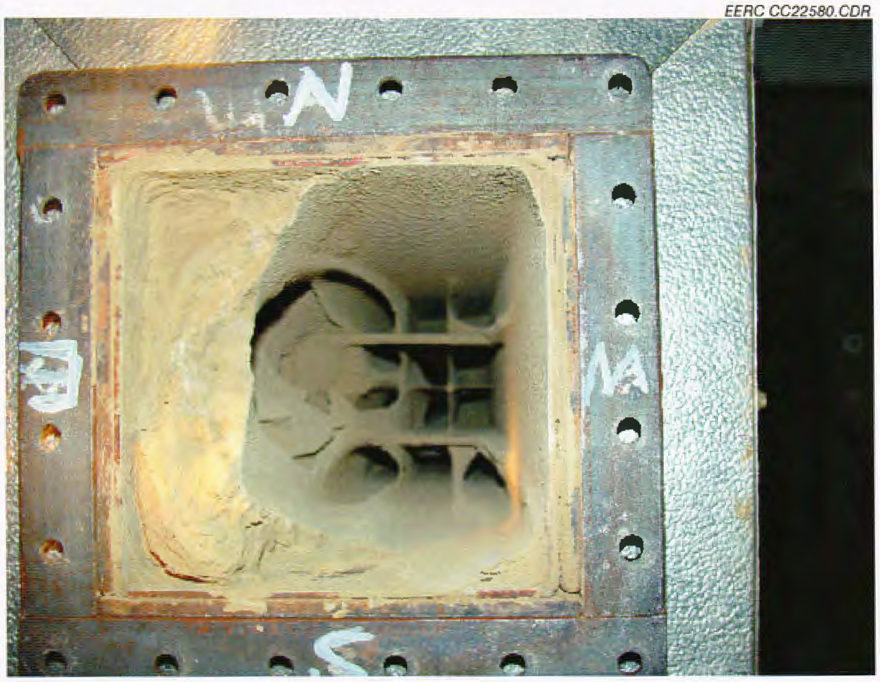

Figure 4. Ash deposition on the flow straighteners upstream of the catalyst section of the SCR reactor view looking upstream; Coyote Station at the 2-month test interval.

EERC CC22584.CDR

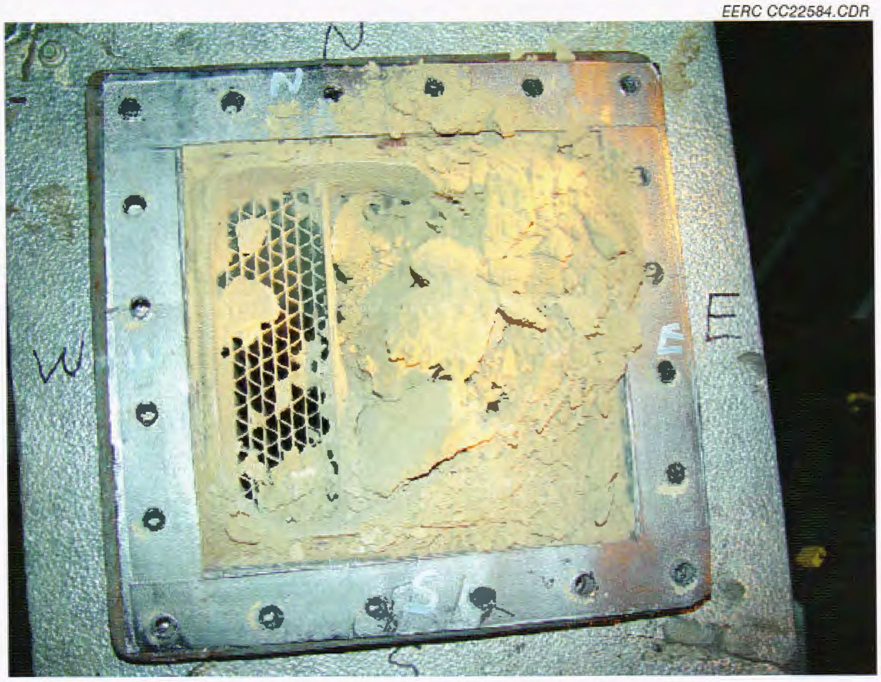

Figure 5. Inlet of the SCR catalyst section after 2 months of field testing at the Coyote Station.

EERC CC22581.CDR

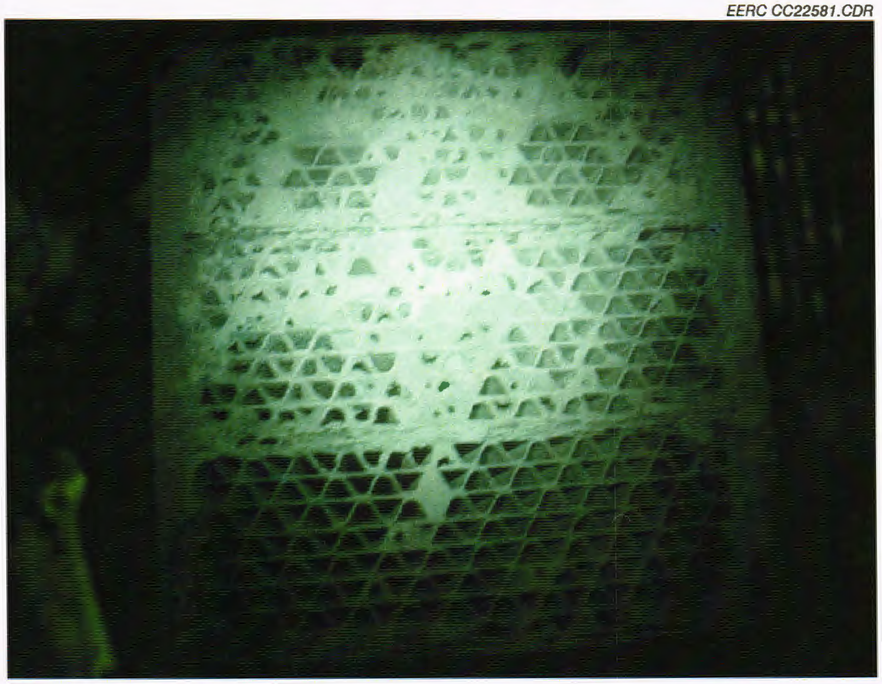

Figure 6. Outlet of the catalyst section of the SCR reactor; view looking upstream; Coyote Station at the 2-month test interval.

EERC CC22583.CDR

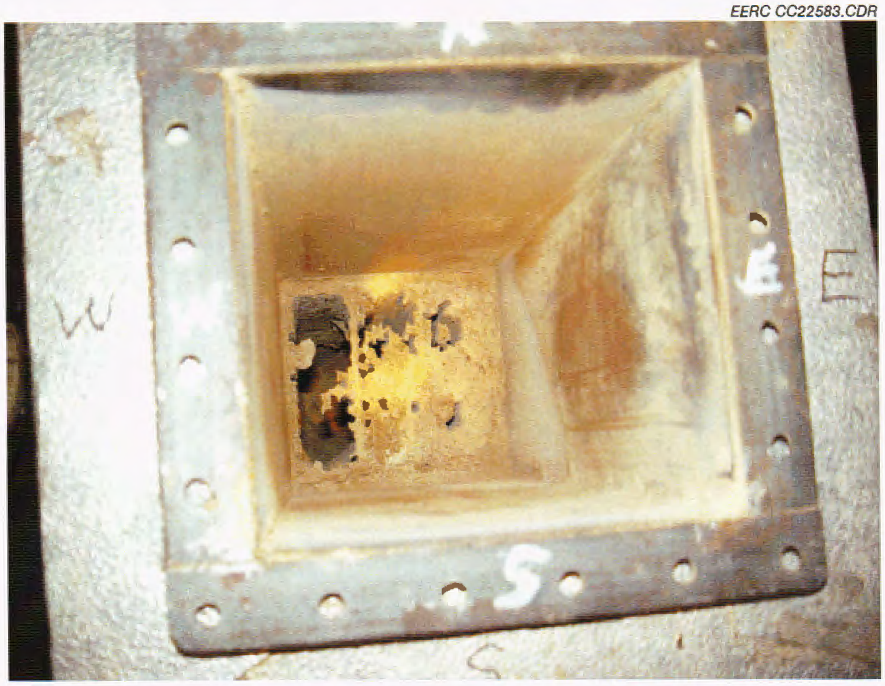

Figure 7. Inlet of the catalyst section of the SCR reactor after catalysts have been removed; view looking downstream; Coyote Station at the 2-month test interval.

EERC CC22585.CDR

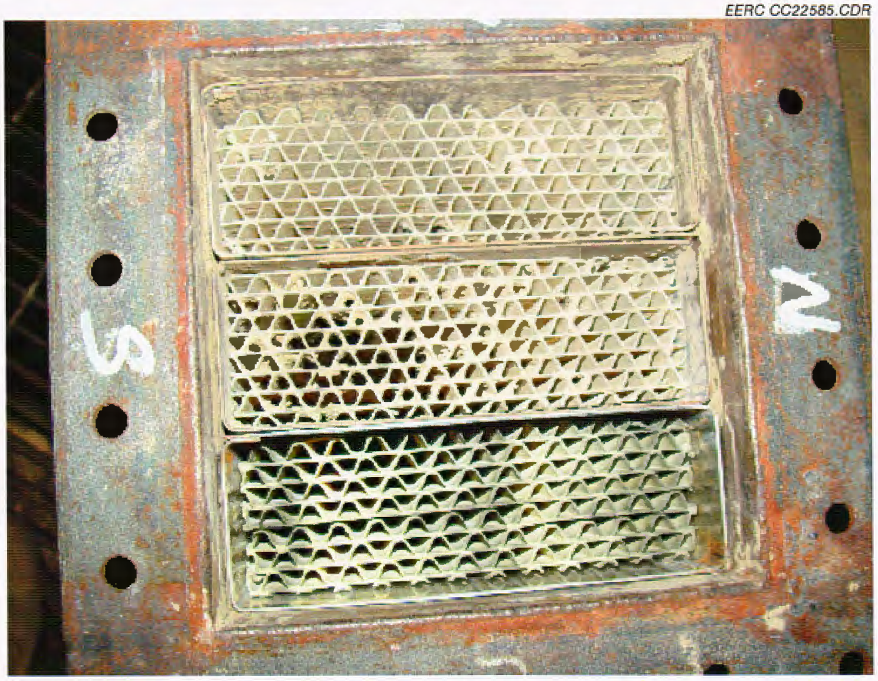

Figure 8. Catalyst ready for the SCR reactor assembly. Two physically cleaned, previously exposed catalysts at the top, new catalyst at the bottom; Coyote Station at the 2-month test interval.

whereas the ash present on the right side of the catalyst fell from the upstream flue section when the joint was separated. Nevertheless, the entire surface appears coated with ash deposits, and some of the catalyst channels were plugged. The catalyst exit, Figure 6, shows the plugged channels. Figure 7 shows the ash layer remaining after the catalyst was removed for cleaning and retrieval of the 2-month sample. The 4- and 6-month catalyst sections were hand cleaned with a brush as well as possible and reinserted into the SCR reactor with a new section of catalyst. Figure 8 shows the catalyst section of the SCR reactor ready for assembly with the previously exposed sections of catalyst above the new section of catalyst.

Task 5 – Determination of SCR Blinding Mechanisms

A database to house all of the SEM data is under construction. SEM analyses of the 2- and 4-month Columbia catalysts have been completed. These data will be compiled in the next quarter. Preliminary review of the morphology data indicates that sulfation of small calcium oxide-rich particles appears to be the dominant mechanism of particle bonding and pore filling on the catalyst surfaces. The presence of the catalyst appears to enhance the sulfation rates. Phosphates do not appear to be contributing to the particle bonding in the samples examined to date. All three catalyst samples from the Columbia Station are being sent to Hitachi for reactivity testing in November following termination of that field test.

Reactivity tests results for the Baldwin Station samples extracted after 1440, 2800 and 4000 operating hours were received from Haldor-Topsoe. The tested catalyst was a DNX-664

(#8053/00) cut to following dimensions: 7.6 in. × 2.6 in., length 19.7 in. Figures 9–11 show the deposition on the inlet and outlet of each catalyst sample. Some surface clogging is observed on one corner the catalyst front edge at 1440 hours of exposures (Figure 9). The clogging picture does not indicate that an oblique entrance angle should be responsible; a lower soot-blowing pressure in that corner is more likely the reason. Like the 1440-hour sample, surface clogging is observed on one corner the catalyst front edge after 2800 hours of exposure (Figure 10). A total of 24 out of 81 channels was clogged, including channels clogged by the support bar. Very heavy clogging was observed on the 4000-hour sample (Figure 11). The deposits on the front edge, however, did not look like popcorn or agglomerated fly ash but more like something that had been melted and solidified on the surface. An inductively coupled plasma (ICP) scan for elements, combined with a wet chemical analysis of the deposit, revealed 47.2% SO_3, 5.6% CaO, 3.8% Al_2O_3, 1.4% Fe_2O_3, 1.7% MgO, 6.7% Na_2O, and <500ppm C; the missing 33.6% is probably NH_3 or H_2O, which are not detected by the ICP scan. In other words, the clogging seems to originate from operation below the H_2SO_4 or NH_4HSO_4 dew point. Note that the front deposits were removed before the activity test.

The catalyst samples and a reference sample from the original catalyst was tested in a SCR reactor (1.81 in. × 1.81 in.). The test conditions were as follows: gas flow composition of 3% O_2, 6% H_2O, 500 ppm SO_2, and 350 ppm NO_x in N_2 carrier gas; a superficial gas velocity of $1.87 Nm^3/m^2/s$; and a reaction temperature at 662°F. The activity was measured with an NH_3/NO_x ratio of 1.10. The activity is given as standard cubic feet per hour (scfh)/ft^3 and defined as:

$$k_{\text{-NOx}} = \text{Gas flow/Catalyst volume} \times \log(\text{NO}_x\ \text{inlet/NO}_x\ \text{outlet})$$

The measured activities are given in Table 1. The uncertainty on each activity measurement is typically 3%.

The results indicate that the activity of the 4000-hour sample is 86% of the initial activity, corresponding to a logarithmic deactivation rate of 32%/10.000 hour.

EERC CC22772.CDR

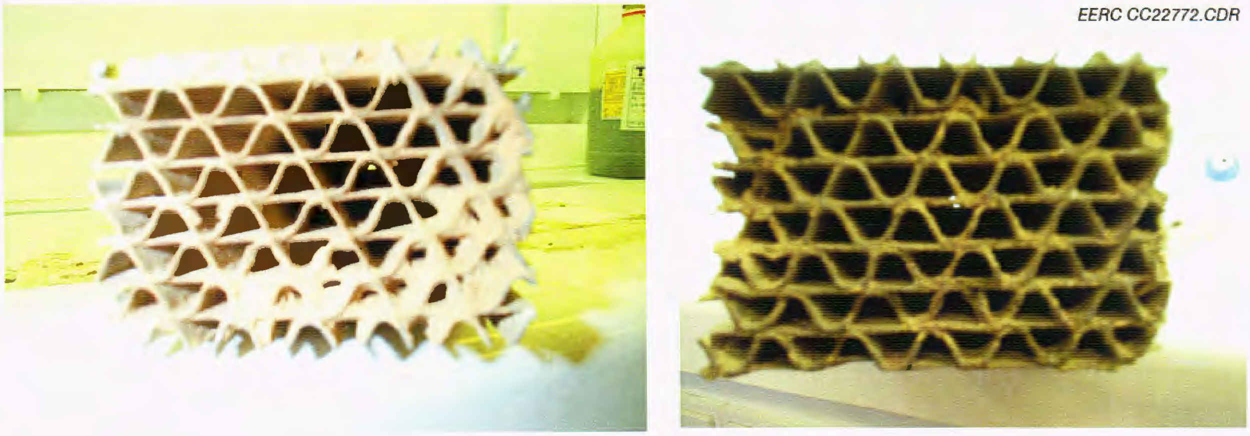

Figure 9. Inlet and outlet of the catalyst after 1440 hours of exposure to bituminous fly ash at the Baldwin Station.

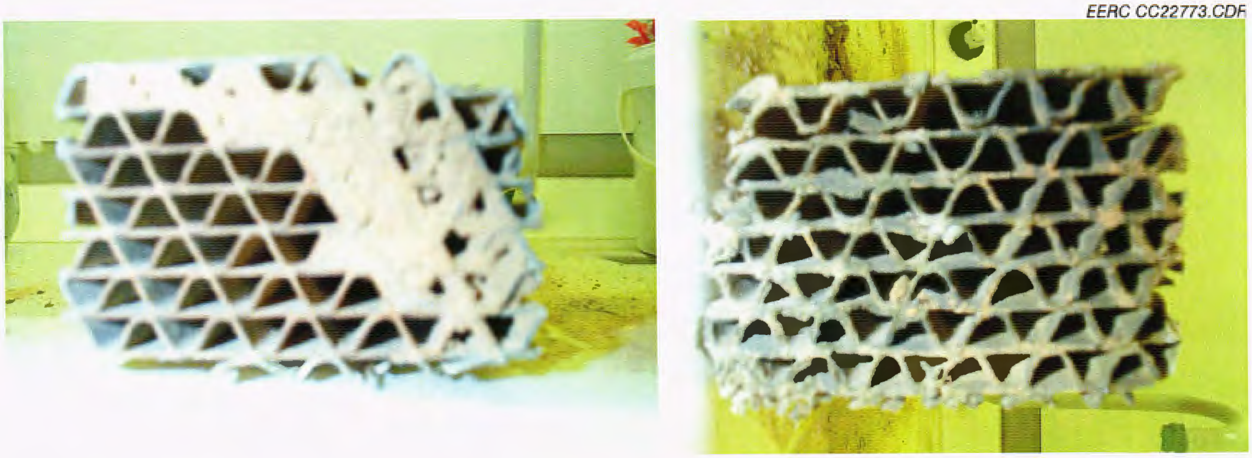

Figure 10. Inlet and outlet of the catalyst after 2800 hours of exposure to bituminous fly ash at the Baldwin Station.

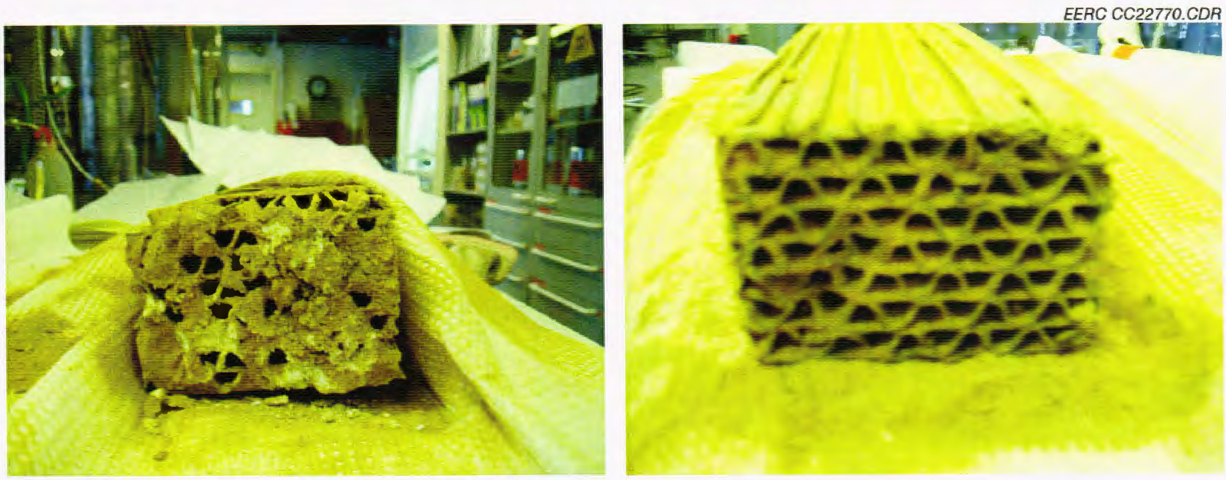

Figure 11. Inlet and outlet of the catalyst after 4000 hours of exposure to bituminous fly ash at the Baldwin Station.

Table 1. Measured NO_x Activity of the Catalyst

Sample	k_{NO_x} 662°F, scfh/ft^3	k/k_0 662°F
Reference	22,808	
1440 hour	23,400	1.03
2800 hour	21,361	0.94
4000 hour	19,510	0.86

The center of each catalyst samples was examined for the presence of poisons. Table 2 compares the surface composition of each sample. Note that only soluble K and Na are strong poisons. As, P, Ca, and Mg are weak poisons, and the rest of the elements are without chemical

Table 2. Surface Chemistry of the Catalyst Interior Comparing Accumulation of Potential Catalyst Poisons

Parameter	Unit	Reference	1440 hour	2800 hour	4000 hour
K (soluble)	ppmw	120	505	570	640
K (total)	ppmw	<840	945	670	735
Na (soluble)	ppmw	500	2040	2285	2040
Na (total)	ppmw	900	2730	2440	3050
As	ppmw	20	<5	<5	15
P	ppmw	2500	1650	1100	955
Ca	wt%	2.0	1.94	2.68	3.21
Mg	wt%	<0.08	0.22	0.15	0.25
Fe	wt%	<0.08	0.25	0.14	0.29
S	wt%	0.01	0.48	.058	0.70

effect. Compared with a fresh reference, only Na and S have accumulated significantly. The S accumulation is quite typical and due to equilibrium-determined uptake of the titania carrier. The As accumulation is low compared with bituminous coal-fired applications.

The catalysts were also analyzed for internal surface area using a Brunauer-Emmet-Teller instrument. The drop in surface area, indicated in Table 3, is quite typical and results from an initial thermal sintering during the first 500–1000 operating hours. After 1000 hours, the catalyst surface area will be in equilibrium with the given operating temperature, and no further sintering takes place. The initial sintering observed on these samples has insignificant effect on the observed activity.

Table 3. Internal Surface Area of the Catalyst Samples

Sample	hbet, m^2/g
Reference	68
1440 hour	48
2800 hour	42.5
4000 hour	46

The surfaces of the 1440-hour and 2800-hour samples were examined using SEM. Figure 12 shows a wall profile and the catalyst surface of the 1440-hour sample. Only small amounts of fly ash were observed on the catalyst surface, some fly ash particulate is present as white spots on the right picture. A submicrometer fouling layer could not be observed, which otherwise is typical for deactivation with PRB subbituminous firing. Figure 13 shows a wall profile of the 2800-hour catalyst sample with some surface fouling. A decreased porosity was observed in the outermost 1micrometer. An energy-dispersive spectrometry (EDS) analysis showed some Ca and S enrichment at the surface consistent with initial $CaSO_4$ fouling.

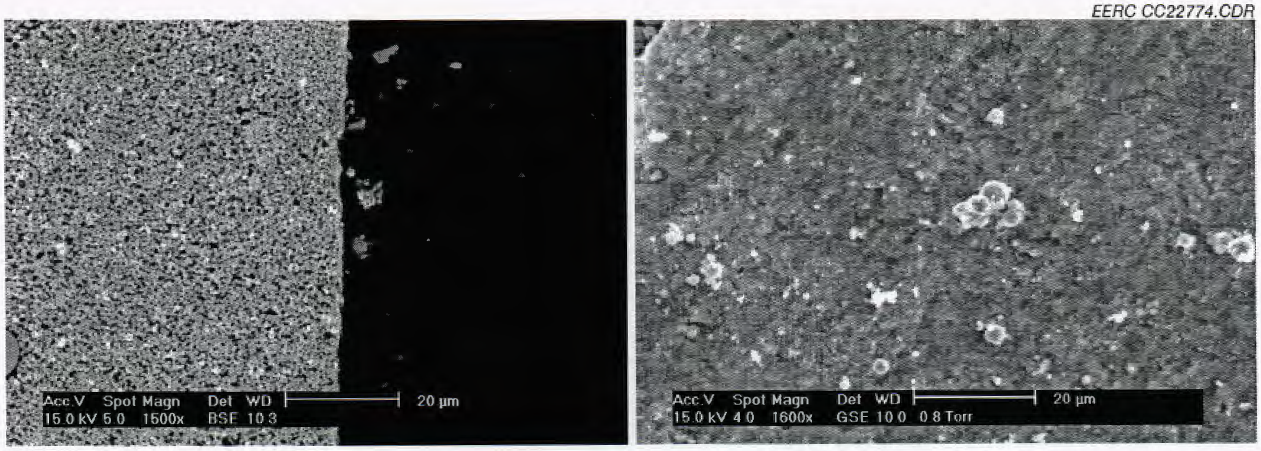

Figure 12. Wall profile (magnified 1500×) and surface (magnified 1600×) of the catalyst after 1400 hours of exposure to bituminous fly ash at the Baldwin Station.

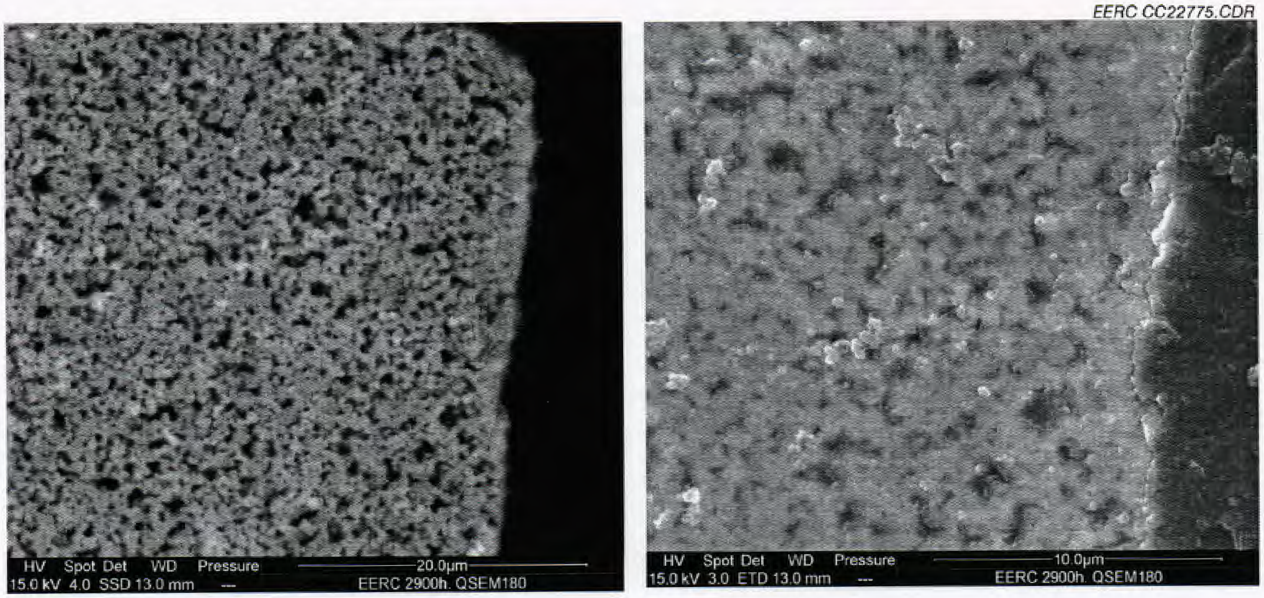

Figure 13. Wall profile and surface (magnified >1600×) of the catalyst after 2800 hours of exposure to bituminous fly ash at the Baldwin Station.

The activity measurements and the chemical analysis indicate that after 4000 hours of operation of DNX-664 at Dynegy Baldwin, 14% catalytic deactivation was observed. Initial surface fouling by $CaSO_4$ was observed. The deposit at the catalyst front was identified as a condensed material, probably NH_4HSO_4.

FUTURE WORK – NEXT QUARTER

Work in the upcoming quarter will involve site visits and data reduction. The 4- and 6-month catalyst samples will be removed from the Coyote Station site in January and March 2004. Flow data and catalyst morphology from all three sites will be analyzed as they become available. Quarterly reports will be prepared. The Coyote Station field test is scheduled to be terminated in March 2004.

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May 14, 2004

Mr. Harvey Ness
Director
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Bismarck, ND 58502

#8 No Payment due
Final report next –

Dear Mr. Ness:

Subject: Evaluation of Potential SCR Catalyst Blinding During Coal Combustion
Contract No. FY-00-XXXVI-100

Enclosed is the January 1 – March 31, 2004, Quarterly Status Report for the subject task. If you have any questions, please call me at (701) 777-5177, fax at (701) 777-5181, or e-mail at sbenson@undeerc.org.

Sincerely,

Steven A. Benson
Senior Research Manager

SAB/kal

Enclosure

EERC
Energy & Environmental Research Center

EVALUATION OF POTENTIAL SCR CATALYST BLINDING DURING COAL COMBUSTION

Quarterly Report

(For the period January 1 – March 31, 2004)

Prepared for:

Mr. Harvey Ness

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Contract No. FY-00-XXXVI-100

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May 2004

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INTRODUCTION

The U.S. Environmental Protection Agency (EPA) rule of New Source Performance Standards, under the authority of the 1990 Clean Air Act Amendments, established new NO_x emission standards and defines selective catalytic reduction (SCR) as a "best demonstrated system" for NO_x control in utility and industry boilers, which may not be true for lower-rank coal boilers. Recent studies on German coals show an impact of sodium, calcium, sulfur, and phosphorus on the performance of SCR catalysts. Over a period of time, blinding of the SCR catalyst occurred, resulting in decreased conversion efficiency. Extrapolation of the German experience to U.S. applications reveals that catalyst deactivation may occur because of the high alkaline metals, sulfur, arsenic, and SO_3 contents in some U.S. coals. SCR systems operate in flue gas ducts downstream of the economizer and just prior to the air heater where entrained ash or dust can deposit. The high alkali and alkaline-earth element contents (sodium and calcium) of entrained fly ash generated from combustion of low-rank coals react with gaseous SO_2 to form low-temperature sulfate-based ash deposits on catalyst surfaces. Deposit buildup of this type can effectively blind or mask the catalyst, diminishing its reactivity for converting NO_2 to N_2 and water and potentially creating increased ammonia slip.

The North Dakota challenge and petition of the NO_x ruling was denied by EPA with explanations that include insufficient evidence to show that catalyst poisoning from alkali metals occurs with low-rank coals. Thus research is needed to determine the true extent of potential SCR blinding for lower-rank coals. If masking of SCR catalyst material is indeed an issue, then SCR technology may not be the best available technology for NO_x control at North Dakota utility sites, and the EPA ruling may need to be amended. Other options that may surface as results of such research include providing technological and fundamental science and engineering knowledge for manufacturing SCR catalysts that resist blinding from low-rank coal-type ash material or designing SCR systems that can be cleaned online.

The primary goal of this Energy & Environmental Research Center (EERC) project is to determine the potential of low-rank coal ash to cause blinding or masking of SCR catalysts. A secondary goal will be to determine the degree of elemental mercury conversion across the catalysts. Specific objectives include 1) identify candidate coals and blends for testing under bench-scale conditions; 2) conduct bench-scale testing to screen coals and identify key conditions for testing at the full scale; 3) design and construct a SCR slipstream test chamber for sampling at full-scale facilities; 4) conduct testing at full-scale facilities; 5) identify SCR blinding mechanisms, rates, and cleaning methods as well as mercury conversion efficiencies; and 6) interpret data, prepare a report, and attend sponsor meetings to develop recommendations related to expected catalyst life and degree of mercury conversion.

WORK PLAN

The work plan for this project consists of six tasks outlined as follows:

- Task 1 – Identification of Test Coals and Utility Host Sites
- Task 2 – Bench-Scale Testing and Screening
- Task 3 – Design and Construction of the SCR Slipstream Test Chamber
- Task 4 – SCR Test Chamber Installation and Data Collection at Utility Host Sites
- Task 5 – Determination of SCR Blinding Mechanisms
- Task 6 – Final Interpretation, Recommendations, and Reporting

BACKGROUND

Recent studies conducted by Hartenstein et al. (1) showed an impact of sodium, calcium, sulfur, and phosphorus on the performance of SCR catalysts when German coals were fired. Over a period of time, blinding of the SCR catalyst occurred, resulting in decreased conversion efficiency. Extrapolation of the German experience to U.S. applications reveals that catalyst deactivation may occur because of the high alkaline metals, sulfur, and SO_3 contents in some U.S. coals. SCR systems operate in flue gas ducts downstream of the economizer and just prior to the air heater where entrained ash or dust can deposit. The high alkali and alkaline-earth element contents (sodium and calcium) of entrained fly ash generated from combustion of low-rank coals react with gaseous SO_2 to form low-temperature sulfate-based ash deposits on catalyst surfaces.

The mechanisms for this type of low-temperature deposition have been examined and modeled in detail at the EERC in work termed Project Sodium and Project Calcium in the early 1990s; however, the focus of those projects was specific to primary superheater and economizer regions of boilers and not SCR systems (2–3). Deposit buildup of this type can effectively blind or mask the catalyst, diminishing its reactivity for converting NO_2 to N_2 and water and potentially creating increased ammonia slip (3). Arsenic and phosphates, which are not uncommon in low-rank coals, may also play a role in catalyst degeneration. Arsenic is a known catalyst poison (4) in applications such as catalytic oxidation for pollution control. Phosphates can occur in low-temperature ash deposits to create blinding effects, and they also occur with arsenic and can cause catalyst poisoning (5).

EXPERIMENTAL

Objective and Goals

The goals of this project are to determine the potential of low-rank coal ash to cause blinding or masking of SCR catalysts. Specific objectives include 1) identify candidate coals and blends for testing under bench-scale conditions; 2) conduct bench-scale testing to screen coals and identify key conditions for testing at the full scale; 3) design and construct an SCR slipstream test chamber for sampling at full-scale facilities; 4) conduct testing at full-scale facilities;
5) identify SCR blinding mechanisms, rates, and cleaning methods; and 6) interpret data, prepare a report, and attend sponsor meetings to develop recommendations related to expected catalyst life and degree of mercury conversion.

PLANNED SCOPE OF WORK

Task 1 – Identification of Test Coals and Utility Host Sites

This task includes a kickoff meeting between the multiclient consortium members to determine which utilities and boiler units will have the SCR slipstream test chamber installed in them and which coals should be tested. Three utility host sites were selected for long-duration tests using the SCR slipstream test chamber, including at least one lignite boiler and one Powder River Basin (PRB) boiler. Baldwin Station in Baldwin, Illinois, has a cyclone-fired PRB boiler; Columbia Station in Portage, Wisconsin, burns PRB coal; and Coyote Station in Beulah, North Dakota, burns Beulah lignite coal. The coals burned as part of the full-scale slipstream SCR testing are part of the test pool; in addition, other coals that sponsors may want to test at the bench scale, which would not be tested at a utility host site, will be selected and acquired. The time-consuming nature of the utility field testing precludes the testing of multiple coals at full-scale units. A maximum of six test coals will be selected and acquired for this program. A final objective of Task 1 will be to finalize the project work plan.

Task 2 – Bench-Scale Testing and Screening

Bench-scale combustion testing accomplishes two main objectives. The first is to obtain potentially useful information on SCR blinding propensity for several coals other than those used in the field test. Three coals are being field-tested: a blend of PRB coals at Baldwin, Black Thunder PRB at Columbia, and Beulah lignite at Coyote. A bench-scale thermogravimetric analysis (TGA) test program will be able to test six coals for SCR catalyst blinding and reactivity degradation testing. These bench-scale tests may also lead to more time-efficient and economical means of testing SCR blinding potential in the future. These tests may be conducted in collaboration with a project funded through the EERC's Center for Air Toxic Metals®, which is focused on SCR catalyst impacts on mercury transformations.

The second objective of the bench-scale SCR reaction chamber testing is to obtain fundamental information on the formation of phases and components that makeup SCR blinding deposits. Some studies have observed phosphate-rich ash deposits making up SCR deposits. Calcium aluminum phosphate minerals have been observed in North Dakota lignites and PRB coals, and there may be potential problems if, indeed, certain low-temperature ash deposition mechanisms for SCR systems involve phosphatic materials. Information on how these phosphate-rich phases develop and form will be invaluable for predicting SCR deposition and formulating ash deposit mitigation measures.

All test coals will be analyzed for proximate and ultimate analyses, heating value, and bulk inorganic composition using standard American Society for Testing and Materials (ASTM) procedures. Advanced analytical techniques using scanning electron microscopy (SEM) will be used to study fly ash and deposit characteristics.

Task 3 – Design and Construction of the SCR Slipstream Test Chamber

Two portable test chambers were constructed under this task for testing SCR masking at two low-rank coal boilers (i.e., PRB and lignite boilers). Each chamber will maintain the correct temperature, surface area, and orientation of SCR catalyst material while an isokinetically drawn slipstream of the boiler flue gas is passed through the chamber using a purchased induced-draft fan.

The slipstream system is presented in Figure 1. A purge section is installed ahead of the reactor to remove accumulated dust. Thermocouple and pressure taps are located in the purge sections for measurements before and after each section. The SCR reactor is an approximately

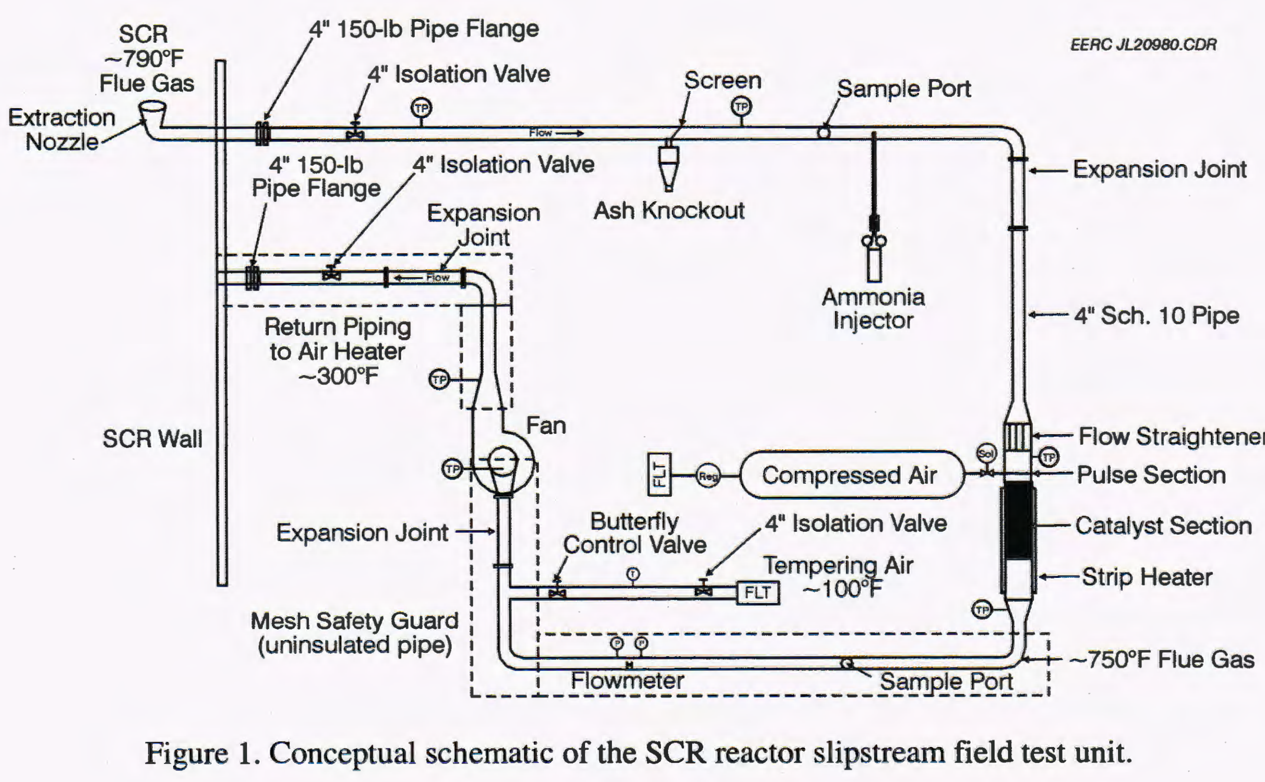

Figure 1. Conceptual schematic of the SCR reactor slipstream field test unit.

7.5-in.-square by 8-ft-long steel housing that consists of two sections: one flow straightener and a catalyst test section. Support brackets located on the piping entering and leaving the reactor will enable individual sections of the SCR to be removed. Strip heaters are installed on the catalyst section, and the entire housing is insulated for temperature control. A remote computer located at the EERC controls the reactor, with an on-site computer for monitoring purposes. Several reactor temperatures, pressure drop across the catalyst, and pressure drop across an orifice meter are monitored. Additional slots are available on the data acquisition boards for future equipment and monitors. To achieve an approach velocity of 5.2 m/s (17.0 ft/s), approximately 400 acfm (200 scfm) of flue gas is extracted from the convective pass of the utility boiler immediately downstream from the economizer at a temperature in the 700°F range. The total gas flow through the reactor represents a thermal load of approximately 300 kW.

The first section of the reactor is a short length (6-in.) used as a flow straightener. The catalyst test section is 3.28 ft (1 m) in length. The catalyst section consists of three 2.5-in. × 7.5-in. plate-type sections. A steel catalyst holder holds the catalyst pieces together inside the reactor (Figure 2). The catalyst holders are located on each end of the catalyst section. The holder consists of an angle iron welded together in a square with bars spanning between two of the flanged sides. One leg of the angle is sandwiched between the reactor shell flanges, and the other holds the catalyst sections tightly together in place. The holder keeps the catalyst away from the reactor shell, prevents flow around the catalyst, and allows for easy removal of the catalyst from the reactor.

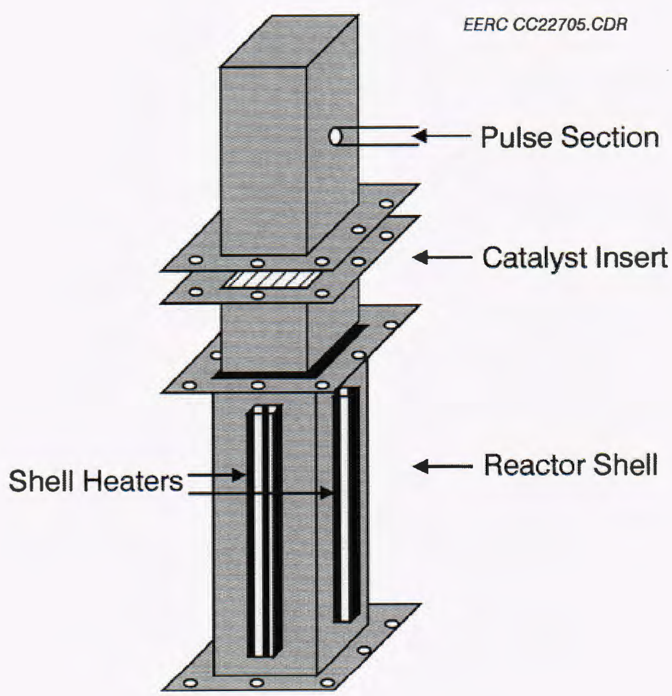

Figure 2. SCR catalyst section.

For catalyst inspection or replacement, the catalyst section can be unbolted and slid out from the reactor (support brackets hold the remaining reactor pieces in place). Once a catalyst reactor section is removed, the top catalyst holder can be removed and the section(s) of interest removed by pushing it up from the bottom and out the top. A new section is then inserted from the top to replace the piece removed.

Task 4 – SCR Test Chamber Installation and Data Collection at Utility Host Sites

SCR test chambers will be installed in a slipstream arrangement at three utility boilers. Since SCR masking or blinding phenomena occur over longer periods of time, the SCR test chamber will be kept in a slipstream arrangement in the region ahead of the air heater at each boiler for a period of 6 months. Upon installation of the test chamber at each boiler unit, measurements of flue gas temperature, composition, and velocity will be taken using portable equipment. Periodic checks of the chamber by a trained boiler technician will be made to ensure experimental quality. The test chamber will be constructed so that periodic samples of the catalyst can be removed to assess reactivity as a function of time. Testing was initiated at the Baldwin Station in July 2001 and completed in December 2002. Installation at the Columbia Station began in March 2002 using the second slipstream test chamber. After permitting delays were resolved, the field test was initiated in October 2002. That test is scheduled for termination in November 2003. The field test included shutdowns. The SCR slipstream test chamber used at the first utility boiler site test chamber will be installed at the third utility boiler at the Coyote Station with installation of fresh catalyst.

Task 5 – Determination of SCR Blinding Mechanisms

Upon completion of the SCR chamber experiments at each plant, the SCR catalyst section in the test chamber will be sent to Hitachi in Japan for measuring any degradation in catalyst reactivity. These are standard tests routinely performed by catalyst vendors.

The nature of any ash deposition or ash–catalyst reactions will be investigated by the EERC using SEM, x-ray diffraction, and other analytical techniques. These same techniques and other fine-particle SEM analytical techniques will be used to analyze the entrained ash samples collected at the field sites. Correlations between the physical and chemical characteristics of any ash deposits on the SCR test section, the entrained ash sample collected at the chamber inlet, and the coal inorganic composition will be made to discern mechanisms of SCR blinding. Minor and trace element analyses of deposits and SCR catalyst material will be performed in order to evaluate the effects of As, Sr, and Ba, which may act as poisoning agents.

Task 6 – Final Interpretation, Recommendations, and Reporting

Task 6 will bring together all of the data interpretation on SCR-blinding mechanisms and mercury conversion efficiencies. Potential cleaning methods, if necessary, or other blinding remedial measures will be recommended. Project reporting, periodic meetings with all consortium members, and efficient transfer of information will be facilitated in this task. Quarterly interim reports and a final report will be submitted to project sponsors at the end of the project.

RESULTS AND DISCUSSION

Activities under Tasks 4 and 5 were continued during this quarter.

Task 4 – SCR Test Chamber Installation and Data Collection at Utility Host Sites

One portable slipstream SCR reactor was in operation at Coyote Station during this quarter. The 4-month catalyst samples in the reactor at Coyote Station were removed in January. Figures 3 and 4 show the test periods from 0 to 2 months and 2 to 4 months. The pressure drop across the catalyst upon installation was about 0.4 inches of water. After only 750 hours, the pressure drop was 1.5 inches of water, indicating significant plugging and blinding. Very aggressive air pulsing was conducted, with little success in removing the deposits. The pressure drop for the catalyst was over 2 times greater than the pressure drop observed for the Baldwin Station utilizing the same reactor and same catalyst. At about 1700 hours, the reactor was opened and cleaned, and a section of catalyst was removed for characterization. The pressure drop after cleaning was about 0.8 to 1.0 inches of water. The pressure drop did not increase as rapidly because of the higher velocities through the clean section of the catalyst.

Figure 5 compares the deposition on the catalyst at Coyote Station after 4 months of field testing with the sample catalyst type after 4 months at Baldwin Station. Both photographs show the inlet SCR catalyst section. The entire surface appears coated with ash deposits, and some of the catalyst channels were plugged. The most significant accumulation occurred at the Coyote Station, while some accumulation was noted for the Baldwin Station. The Coyote Station had some larger pieces of ash deposit material on the surface as well as plugging of the catalyst passages.

Task 5 – Determination of SCR Blinding Mechanisms

The characteristics of the ash materials that collected on the catalyst surfaces and pores were characterized by SEM and x-ray microanalysis, and in selected cases, x-ray diffraction was used to determine the crystalline phases present. The catalysts were sampled after 2, 4, and 6 months. The sections were sampled, and approximately 2.5-cm squares were mounted for SEM analysis on double-stick tape and in epoxy resin. The double-stick tape samples allowed for characterization of the external morphology of the particles and catalyst surface. The samples mounted in resin were cross-sectioned and polished, which allowed for more detailed and quantitative analysis of the bonding materials and materials that accumulated in the pores of the catalyst. Samples from the Columbia and Coyote Stations were analyzed during this quarter.

Columbia Station Deposits

The 2-month sample from the Columbia Station showed particles adhering to the surface and filling pores in the catalyst, as shown in Figure 6. Figure 6A shows the external morphology of the catalyst surface showing particles trapped in the pores of the catalysts. Chemical compositions of selected points are shown in Table 1. The 2-month sample shows significant evidence of sulfation after only 2 months of exposure. It appears to be more significant than that observed for the Baldwin 2-month sample. Figures 6B and 6C show higher-magnification

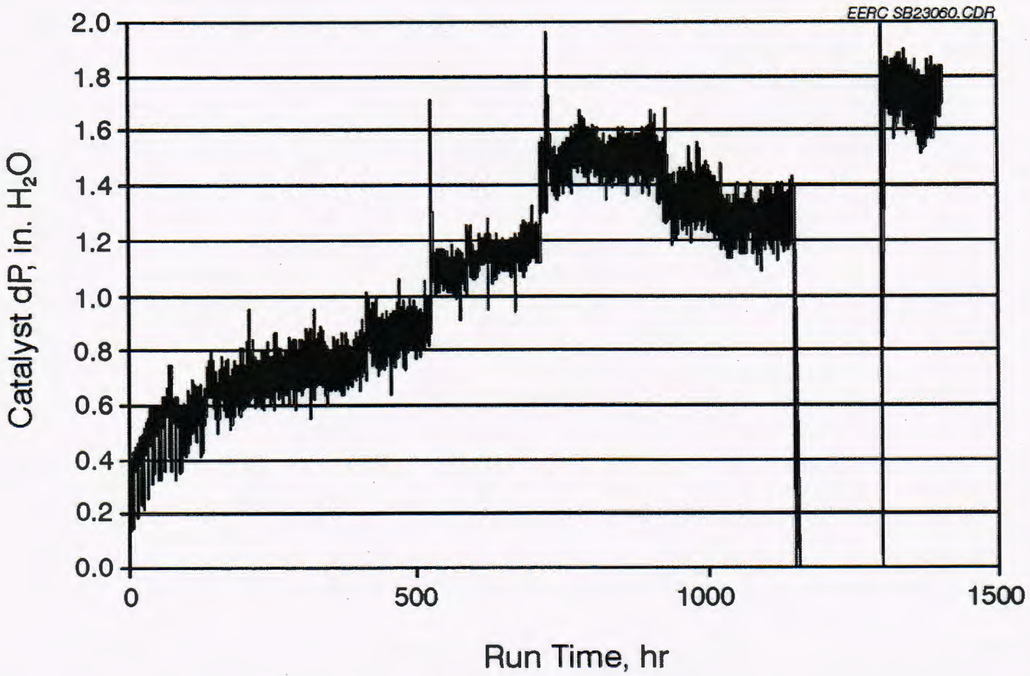

Figure 3. Catalyst pressure drop at Coyote Station at 0–2 months of operation.

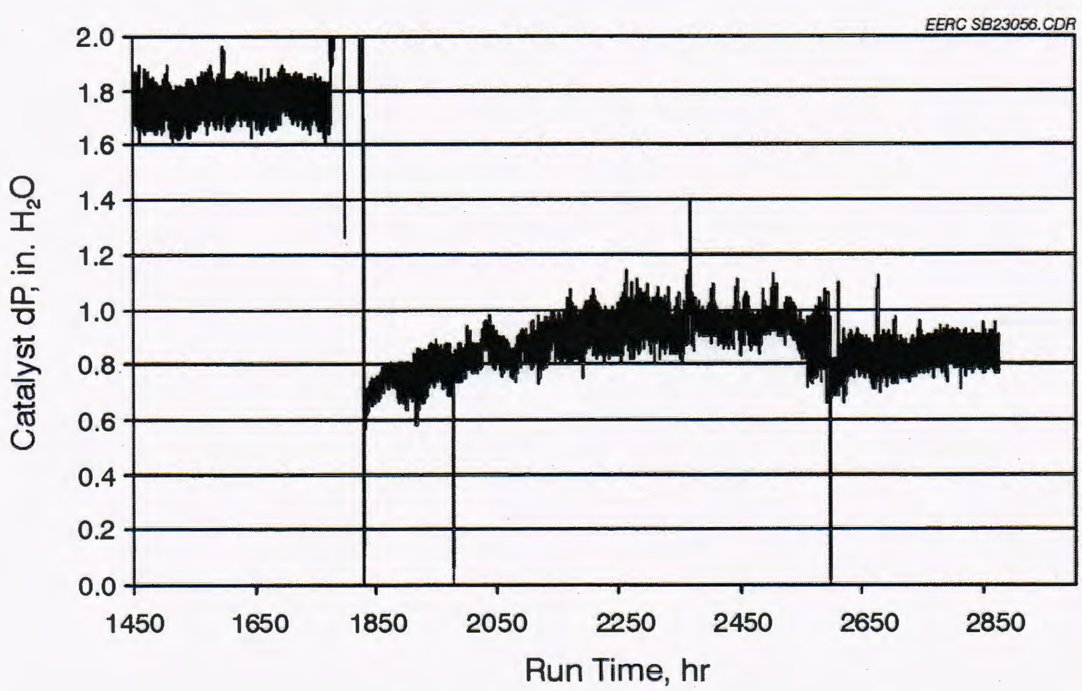

Figure 4. Catalyst pressure drop at Coyote Station at 2–4 months of operation.

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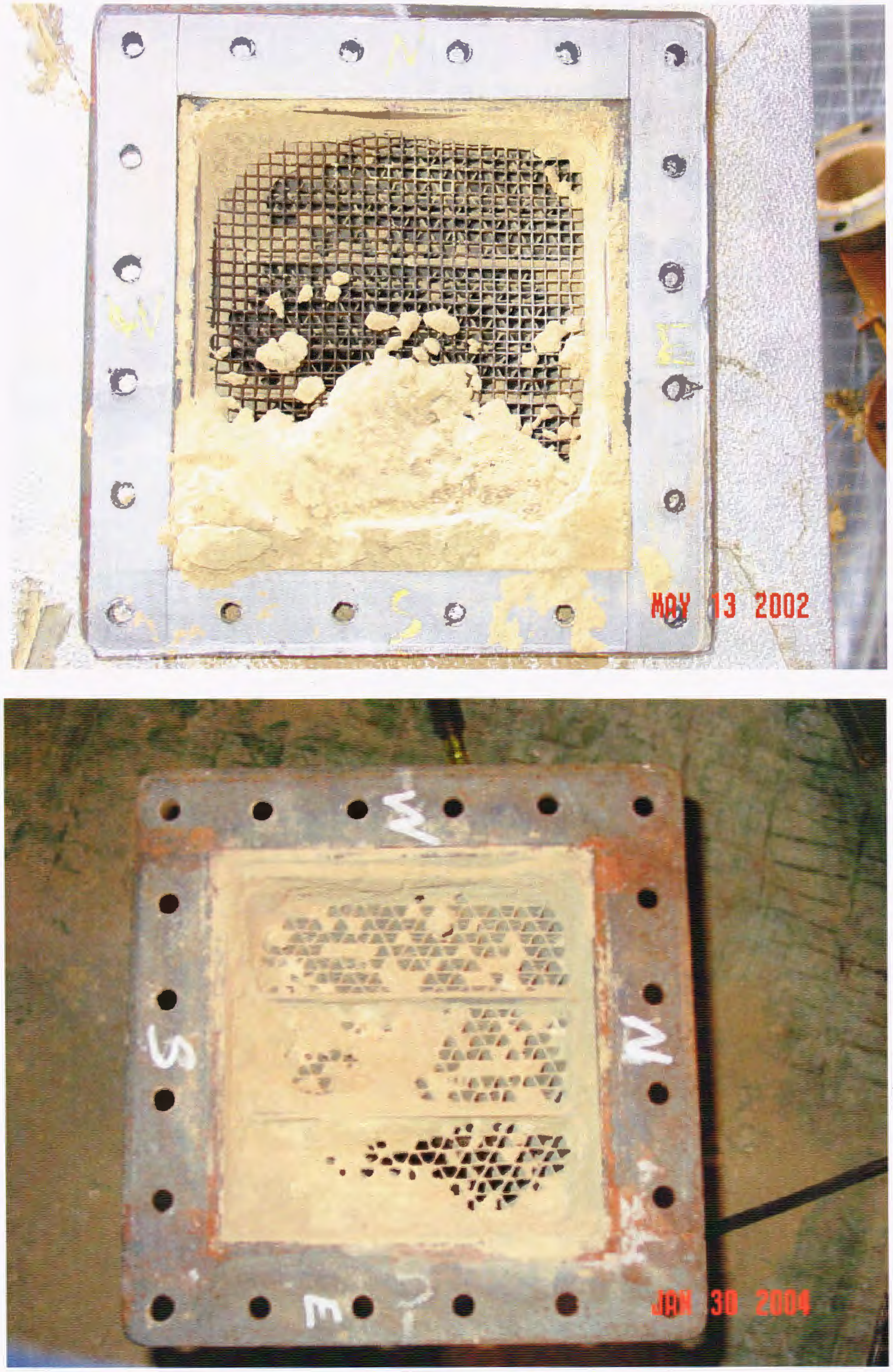

Figure 5. Pictures of catalyst inlet after about 4 months of exposure to flue gas and particulate. The top is the Haldor-Topsoe catalyst from Baldwin Station; the bottom is the Haldor-Topsoe catalyst at Coyote Station.

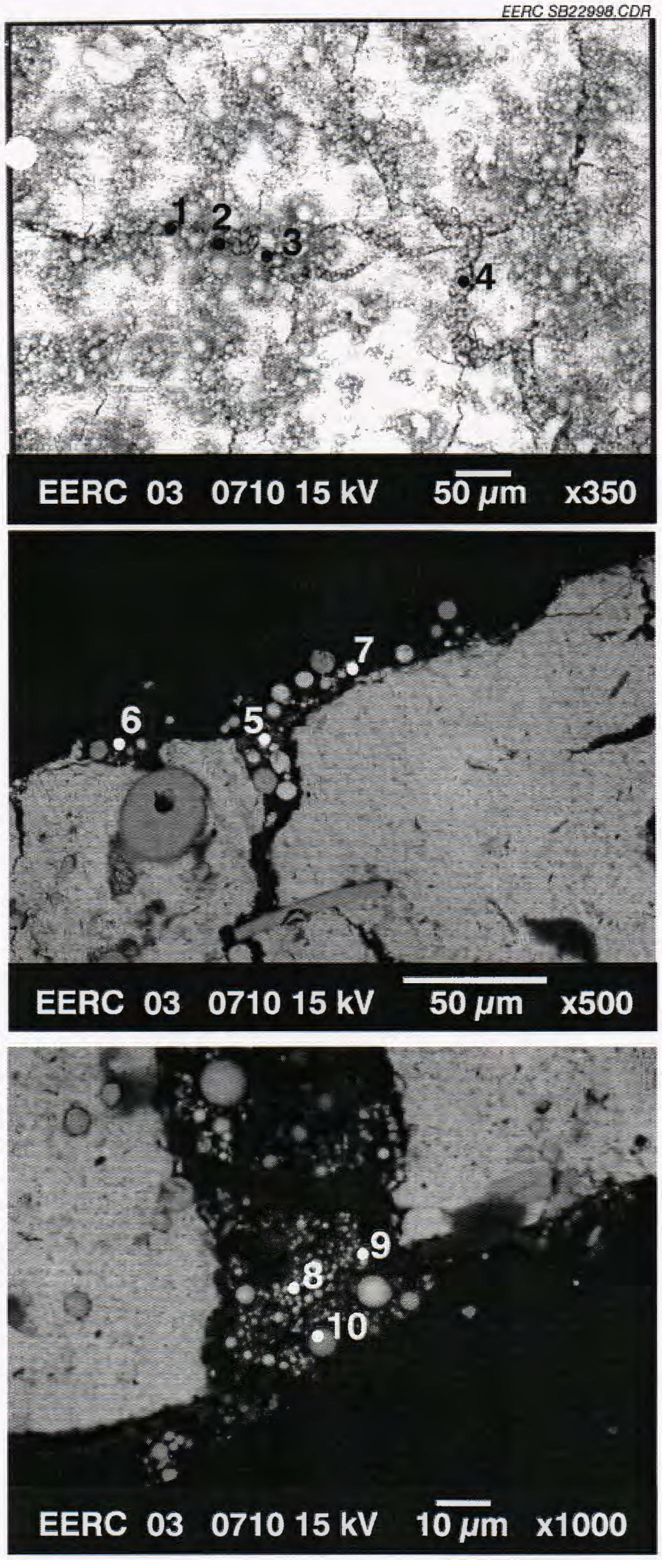

Figure 6. SEM images of ash collected on the catalyst surface at the Columbia Station after 2 months of exposure: A) low-magnification image of ash deposit on catalyst surface, B) low-magnification image of polished cross section showing particles in a matrix of calcium- and sulfur-rich materials, and C) higher-magnification image of bonding.

Table 1. Chemical Composition of Selected Points and Areas in Figure 6

	Oxide, wt%				
Oxide	Point 1	Point 2	Point 3	Point 4	Point 5
Na_2O	0.0	0.9	1.3	0.1	0.3
MgO	0.7	1.5	3.2	3.9	0.9
Al_2O_3	12.2	17.6	20.9	12.2	5.9
SiO_2	10.8	4.1	23.3	7.3	6.3
P_2O_5	0.9	0.1	0.0	1.4	2.6
SO_3	15.2	17.6	16.8	17.1	32.3
K_2O	0.2	0.0	0.5	0.0	0.1
CaO	14.1	43.1	25.0	42.0	34.9
TiO_2	44.8	2.8	1.1	10.5	5.2
Fe_2O_3	1.1	12.3	3.9	5.5	11.5
BaO	0.0	0.0	4.2	0.0	0.0
Total	100.0	100.0	100.0	100.0	100.0
Oxide	Point 6	Point 7	Point 8	Point 9	Point 10
Na_2O	0.0	0.6	1.0	0.5	1.8
MgO	0.0	1.5	2.9	1.4	0.7
Al_2O_3	5.5	12.4	13.6	9.0	20.7
SiO_2	9.4	6.1	15.4	7.9	61.8
P_2O_5	1.2	0.6	1.7	3.1	0.2
SO_3	33.3	22.0	19.5	30.7	0.0
K_2O	0.0	0.0	0.1	0.2	2.5
CaO	44.1	48.5	34.1	38.3	4.4
TiO_2	0.5	4.4	2.4	2.6	2.2
Fe_2O_3	3.1	2.3	6.0	6.3	4.4
BaO	2.8	1.6	3.3	0.0	1.3
Total	100.0	100.0	100.0	100.0	100.0

views of the deposit that is filling the catalyst pores. The deposit consists of particles of fly ash bonded together by a matrix of calcium- and sulfur-rich material, likely in the form of calcium sulfate.

The 4-month sample from the Columbia Station showed particles adhering to the surface and filling pores in the catalyst, as shown in Figure 7. Figure 7A shows the external morphology of the catalyst surface showing particles trapped in the pores of the catalysts. Chemical compositions of selected points are shown in Table 2. It appears to be more significant than that observed for the Baldwin 2-month sample. Figures 7B and 7C show higher-magnification views of the deposit that is filling the catalyst pore. The deposit consists of particles of fly ash bonded together by a matrix of calcium- and sulfur-rich material, likely in the form of calcium sulfate.

The 6-month sample from the Columbia Station showed particles adhering to the surface and filling pores in the catalyst as shown in Figure 8. Figure 8A shows the external morphology of the catalyst surface showing particles trapped in the pores of the catalysts. Chemical compositions of selected points are shown in Table 3. Figures 8B and 8C show higher-

Table 2. Chemical Composition of Selected Points and Areas in Figure 7

	Oxide, wt%			
Oxide	Point 1	Point 2	Point 3	Point 4
Na_2O	0.5	0.0	0.6	0.3
MgO	3.3	1.9	3.2	2.4
Al_2O_3	13.1	10.2	13.0	6.3
SiO_2	12.4	8.4	8.4	3.6
P_2O_5	1.3	0.5	2.1	0.6
SO_3	27.7	29.9	32.2	47.4
K_2O	0.2	0.6	0.1	0.8
CaO	32.1	38.1	28.9	33.2
TiO_2	1.0	2.7	1.3	0.0
Fe_2O_3	6.3	6.3	7.6	2.6
BaO	2.0	1.4	2.5	2.6
Total	100.0	100.0	100.0	100.0

magnification views of the deposit that is filling the catalyst pore. The deposit consists of particles of fly ash bonded together by a matrix of calcium- and sulfur-rich material, likely in the form of calcium sulfate. The 6-month samples show the most extensive degree of sulfation of the Columbia Station samples.

Coyote Station Deposits

The 2-month sample from the Coyote Station showed particles adhering to the surface and filling pores in the catalyst as shown in Figure 9. Figure 9A shows the external morphology of the catalyst surface showing particles trapped in the pores of the catalysts. Chemical compositions of selected points are shown in Table 4. The 2-month sample shows significant evidence of sulfation after only 2 months of exposure and was much more pronounced than the 2-month samples for the Baldwin and Columbia Stations that fire PRB coals. Figures 9B and 9C show higher-magnification views of the deposit that is filling the catalyst pores. The deposit consists of particles of fly ash bonded together by a matrix of calcium- and sulfur-rich material, likely in the form of calcium sulfate. The presence of sodium enhances the bonding and sulfation of the particles to form a strongly bonded matrix.

The 4-month sample from the Coyote Station showed particles adhering to the surface and completely filling and masking the pores in the catalyst as shown in Figure 10. Figure 10A shows the external morphology of the catalyst surface showing the masking of the catalyst surface. Chemical compositions of selected points are shown in Table 5. The 4-month sample shows more sulfation than the 2-month exposure samples. Figures 10B and 10C show higher-magnification views of the deposit that is filling the catalyst pores. The deposit consists of particles of fly ash bonded together by a matrix of sodium-, calcium-, and sulfur-rich material, likely in the form of calcium sulfate. The presence of sodium and potassium enhances the bonding and sulfation of the particles to form a strongly bonded matrix. Significant sodium was found in the deposits, as shown in Table 5.

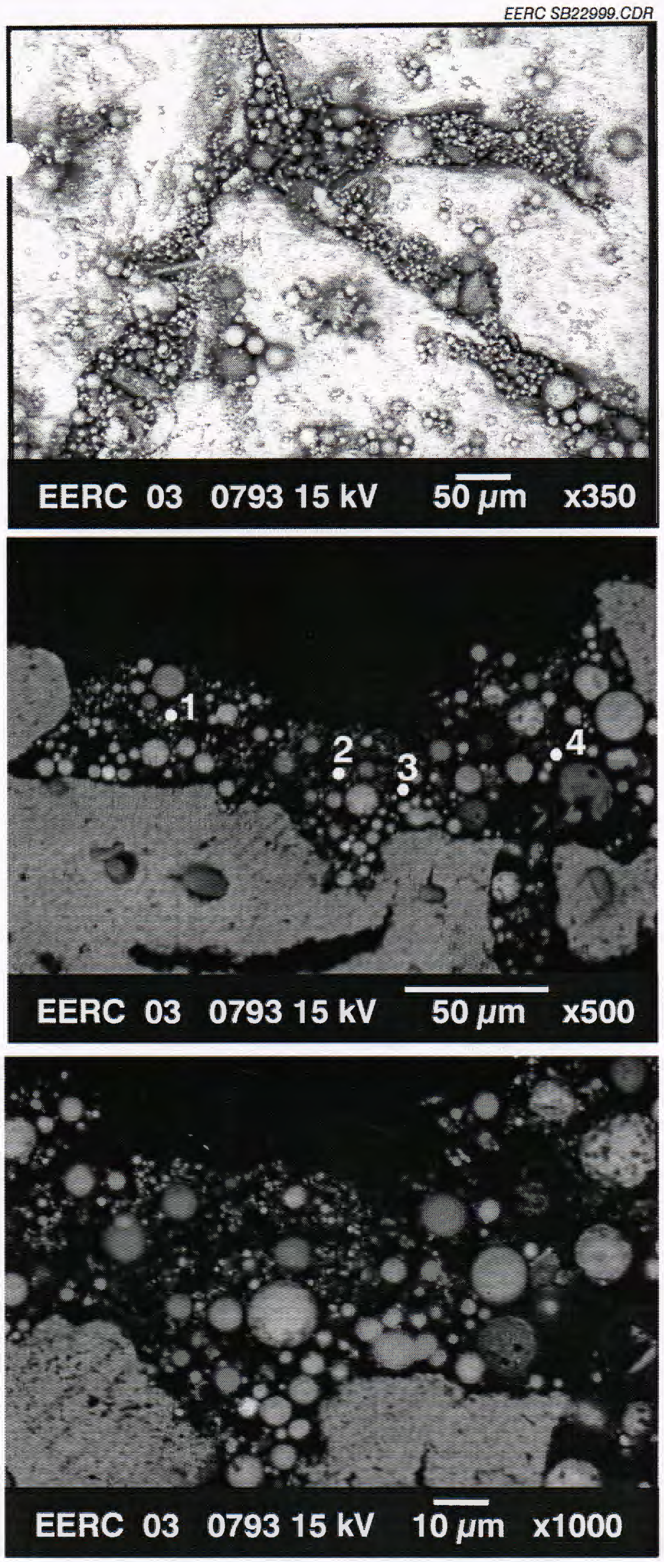

Figure 7. SEM images of ash collected on the catalyst surface at the Columbia Station after 4 months of exposure: A) low-magnification image of ash deposit on catalyst surface, B) low-magnification image of polished cross section showing particles in a matrix of calcium- and sulfur-rich materials, and C) higher-magnification image of bonding.

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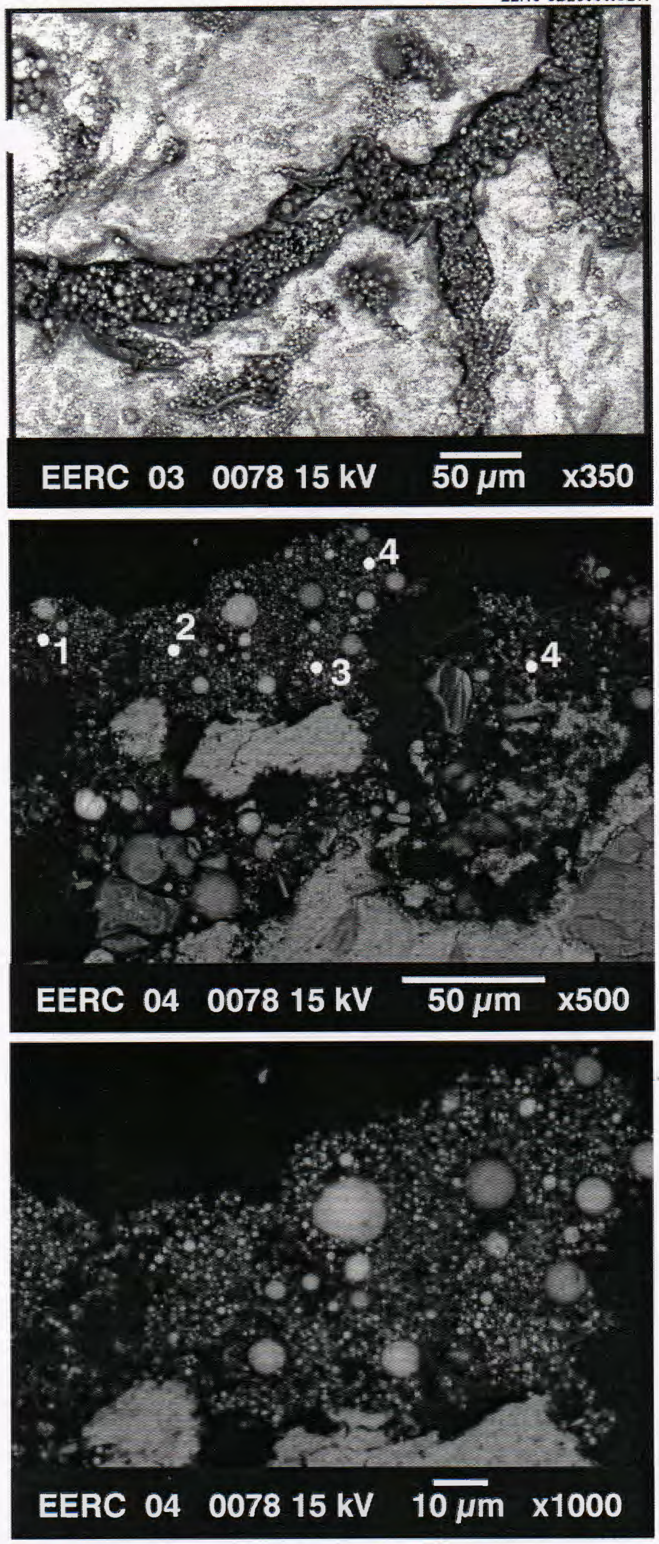

Figure 8. SEM images of ash collected on the catalyst surface at the Columbia Station after 6 months of exposure: A) low-magnification image of ash deposit on catalyst surface, B) low-magnification image of polished cross section showing particles in a matrix of calcium- and sulfur-rich materials, and C) higher-magnification image of bonding.

Table 3. Chemical Composition of Selected Points and Areas in Figure 8

	Oxide, wt%			
Oxide	Point 1	Point 2	Point 3	Point 4
Na_2O	0.1	0.0	0.3	0.6
MgO	1.8	0.7	1.7	2.2
Al_2O_3	10.9	9.6	6.2	11.3
SiO_2	13.1	11.3	12.4	19.5
P_2O_5	3.9	4.8	0.2	2.1
SO_3	27.6	34.0	35.5	30.0
K_2O	0.5	0.3	0.1	1.2
CaO	33.0	25.9	39.8	25.8
TiO_2	0.8	2.5	1.6	3.3
Fe_2O_3	6.1	9.7	1.9	2.9
BaO	2.1	1.2	0.0	1.1
Total	100.0	100.0	100.0	100.0

Table 4. Chemical Composition of Selected Points and Areas in Figure 9

	Oxide, wt%			
Oxide	Point 1	Point 2	Point 3	Point 4
Na_2O	0.9	0.7	1.2	1.0
MgO	5.0	1.6	5.6	1.7
Al_2O_3	12.3	5.8	11.9	5.5
SiO_2	24.6	3.1	21.1	2.6
P_2O_5	0.7	0.0	0.5	0.0
SO_3	23.5	44.0	17.4	31.8
K_2O	0.5	0.3	0.8	0.4
CaO	14.9	36.4	19.6	46.9
TiO_2	7.2	1.9	8.0	2.1
Fe_2O_3	9.2	5.5	11.8	6.9
BaO	1.3	0.7	2.1	1.1
Total	100.0	100.0	100.0	100.0

Task 6 – Final Interpretation, Recommendations, and Reporting

Reporting activities during this quarter included preparation of a technical paper summarizing the research performed in this project and presentation of some of the results at a national technical meeting. The paper, "SCR Catalyst Performance in Flue Gases Derived from Subbituminous and Lignite Coals," was prepared and submitted to *Fuel Processing Technology*. Two papers at the 227th American Chemical Society Meeting in Anaheim, California, were presented in the Division of Fuel Chemistry: "SCR Catalyst Blinding Due to Sodium and Calcium Sulfate Formation" and "Mercury Measurement, Transformations, Control, and Related Issues in Power Systems," describing the catalyst blinding and mercury oxidation aspects of the research, respectively.

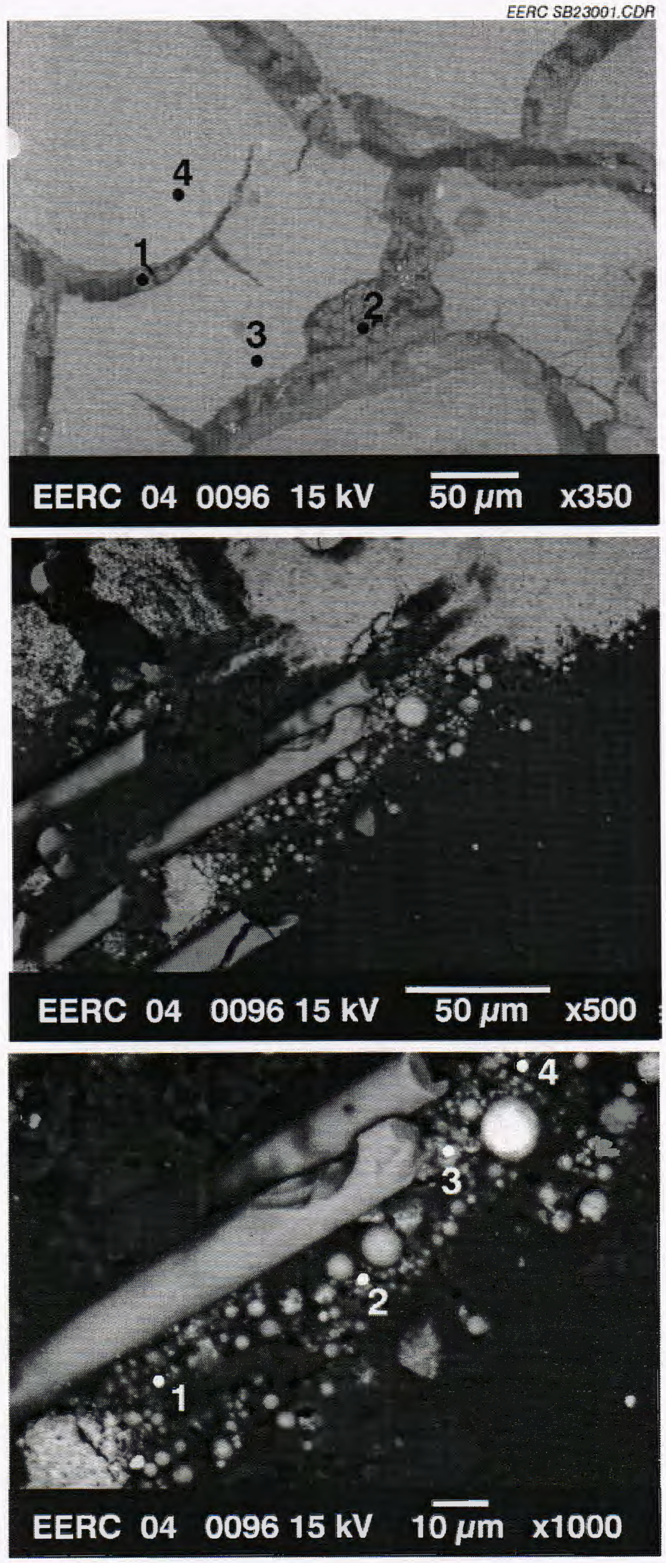

Figure 9. SEM images of ash collected on the catalyst surface at the Coyote Station after 2 months of exposure: A) low-magnification image of ash deposit on catalyst surface, B) low-magnification image of polished cross section showing particles in a matrix of calcium- and sulfur-rich materials, and C) higher-magnification image of bonding.

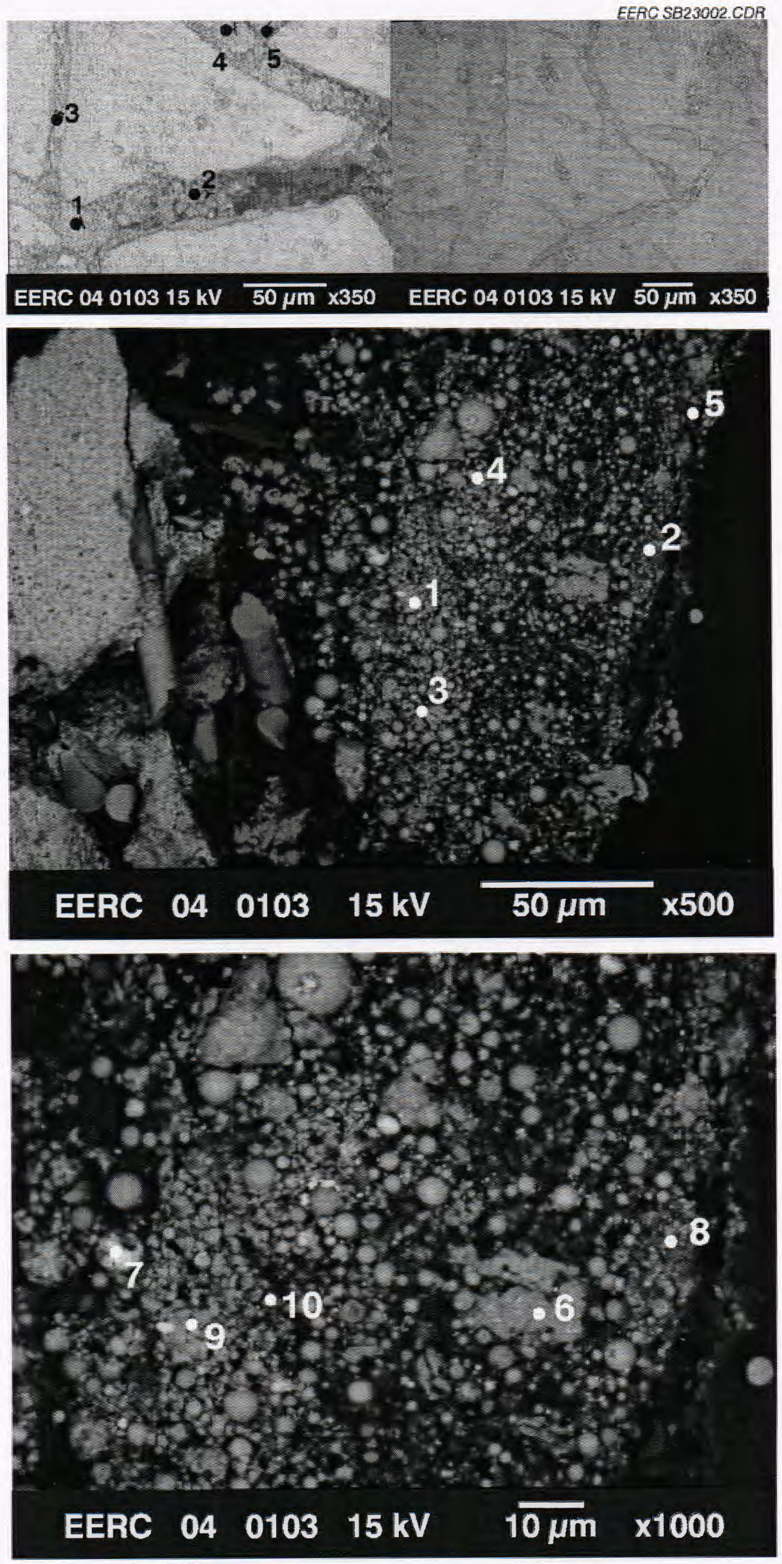

Figure 10. SEM images of ash collected on the catalyst surface at the Coyote Station after 4 months of exposure: A) low-magnification image of ash deposit on catalyst surface, B) low-magnification image of polished cross section showing particles in a matrix of calcium- and sulfur-rich materials, and C) higher-magnification image of bonding.

Table 5. Chemical Composition of Selected Points and Areas in Figure 10

	Oxide, wt%				
Oxide	Point 1	Point 2	Point 3	Point 4	Point 5
Na_2O	6.7	1.9	7.1	6.2	3.1
MgO	1.1	1.7	1.1	2.6	3.2
Al_2O_3	2.6	8.8	4.0	4.8	10.5
SiO_2	7.0	21.1	11.3	5.6	32.2
P_2O_5	0.2	2.4	0.0	0.2	0.9
SO_3	54.7	38.5	56.4	57.5	30.4
K_2O	2.0	2.8	0.7	2.8	2.4
CaO	18.0	3.4	15.8	9.3	2.3
TiO_2	0.6	0.8	1.1	1.3	1.5
Fe_2O_3	5.8	5.1	2.1	6.5	9.8
BaO	1.4	13.5	0.5	3.4	3.6
Total	100.0	100.0	100.0	100.0	100.0
Oxide	Point 6	Point 7	Point 8	Point 9	Point 10
Na_2O	9.5	2.6	10.4	8.9	4.4
MgO	1.2	1.9	1.3	3.0	3.7
Al_2O_3	2.6	8.6	4.2	4.9	10.6
SiO_2	6.3	18.2	10.5	5.0	28.9
P_2O_5	0.1	1.9	0.0	0.1	0.7
SO_3	41.8	28.4	44.9	44.5	23.4
K_2O	3.2	4.3	1.2	4.4	3.8
CaO	24.5	4.4	22.5	12.8	3.1
TiO_2	0.6	0.8	1.3	1.5	1.8
Fe_2O_3	7.7	6.6	2.9	8.9	13.2
BaO	2.4	22.3	0.9	5.9	6.3
Total	100.0	100.0	100.0	100.0	100.0

FUTURE WORK – NEXT QUARTER

Work in the upcoming quarter will involve site visits and data reduction. The 6-month catalyst sample will be removed from the Coyote Station site in April 2004. Flow data and catalyst reactivity from Columbia and Coyote sites will be analyzed as they become available. Quarterly reports will be prepared. The Coyote Station field test is scheduled to be terminated in April 2004.

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Fine, Karlene K.

From: Crocker, Charlene R. [ccrocker@undeerc.org]
Sent: Monday, August 23, 2004 5:41 PM
To: 'kfine@state.nd.us'
Cc: 'hness@lignite.com'; Benson, Steven A.
Subject: Selective Catalytic Reduction Quarterly Report

August 23, 2004

Ms. Karlene Fine
Executive Director
North Dakota Industrial Commission
State Capitol, 10th Floor
600 East Boulevard Avenue
Bismarck, ND 58505-0310

Dear Ms. Fine:

Subject: Evaluation of Potential SCR Catalyst Blinding During Coal Combustion
Contract No. FY-00-XXXVI-100

This letter comprises the April 1 - June 30, 2004, Quarterly Status Report for the subject task. During this quarter, the catalyst test at Coyote Station was terminated, and the reactor was retrieved. Work in the upcoming quarter will involve preparation of the final report.

If you have any questions, please contact me by phone at (701) 777-5177, by fax at (701) 777-5181, or by e-mail at sbenson@undeerc.org.

Sincerely,

Steven A. Benson
Senior Research
Manager

100
Draft final

EERC Energy & Environmental Research Center

UNIVERSITY OF NORTH DAKOTA

15 North 23rd Street — PO Box 9018 / Grand Forks, ND 58202-9018 / Phone: (701) 777-5000 Fax: 777-5181
Web Site: www.undeerc.org

September 1, 2004

Ms. Karlene Fine
Executive Director
North Dakota Industrial Commission
State Capitol, 10th Floor
600 East Boulevard Avenue
Bismarck, ND 58505-0310

Dear Ms. Fine:

Subject: Draft Final Report for Evaluation of Potential SCR Catalyst Blinding During Coal Combustion and Add-On: Impact of SCR Catalyst on Mercury Oxidation in Lignite-Fired Combustion Systems; Contract No. FY-00-XXXVI-100

Enclosed is the draft final report for the subject task. Please review and return any comments you have to me by October 1, 2004.

We are also in the process of scheduling a final project meeting or conference call. Please contact Connie Wixo by phone at (701) 777-5161 or by e-mail at cwixo@undeerc.org with your preference (call or meeting) to schedule a suitable time.

If you have any questions, please call me at (701) 777-5177, fax at (701) 777-5181, or e-mail at sbenson@undeerc.org.

Sincerely,

Steven A. Benson *for*
Senior Research Manager

SAB/drh

Enclosures

EERC
Energy & Environmental Research Center

DRAFT

EVALUATION OF POTENTIAL SCR CATALYST BLINDING DURING COAL COMBUSTION AND ADD-ON: IMPACT OF SCR CATALYST ON MERCURY OXIDATION IN LIGNITE-FIRED COMBUSTION SYSTEMS

Draft Final Report

(for the period of November 1, 2000 – June 30, 2004)

Prepared for:

Ms. Karlene Fine

Executive Director
North Dakota Industrial Commission
State Capitol, 10th Floor
600 East Boulevard Avenue
Bismarck, ND 58505-0310

Contract No. FY-00-XXXVI-100

Prepared by:

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September 2004

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DRAFT

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DOE ACKNOWLEDGMENT

This report was prepared with the support of the U.S. Department of Energy (DOE) National Energy Technology Laboratory Cooperative Agreement No. DE-FC26-98FT40321. However, any opinions, findings, conclusions, or recommendations expressed herein are those of the authors(s) and do not necessarily reflect the views of DOE.

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(B) Assumes any liabilities with respect to the use of, or for damages resulting from the use of, any information, apparatus, method, or process disclosed in this report.

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JV 31 – EVALUATION OF POTENTIAL SCR CATALYST BLINDING DURING COAL COMBUSTION AND ADD-ON: IMPACT OF SCR CATALYST ON MERCURY OXIDATION IN LIGNITE-FIRED COMBUSTION SYSTEMS

ABSTRACT

Lignite and subbituminous coals from the United States of America have characteristics that impact the performance of catalysts used in selective catalyst reduction (SCR) for nitrogen oxide removal and mercury oxidation. Typically, these coals contain ash-forming components that consist of inorganic elements (sodium, magnesium, calcium, and potassium) associated with the organic matrix and mineral grains (quartz, clays, carbonates, sulfates, and sulfides). Upon combustion, the inorganic components undergo chemical and physical transformations that produce intermediate inorganic species in the form of inorganic gases, liquids, and solids. The alkali and alkaline-earth elements are partitioned between reactions with minerals and reactions to form alkali and alkaline-earth-rich oxides during combustion. The particles resulting from the reaction with minerals produce low-melting-point phases that cause a wide range of fireside deposition problems. The alkali and alkaline-earth-rich oxides consist mainly of very small particles (<5 µm) that are carried into the backpasses of the combustion system and react with flue gas to form sulfates and, possibly, carbonates. These particles cause low-temperature deposition, blinding, and plugging problems in SCR systems. These coals also lack sufficient levels of chlorine needed to oxidize mercury. Slipstream testing was conducted at two subbituminous-fired power plants and one lignite-fired power plant to determine the impacts of ash on SCR plugging, blinding, and mercury oxidation. The results indicated a high potential for blinding and plugging because of the formation of sulfate-bonded deposits but no evidence of mercury oxidation.

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LIST OF FIGURES

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JV 31 – EVALUATION OF POTENTIAL SCR CATALYST BLINDING DURING COAL COMBUSTION AND ADD-ON: IMPACT OF SCR CATALYST ON MERCURY OXIDATION IN LIGNITE-FIRED COMBUSTION SYSTEMS

EXECUTIVE SUMMARY

The goal of this project by the Energy & Environmental Research Center (EERC) is to determine the potential of low-rank coal ash to cause blinding or masking of selective catalytic reduction (SCR) catalysts. The primary goal of the add-on is to determine the effects of new and aged catalyst on the oxidation of mercury at full-scale power plants.

Two SCR slipstream reactors were constructed to accomplish the goals of this project. The test chambers are approximately 19 cm (7.5 inches) square and are able to accommodate catalyst sections up to 1 meter (3.3 feet) in length. The chambers are electrically heated and fully instrumented to limit heat loss and to maintain a face velocity of 5 m/s (16.4 ft/s).

The SCR reactors were installed at three different plant locations and operated until the catalyst had 6 months of operating time. The utilities that were chosen for this study are the Columbia Station (pulverized coal-fired), the Baldwin Station (cyclone-fired), and the Coyote Station (cyclone-fired). The Coyote Station fires North Dakota lignite, while the other two stations burn Powder River Basin (PRB) coal. The catalyst was sampled every 2 months and analyzed with scanning electron microscopy (SEM).

Bench-scale and Facility for Analysis of Chemical Thermodynamics (FACT) modeling studies were also conducted in the laboratory prior to the reactors being installed at the host utilities. Experiments were carried out in a thermogravimetric analyzer (TGA) system at 315°C (600°F), 370°C (700°F), and 427°C (800°F) with simulated flue gas. Ash samples created from the test coals were placed on the TGA pan with and without catalyst. The rate of sample weight gain was then monitored. The ash was then analyzed with SEM techniques to identify the species that were present.

The results of the bench-scale analysis indicate that the rate of weight gain increases with increasing temperature, and calcium sulfates were the predominant species formed. The rate of sulfate formation could increase as much as tenfold with the addition of catalyst to the system. Low-sulfur bituminous and PRB blends exhibited a higher rate of sulfate formation and, therefore, would have a higher blinding potential than a 100% PRB or lignite. Results of the FACT modeling indicate that there is a high potential to form alkali and alkaline-earth sulfates, carbonates, and phosphates while SCRs are operated at utilities burning lignite and PRB coals.

The data collected during the three slipstream reactor tests indicate that the pressure drop across the catalyst was found to be the most significant for the lignite-fired plant as compared to the subbituminous-fired plants. Both lignite and PRB coals had significant accumulations of ash on the catalyst, on both macroscopic and microscopic levels. On a macroscopic level, there were significant observable accumulations that plugged the entrance as well as the exit of the catalyst

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sections. On a microscopic level, the ash materials filled pores in the catalyst and, in many cases, completely masked the pores within 4 months of operation.

The deposits on the surfaces and within the pores of the catalyst consisted of mainly alkali and alkaline-earth element-rich phases that have been sulfated. The mechanism for the formation of the sulfate materials involves the formation of very small particles rich in alkali and alkaline-earth elements, transport of the particles to the surface of the catalyst, and reactions with SO_2/SO_3 to form sulfates. X-ray diffraction analysis identified $CaSO_4$ as a major phase and $Ca_3Mg(SiO_4)_2$ and $CaCO_3$ as minor phases.

Lignite and subbituminous coals contain high levels of organically associated alkali and alkaline-earth elements, including sodium, magnesium, calcium, and potassium in addition to mineral phases. During combustion, the inorganic components in the coal are partitioned into various size fractions based on the type of inorganic component and their association in the coal and combustion system design and operating conditions. The results of this testing found that the smaller size fractions of ash are dominated by partially sulfated alkali and alkaline-earth elements. The composition of the size fractions was compared to the chemical composition of the ash deposited on and in the catalyst. The comparison shows that the composition of the particle captured in the SCR catalyst is very similar to the <5-μm size fraction.

The results of this study lead the authors to suggest careful evaluation of each SCR installation on applications using subbituminous coals and suggest no installations of SCRs on plants firing lignite coal until further evaluations/improvements to the current technology can be carried out. Installations involving lignite fuels will need advanced cleaning techniques to handle the high sodium and high dust loads associated with burning most lignite fuels.

The ability of mercury to be oxidized across the SCR catalyst was investigated at the Coyote Station. The Coyote Station is fired on North Dakota lignite, and the flue gases are dominated by elemental mercury. Measurement of mercury speciation was conducted using the Ontario Hydro (American Society for Testing and Materials D6784-02) method at the inlet and the outlet of the SCR reactor. These results show limited oxidation of mercury across the SCR catalyst when lignite coals are fired. The reasons for the lack of mercury oxidation include the following: no chlorine present in the coal and flue gas to catalytically enhance the oxidation of Hg^0, higher levels of alkali and alkaline-earth elements acting as sorbents for any chlorine present in the flue gas, and lower levels of acid gases present in the flue gas.

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JV 31 – EVALUATION OF POTENTIAL SCR CATALYST BLINDING DURING COAL COMBUSTION AND ADD-ON: IMPACT OF SCR CATALYST ON MERCURY OXIDATION IN LIGNITE-FIRED COMBUSTION SYSTEMS

INTRODUCTION

The Energy & Environmental Research Center (EERC) investigated selective catalytic reduction (SCR) for NO_x control and mercury oxidation using a slipstream reactor at power plants firing subbituminous and lignite coals to determine the potential for ash plugging and blinding and mercury oxidation. SCR units lower NO_x emissions by reducing NO_x to N_2 and H_2O. Ammonia (NH_3) is the most common reducing agent used for the SCR of NO_x. The SCR process involves the use of a metal oxide catalyst such as titanium dioxide (TiO_2)-supported vanadium pentoxide (V_2O_5). These units are operated at about 340°–370°C (650°–700°F). Subbituminous and lignitic coals are known for their ability to produce alkali and alkaline-earth sulfate-bonded deposits at low temperature (<1000°C) in utility boilers. The mechanisms of the formation of low-temperature sulfates have been extensively examined and modeled by the EERC in work termed Project Sodium and Project Calcium in the early 1990s (1, 2). Deposit buildup of this type blinds or masks the catalyst, diminishing its reactivity for converting NO_x to N_2 and water and potentially creating increased NH_3 slip (3). Elemental mercury oxidation has been observed in laboratory-, pilot-, and full-scale testing using SCR catalysts (4–6). In these studies, the metal oxides, V_2O_5 and TiO_2, have been shown to promote the conversion of elemental mercury to oxidized and/or particulate-bound mercury. Full-scale tests in Europe (7) and the United States (8) have indicated that the V_2O_5 and TiO_2 catalyst may promote the formation of oxidized mercury. The ability to oxidize mercury is largely dependent on the composition of the coal (8).

Lignite and subbituminous coals produce ash that plug and blind catalysts (9–12). The problems currently being experienced on SCR catalysts include the formation of sulfate- and phosphate-based blinding materials on the surface of catalysts and the carrying of deposit fragments, or popcorn ash, from other parts of the boiler and depositing them on top of the SCR catalysts (3). The most significant problem that limits the successful application of SCR catalysts to lignite coal is the formation of low-temperature sodium–calcium–magnesium sulfates, phosphates and, possibly, carbonates on the surfaces of catalysts and the carryover of deposits that will plug the catalyst openings, resulting in increased pressure drop and decreased efficiency (3, 11–14). The degree of the ash-related impacts on SCR catalyst performance depends upon the composition of the coal, the type of firing systems, flue gas temperature, and catalyst design (11, 12, 14, 15).

Licata and others (13) conducted tests on a South African and a German Ruhr Valley coal and found that the German Ruhr Valley coal significantly increased the pressure drop across the catalyst because of the accumulation of ash. They found that the German coal produced a highly adhesive ash consisting of alkali (K and Na) sulfates. In addition, they reported that the alkali elements are in a water-soluble form and highly mobile and will migrate throughout the catalyst material, reducing active sites. The water-soluble form is typical of organically associated alkali elements in coals. The German Ruhr Valley coal has about 9.5% ash and 0.9% S on an as-received basis, and the ash consists mainly of Si (38.9%), Al (23.2%), Fe (11.6%), and Ca (9.7%), with lower levels of K (1.85%) and Na (0.85%) (13). Cichanosicz and Muzio (14) summarized the experience in Japan and Germany and indicated that the alkali elements (K and Na) reduced the acidity of the catalyst sites for total alkali content (K + Na + Ca + Mg) of 8%–15% of the ash in European power plants. Licata et al. also found that alkaline-earth elements such as calcium react with SO_3 on the catalyst, resulting in plugging of pores and a decrease in the ability of NH_3 to bond to catalyst sites. The levels of calcium in the coals that caused blinding ranged from 3% to 5% of the ash. Studies conducted on the impact of alkali elements associated with biomass found that, when biomass is fired, poisoning and blinding of SCR catalysts occurred (16, 17).

The slipstream reactors were installed at three power plants. Two of the plants were cyclone fired: one with lignite and one with subbituminous coal. The third plant was a pulverized-coal (pc), tangentially fired unit with subbituminous coal. The slipstream reactors were designed to expose SCR catalysts to flue gas and particulate matter under conditions that simulate gas velocities, temperatures, and NH_3 injection of a full-scale pilot plant. The control system maintains catalyst temperature, pulse air to remove accumulated deposits, and constant gas flow across the catalyst and logs pressure drops and temperatures. The reactor was operated in an automated mode and can be controlled via modem connection. Testing at each power plant was conducted over a 6-month period. The reactor was inspected and cleaned at 2-month intervals, and a catalyst section was removed for analysis. The catalysts and associated ash deposits were analyzed to determine the characteristics of the ash on the surface and in the pores. In addition, the mercury speciation in the flue gas upstream and downstream of the catalyst was conducted at 2-month intervals during the testing at the lignite-fired plant. The ability of the SCR catalyst materials to catalyze gaseous elemental mercury (Hg^0[g]) to more soluble and chemically reactive $Hg^{2+}X(g)$ forms was evaluated, along with the potential increase in particle-associated mercury, Hg(p). Increasing the oxidized and particulate fractions of mercury has the potential to increase the capture efficiency of mercury by conventional control devices such as wet flue gas desulfurization scrubbers and electrostatic precipitators.

EXPERIMENTAL

Bench-Scale Thermogravimetric Analyzer Study

Fuels were first combusted in the EERC's conversion and environmental process simulator. Ash resulting from the combustion of these fuels was collected and size-fractionated. Tests were carried out on the size-fractionated ash in a thermogravimetric analyzer under atmospheric conditions that mimic a combustion environment. The simulated flue gas atmosphere consisted of CO_2, SO_2, NH_3, N_2, O_2, H_2O, and P_2O_5. The flue gas makeup is presented in Table 1. The weight gain of the ash or ash–catalyst mixtures was measured as a function of time and temperature. The tests were conducted at 316°, 371°, and 427°C (600°, 700°, and 800°F). The resulting mixtures were analyzed to determine the influence of SCR catalysts on ash behavior.

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Table 1. Flue Gas Makeup

N_2	74%
H_2O	8%
CO_2	14%
O_2	4%
NH_3	100–300 ppm
SO_2	0.04%
P	1–1000 ppm

Slipstream Reactor Installation and Operation

Upon installation at each utility boiler unit, flue gas temperature, composition, and velocity measurements were obtained using portable equipment. Shakedown testing of the unit was conducted to ensure that all components were operating properly and that data were being logged and could be retrieved. After installation and shakedown were completed, the reactor was operated in a computer-controlled, automated mode and monitored on a daily basis to ensure proper operation and data quality. During operation of the SCR slipstream system, catalyst temperature, sootblowing frequency, and pressure drop across the catalyst were monitored and logged. Samples of the exposed SCR catalyst and associated deposits were obtained after exposure to flue gas and particulate for 2, 4, and 6 months. The samples of the catalyst were analyzed to determine the components that were bonding and filling pores, resulting in decreased reactivity.

The characteristics of ash that accumulated on the catalyst were examined using scanning electron microscopy (SEM)–x-ray microanalysis and x-ray diffraction (XRD) (18). Correlations between the physical and chemical characteristics of any ash deposits on the SCR test section and entrained-ash sample collected at the chamber inlet and the coal inorganic composition will be made to discern mechanisms of SCR blinding. Entrained ash was collected at Columbia Station only and characterized to composition and size.

Mercury Measurement

At the Coyote Station, the Ontario Hydro (OH) mercury speciation sampling train was used to determine mercury forms across the SCR test section. The OH extractive mercury speciation sampling technique was used to measure potential mercury conversion across the SCR system over a period of several hours after fresh installation of the SCR test chamber and again just prior to removal of SCR catalyst sections.

The procedure used to conduct the mercury speciation sampling was American Society for Testing and Materials Method D6784-02 entitled "Standard Test Method for Elemental, Oxidized, Particle-Bound and Total Mercury in Flue Gas Generated from Coal-Fired Stationary Sources (Ontario Hydro method)" (19).

The OH method follows standard U.S. Environmental Protection Agency (EPA) methods for isokinetic flue gas sampling (EPA Methods 1–3 and EPA Method 5/17). A sample is withdrawn from the flue gas stream isokinetically through the filtration system, which is followed by a series of impingers in an ice bath. Particulate-bound mercury is collected on the filter; Hg^{2+} is collected in impingers containing 1 N potassium chloride solution; and elemental mercury is collected in one impinger containing a 5% nitric acid and 10% peroxide solution and in three impingers containing a solution of 10% sulfuric acid and 4% potassium permanganate. An impinger containing silica gel collects any remaining moisture. The filter media is quartz fiber filters. The filter holder is glass or Teflon-coated. An approximate 2-hour sampling time was used, with a target sample volume of 1 standard cubic meter.

RESULTS AND DISCUSSION

Task 1 – Identification of Test Coals and Utility Host Sites

Three host utility sites were chosen for the installation of the SCR reactors. The utilities were chosen based on their ability to provide all of the necessary support and hardware for the operation of the SCR reactors. The electric utility units selected for testing are shown in Table 2. The plants where the SCR slipstream system was installed included Alliant Energy's Columbia Station, Dynegy's Baldwin Station, and Otter Tail Power Company's Coyote Station.

Table 2. Description of Power Plants Tested

	Baldwin	Columbia	Coyote
Unit No.	1	2	1
Utility	Dynegy	Alliant	Otter Tail
Boiler Type	Cyclone	T-fired	Cyclone
Fuel type	Antelope – subbituminous	Caballo – subbituminous	Beulah – Zap lignite
Load	Base	Base	Base
Location	Baldwin, IL	Portage, WI	Beulah, ND
MW	600	520	425

Table 2 describes the plants, and Table 3 summarizes the characteristics and selection criteria. The selection criteria that were most important to the success of this project were geographic location, a base load plant, and a consistent supply of one fuel for the duration of the study.

The units tested were selected based on the fuels fired, boiler type, and availability of the unit for sampling. The average composition of the coals fired during the testing is listed in Tables 4 and 5. The subbituminous coals were typically low ash, nominally 4.5% to 5.5% with very high levels of calcium in the ash. In comparison, the lignite contains higher levels of ash and lower calcium but higher levels of sodium. The alkali and alkaline-earth elements are primarily associated with the organic matrix of the coal as salts of carboxylic acid groups (18). The portion of the ash-forming components that are associated with the organic matrix of the coal for subbituminous coal ranges from 30% to 60% (18); for the lignite coal, the portion is about 20% to 40%. The remaining ash-forming components consist of mineral grains. For these

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Table 3. Key Selection Criteria

Field Test 1 – Columbia Station
• Tangentially fired boiler to show differences in ash partitioning as compared to cyclone-fired systems.
• High-potential-blinding coal in Caballo, which can be burned nearly 100% for the entire test.
Field Test 2 – Baldwin Station
• Plant is cyclone fired.
• Units already are equipped to do slipstream testing.
• Plant currently fires a blend of Antelope coal and tires; plant is willing to fire 100% Antelope.
• High-potential-blinding coal in Antelope.
Field Test 3 – Coyote Station
• Cyclone-fired with lignite.
• High-potential-blinding coal with high alkali and alkaline-earth elements. Coal can have very high sodium content and is known to cause significant low-temperature deposition.

Table 4. Ultimate Analysis Results (dry basis), wt%

	Antelope	Caballo	Beulah
Ash Content	7.28	6.59	11.62
Total Sulfur	0.33	0.51	1.49
Carbon	69.97	67.88	61.50
Hydrogen	4.77	4.83	3.96
Nitrogen	1.05	1.24	1.08
Oxygen (by difference)	16.61	18.96	20.35

Table 5. Ash Composition (wt% equivalent oxide)

Oxide	Antelope	Caballo	Beulah
SiO_2	24.82	26.70	16.50
Al_2O_3	13.55	16.60	13.30
TiO_2	1.39	1.10	0.80
Fe_2O_3	7.52	5.10	16.60
CaO	26.68	25.10	19.50
MgO	7.14	8.00	7.40
K_2O	0.17	0.30	0.20
Na_2O	1.47	1.00	5.20
P_2O_5	0.90	1.70	0.00
SO_3	16.33	14.40	19.80

coals, the percentage organically associated is 29% for the Antelope, 36% for Caballo, and 19% for Beulah. The minerals present in the coals as determined by computer-controlled scanning electron microscopy (CCSEM) analyses are listed in Table 6. The primary minerals present in the subbituminous coals include quartz and various clay minerals with some pyrite and a mineral that is rich in Ca, Al, and P. This mineral has been identified in some coals as crandalite. The primary minerals found in the Beulah coal include clay minerals (kaolinite), pyrite, and quartz.

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Table 6. CCSEM Analysis Results for Beulah, Antelope, and Caballo (values are wt% on a mineral basis)

	Caballo	Antelope	Beulah
Total Mineral wt% on a Coal Basis:	2.8	3.2	8.4
Quartz	40.4	31.5	11.0
Iron Oxide	0.0	2.4	4.4
Periclase	0.0	0.0	0.0
Rutile	2.4	0.3	0.0
Alumina	0.0	0.0	1.1
Calcite	0.0	0.4	0.1
Dolomite	0.0	0.5	0.0
Ankerite	0.0	0.0	0.2
Kaolinite	23.7	17.1	4.9
Montmorillonite	0.4	6.5	6.6
K Al-Silicate	0.0	1.6	7.2
Fe Al-Silicate	0.0	0.8	9.0
Ca Al-Silicate	0.1	1.0	2.6
Na Al-Silicate	0.0	0.0	0.1
Aluminosilicate	0.7	3.3	3.2
Mixed Al-Silicate	0.0	1.0	5.5
Fe Silicate	0.0	0.0	0.0
Ca Silicate	0.0	0.4	0.0
Ca Aluminate	0.0	0.0	0.0
Pyrite	16.2	0.0	0.8
Pyrrhotite	0.0	4.8	18.4
Oxidized Pyrrhotite	0.0	0.5	0.5
Gypsum	0.4	0.0	0.5
Barite	0.8	0.5	3.0
Apatite	0.0	0.2	0.0
Ca Al-P	8.5	13.5	0.1
KCl	0.0	0.0	0.0
Gypsum/Barite	0.0	0.1	0.0
Gypsum/Al-Silicate	0.1	0.9	4.0
Si-Rich	0.3	3.7	4.9
Ca-Rich	0.0	0.0	0.0
Ca-Si-Rich	0.0	0.1	0.0
Unclassified	3.2	8.7	11.9
Totals	100.0	100.0	100.0

Task 2 – Bench-Scale Testing and FACT Modeling

Bench-Scale Testing

The goal of the bench-scale testing was to determine the effect catalyst would have on the conversion of SO_2 to SO_3 and the resulting increase in catalyst blinding. Tests were conducted with and without catalyst on the following fuels: Nanticoke Powder River Basin (PRB), Beulah lignite, and Nanticoke PRB and a low-sulfur U.S. (LSUS) bituminous blend.

The results of the study indicate that the addition of the catalyst to the ash and increased temperature increased the rate of weight gain by as much as tenfold. The weight gain can be directly linked to the rate of sulfation. The test results in Figures 1–3 were compiled using the gas concentrations noted in Table 1 minus the NH_3 and phosphorus compounds (baseline tests). Table 7 contains the ash analysis of the coals used in the bench-scale testing. Figure 1 contains the weight gain curves for the Nanticoke PRB test. The rate of weight gain increased as the temperature increased from 316° to 427°C (600° to 800°F).

Figure 2 contains the weight gain curve for the Beulah lignite. Again the weight gain increased as the temperature was increased from 316° to 427°C (600° to 800°F). The rate of weight gain was similar to what was seen with the Nanticoke PRB test.

A blend of the Nanticoke PRB and an LSUS bituminous coal was tested at a 52/48 blend (PRB–LSUS). The weight gain curves for this test are in Figure 3. The results of this experiment

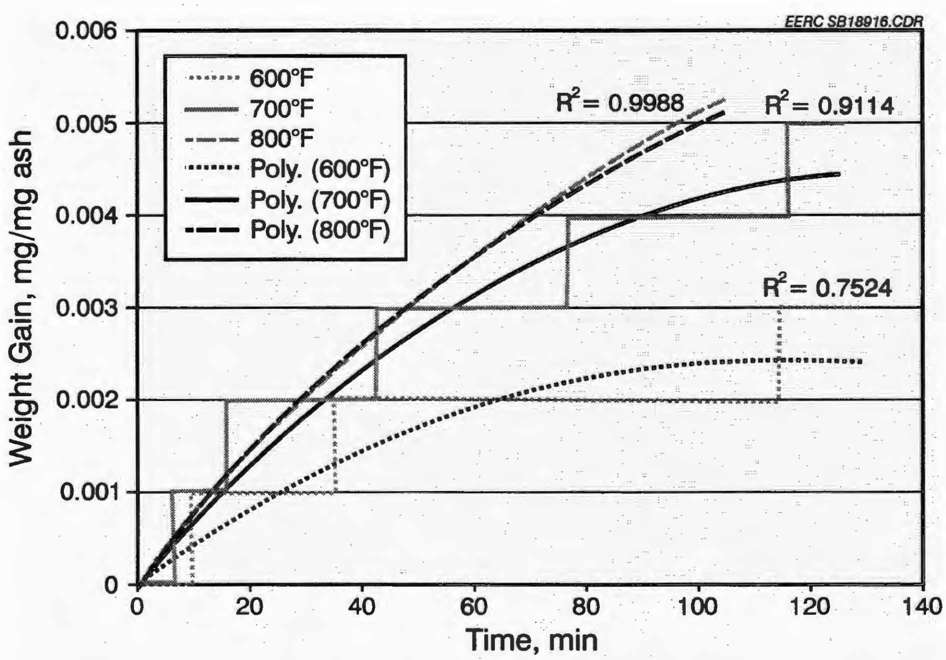

Figure 1. Weight gain curves for Nanticoke PRB (less than 3 μm).

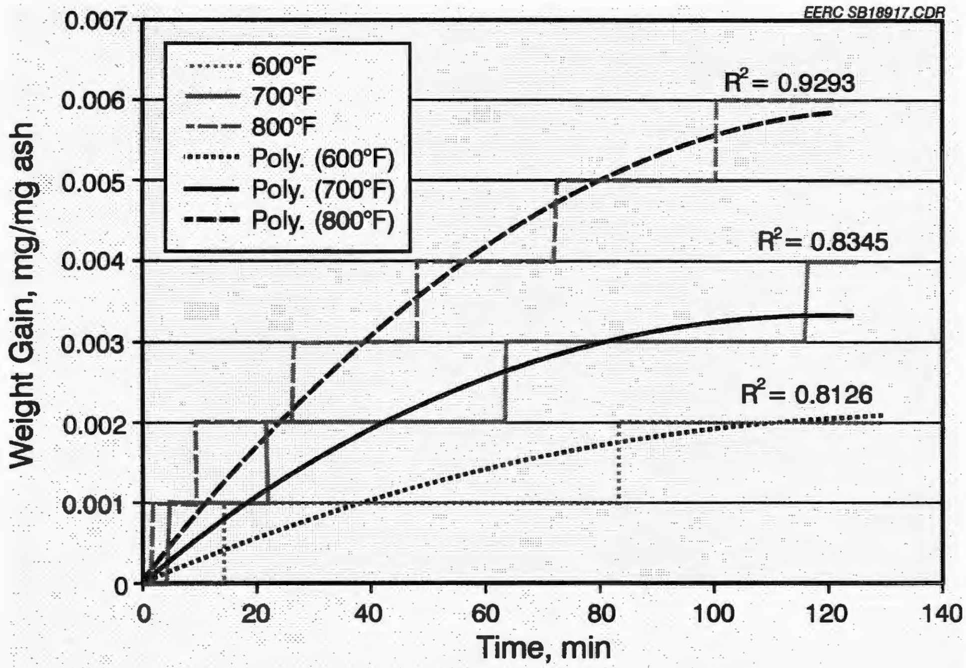

Figure 2. Weight gain curves for Beulah lignite (less than 3 μm).

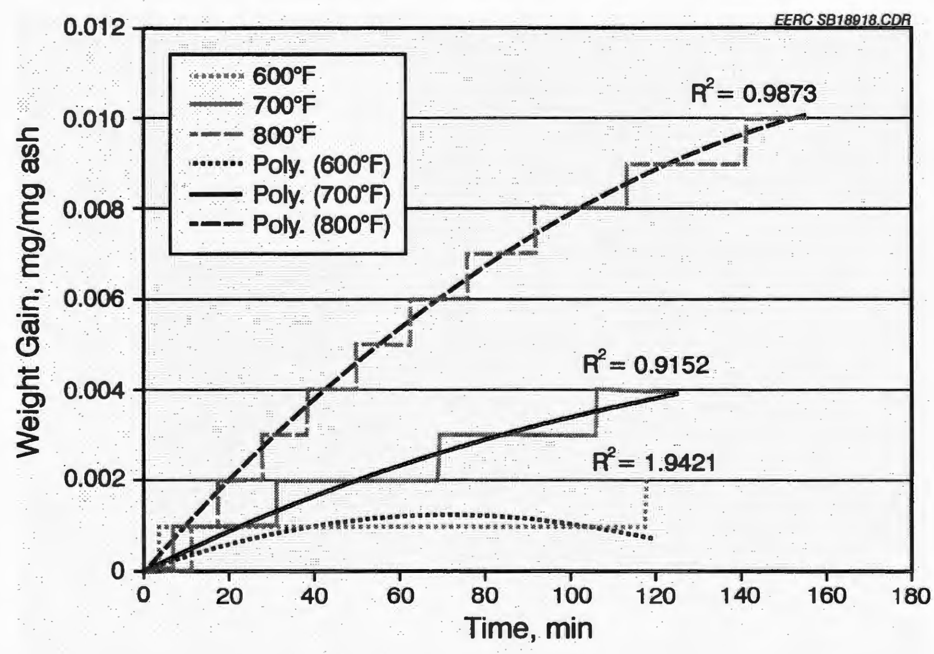

Figure 3. Weight gain curves for Nanticoke PRB–LSUS blend (less than 3 μm).

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Table 7. Composition of Coal Ashes Used in Bench-Scale Testing

Oxides, wt%	Nanticoke 100% PRB (a)[1]	Nanticoke 100% PRB (b)[2]	Nanticoke 52% PRB–48% LSUS (a)	Nanticoke 52% PRB–48% LSUS (b)	Beulah (a)	Beulah (b)
SiO_2	27.9	32.0	43.4	48.4	31.5	39.7
Al_2O_3	17.7	20.3	26.7	29.7	14.2	17.9
Fe_2O_3	6.2	7.1	4.8	5.3	7.3	9.2
TiO_2	1.5	1.8	1.6	1.8	0.8	1.0
P_2O_5	1.0	1.2	0.4	0.4	0.2	0.2
CaO	24.8	28.5	8.5	9.4	15.8	19.9
MgO	6.6	7.6	2.6	2.9	5.8	7.3
Na_2O	1.0	1.2	0.7	0.7	3.1	3.9
K_2O	0.4	0.5	1.2	1.3	0.8	1.0
SO_3	12.9	—	10.2	—	20.6	—

[1] Oxide concentrations normalized to a closure of 100%.
[2] Oxide concentrations renormalized to an SO_3-free basis.

are again similar to those obtained in the previous two cases, with the exception of the 427°C (800°F) test. The 427°C (800°F) test in this case gains slightly more weight than the previous two experiments.

More testing was completed on the Nanticoke PRB and the PRB–LSUS blend. In Figures 4–5, the gas used in the study now contains the NH_3 and phosphorus compounds in addition to the gas used in the previous three tests. Figure 4 contains the data for the Nanticoke PRB test with NH_3 and phosphorus. The addition of the NH_3 and phosphorus compounds increased the rate of weight gain at all temperatures. The difference in rates as temperature was increased became less pronounced.

Figure 5 contains the weight gain curves for the PRB–LSUS test. The rate of weight gain was also increased; however, the temperature effect was still present (increased weight gain with increased temperature).

The baseline tests (without NH_3 and phosphorus compounds) were repeated with the addition of SCR catalyst to the mixture. The results of these tests are in Figures 6–7. Figure 6 contains the weight gain curves for the Nanticoke PRB test with catalyst and the Nanticoke PRB test at baseline conditions and 427°C (800°F). The rate of weight gain with the addition of catalyst at 427°C (800°F) increased approximately 7-fold in this case. The addition of the catalyst will increase the amount of SO_2 that is oxidized to a more reactive form (SO_3), which will in turn increase the rate of sulfate formation.

Figure 7 contains the weight gain curves for the PRB–LSUS blend with catalyst. In this test, the rate of weight gain increased almost tenfold. Again, the increased rate can be attributed to more SO_3 in the system.

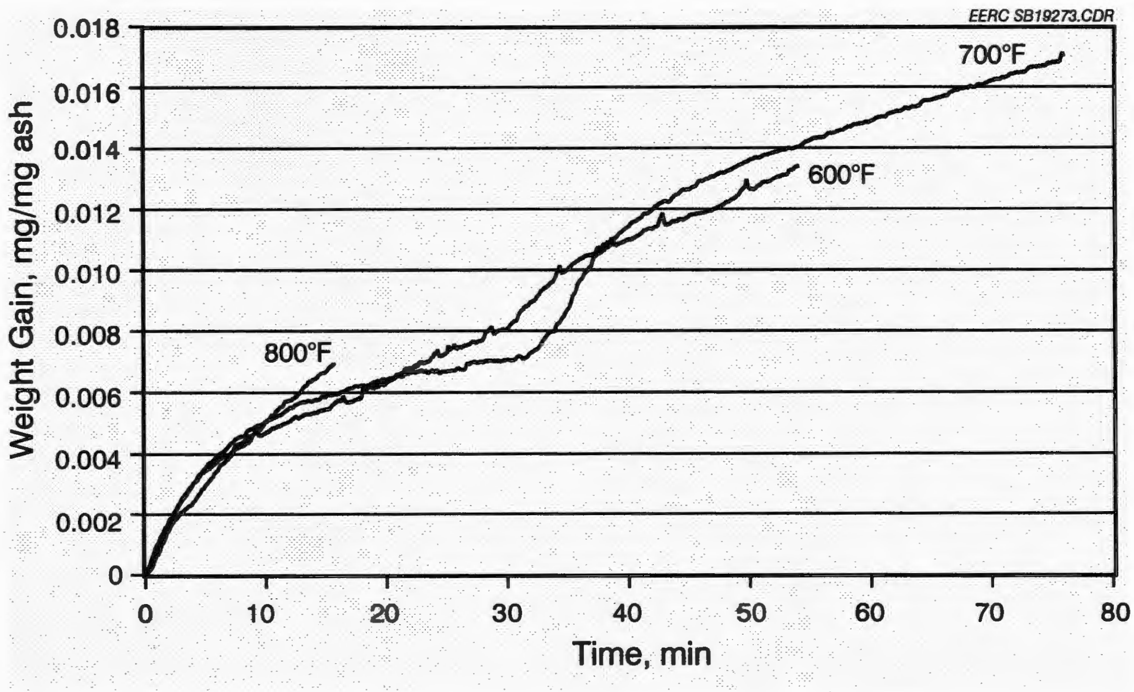

Figure 4. Weight gain curves for Nanticoke PRB (less than 3 μm) with ammonia and phosphorus compounds.

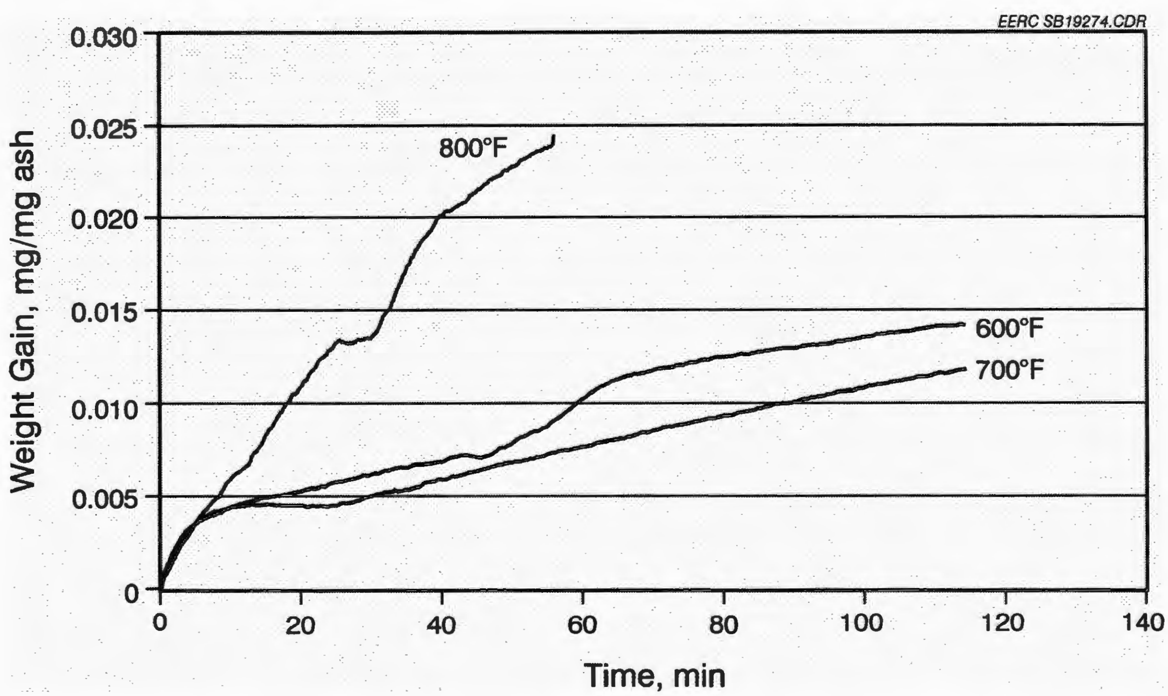

Figure 5. Weight gain curves for Nanticoke PRB–LSUS blend (less than 3 μm) with ammonia and phosphorus compounds.

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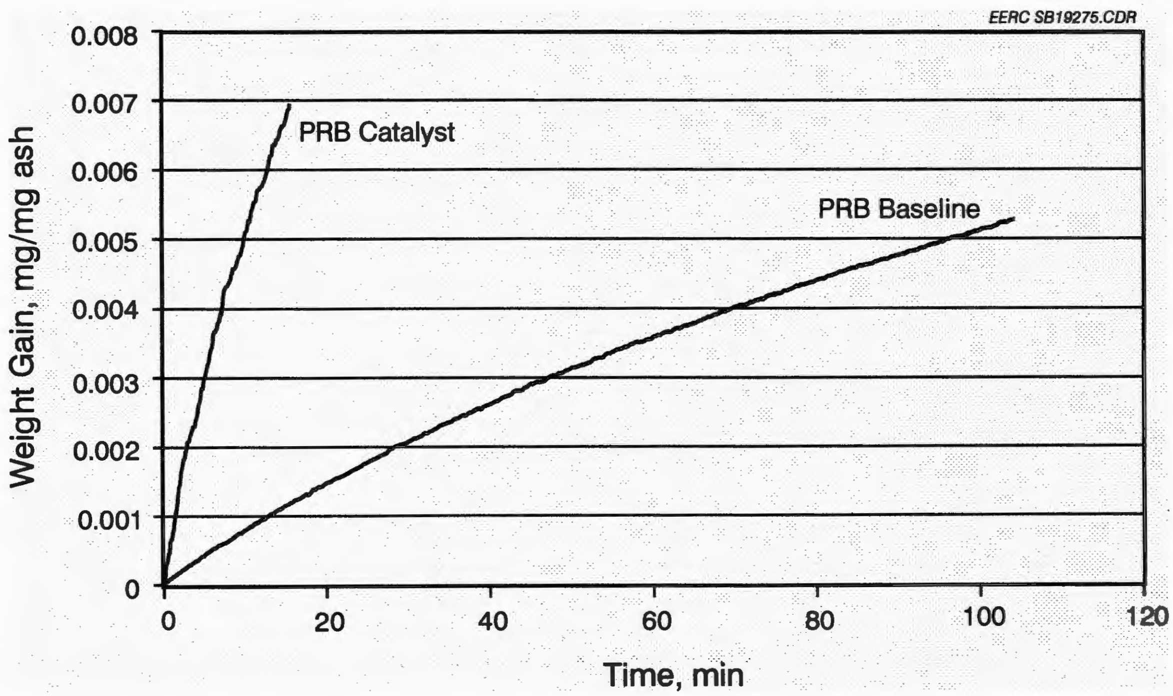

Figure 6. Weight gain curves for baseline Nanticoke PRB and Nanticoke PRB with catalyst.

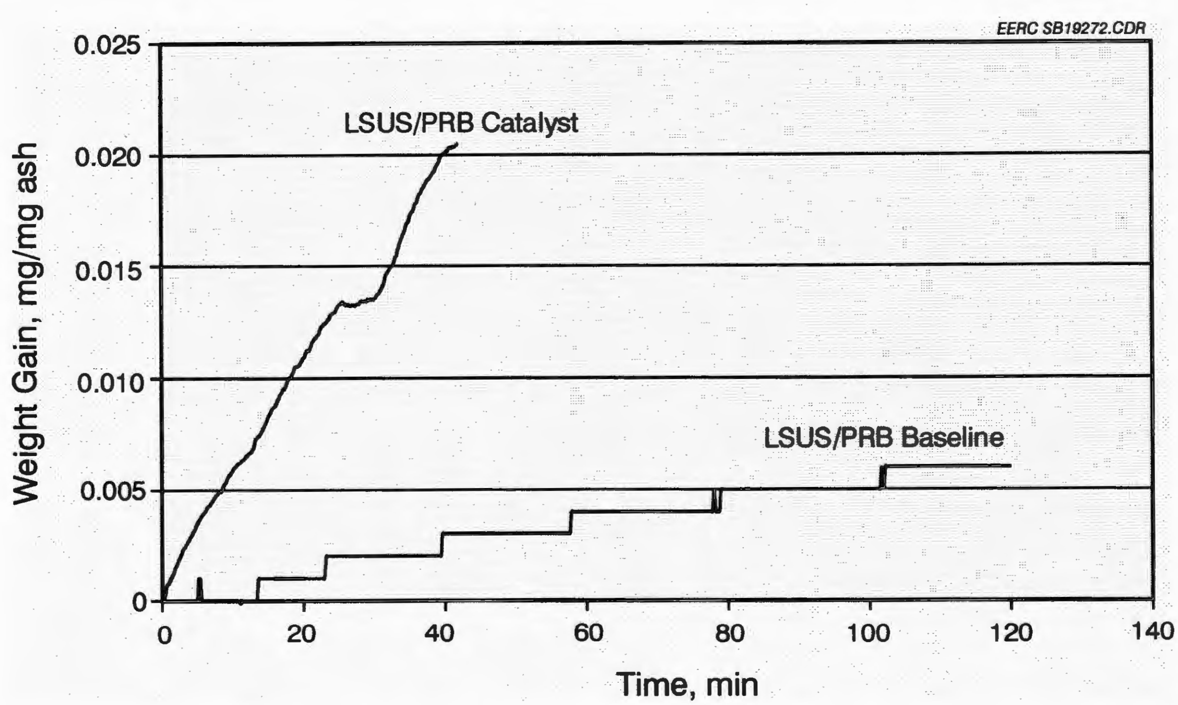

Figure 7. Weight gain curves for baseline LSUS–Nanticoke PRB blend and LSUS–Nanticoke PRB blend with catalyst.

FACT Modeling

Facility for the Analysis of Chemical Thermodynamics (FACT) thermodynamic equilibrium modeling was conducted on each of the ash and flue gas systems tested in the bench-scale screening. The FACT modeling will give an indication of what chemical species are thermodynamically favored at the temperature present in the SCR. Figures 8–13 contain the results of the FACT modeling on the Nanticoke PRB, Beulah lignite, and the Nanticoke PRB–LSUS blend. The gas composition used for the modeling is the same as what was used for the bench-scale analysis in Table 1.

Figures 8–10 have the results for the Nanticoke PRB, Nanticoke PRB–LSUS blend, and the Beulah lignite with 300 ppm NH_3 and 1000 ppm phosphorus pentoxide added. The model predicts that in all three cases the alkali/alkaline-earth phosphates and sulfates will be the predominant species formed. Trace amounts of phosphoric and sulfuric acid will also be present at lower temperatures (232°C [450°F]).

Figures 11–13 have the results for the Nanticoke PRB, the Nanticoke PRB–LSUS blend, and the Beulah lignite with 100 ppm NH_3 and 1 ppm phosphorus pentoxide added. With less phosphorus present, the model predicts that sulfates will dominate. In the case of the Nanticoke PRB, the formation of carbonate compounds is also predicted.

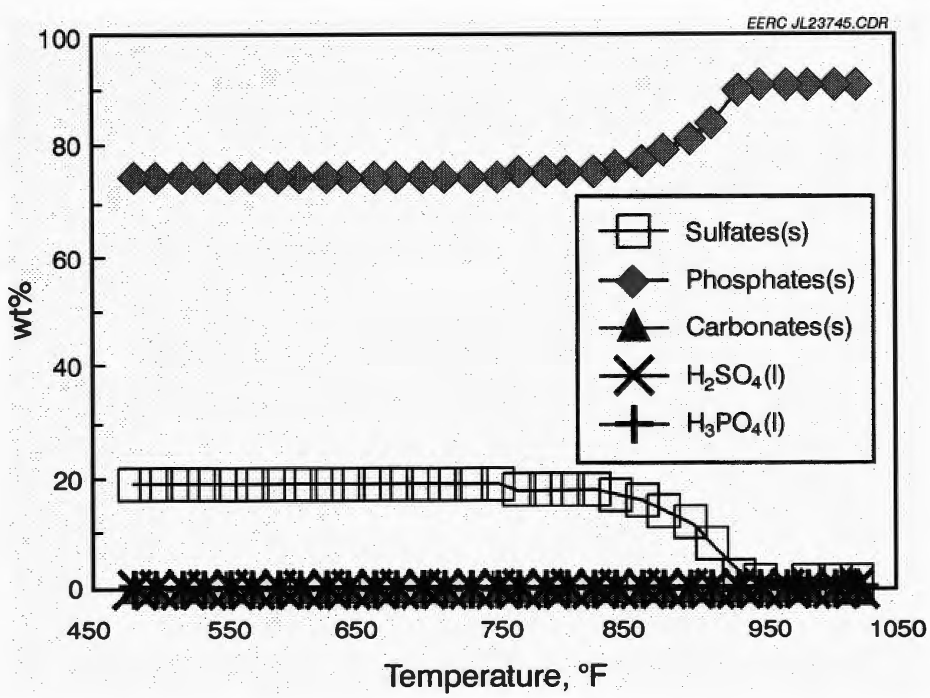

Figure 8. FACT modeling results for Nanticoke PRB with 300 ppm ammonia and 1000 ppm P_2O_5.

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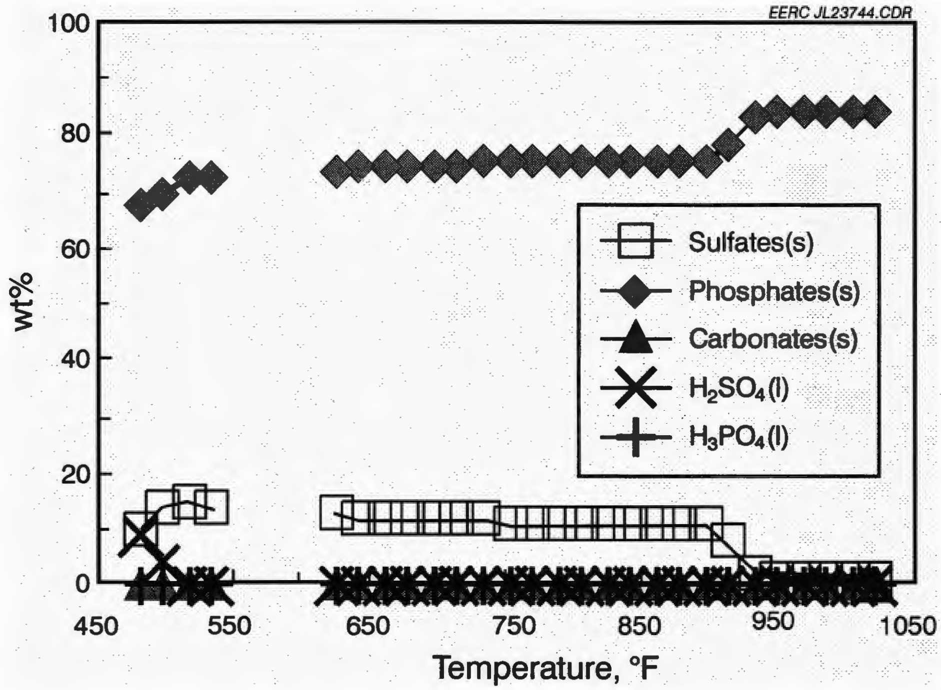

Figure 9. FACT modeling results for Nanticoke PRB–LSUS blend with 300 ppm ammonia and 1000 ppm P_2O_5.

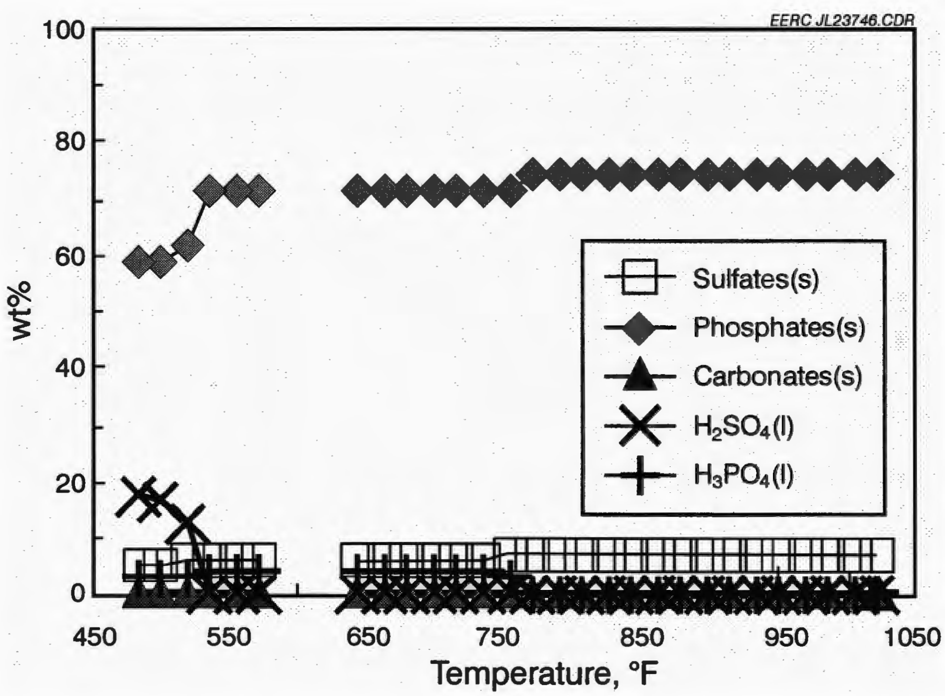

Figure 10. FACT modeling results for Beulah with 300 ppm ammonia and 1000 ppm P_2O_5.

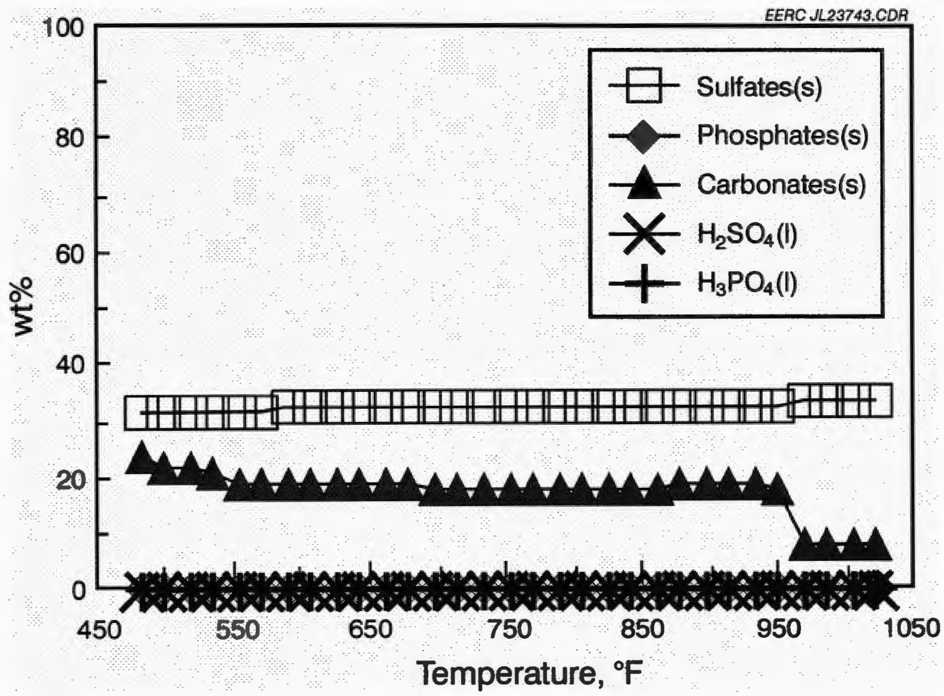

Figure 11. FACT modeling results for Nanticoke PRB with 100 ppm ammonia and 1 ppm P_2O_5.

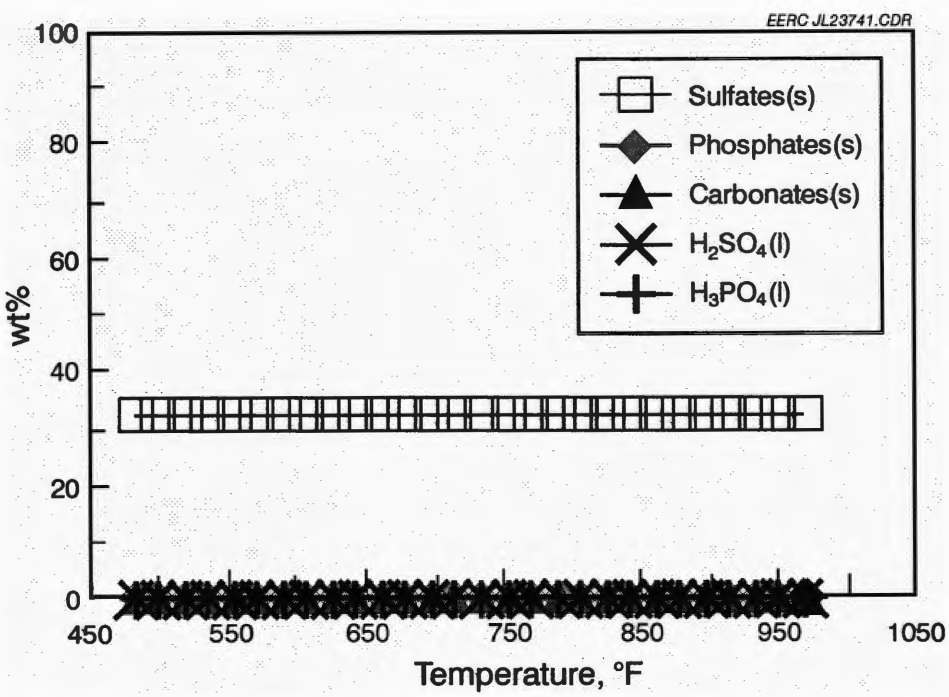

Figure 12. FACT modeling results for Nanticoke PRB–LSUS blend with 100 ppm ammonia and 1 ppm P_2O_5.

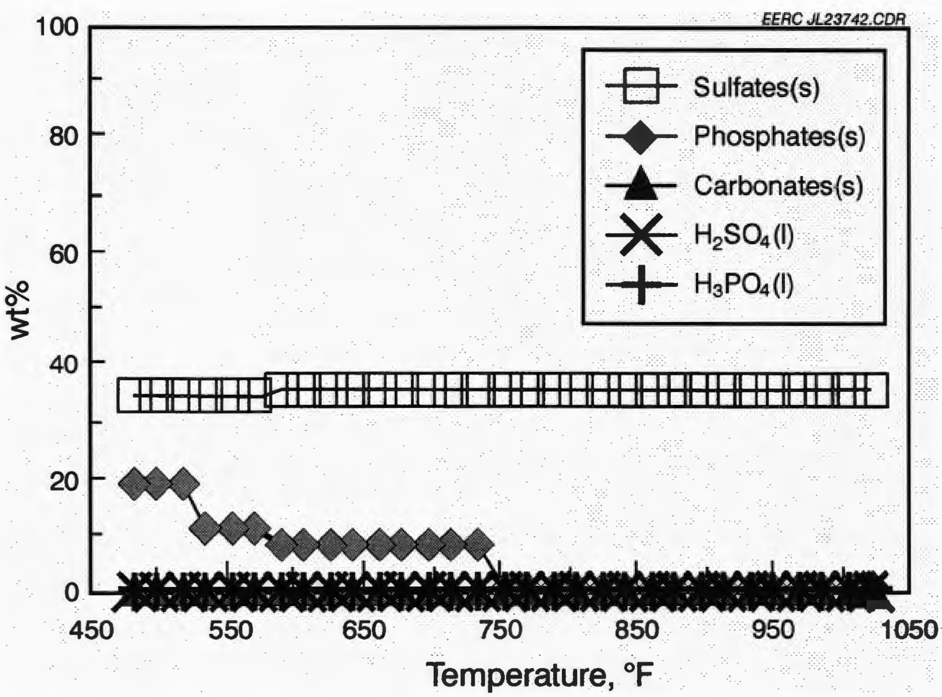

Figure 13. FACT modeling results for Beulah with 100 ppm ammonia and 1 ppm P_2O_5.

Characterization of Reaction Products from Bench-Scale Tests

The reaction products from three of the bench-scale tests were analyzed with SEM to validate the FACT modeling and to determine that the material gained during the tests was indeed a sulfate. Figures 14–16 are SEM micrographs of the fly ash from the Nanticoke PRB, Nanticoke PRB–LSUS blend, and the Beulah lignite. Corresponding Tables 8–10 contain the chemical analysis of several fly ash particles. Sulfur is present in almost all analyses and increases along with calcium. This indicates that most of the sulfur is indeed a calcium sulfate.

Task 3 – Design and Construction of the SCR Slipstream Test Chamber

The SCR slipstream system consists of two primary components: the control room and the SCR reactor. The reactor section consists of a catalyst section, an NH_3 injection system, and sampling ports for NO_x at the inlet and exit of the catalyst section. The control room houses a computer system that logs data and controls the gas flow rates, temperatures, pressure drop across the catalyst, and sootblowing cycles. The computer was programmed to maintain constant temperature of the catalyst, gas flow rates, sootblowing cycles, and NH_3 injection. The computer is equipped with a modem that allowed for downloading of data and modification of the operation of the reactor from a remote computer located at the EERC.

A schematic diagram of the SCR slipstream system is shown in Figure 17. Flue gas is isokinetically extracted from the convective pass of the boiler upstream of the air heater. The temperature is typically about 790°F. The flue gases pass through a 4-inch pipe equipped with sampling, thermocouple, and pressure ports. NH_3 is injected into the piping upstream of the

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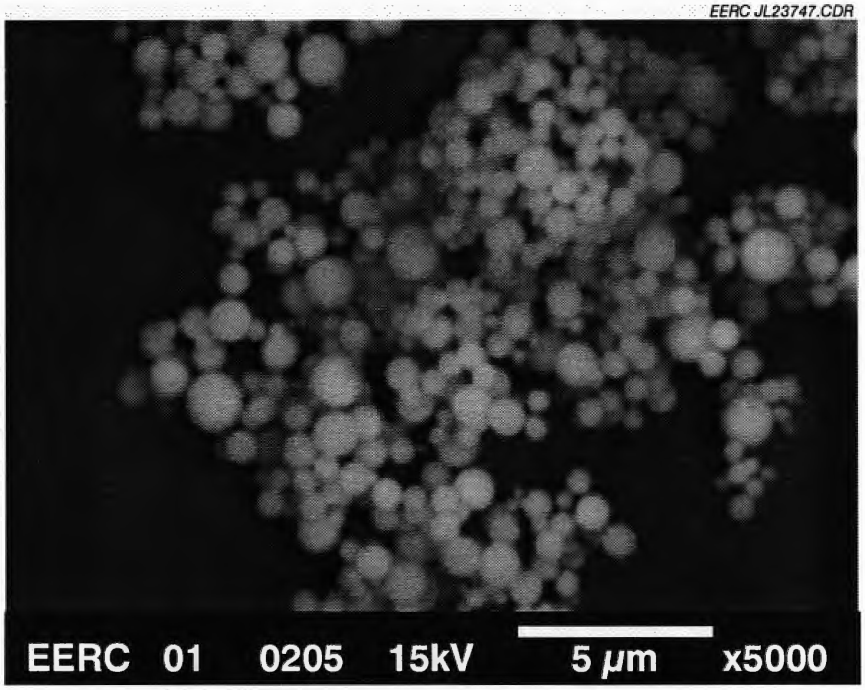

Figure 14. SEM micrograph of reaction products from Nanticoke PRB.

Table 8. SEM/Energy-Dispersive Spectroscopy (EDS) Analysis Results from Nanticoke PRB at 800°F

Element	Percent	Percent
Na	0.50	0.00
Mg	5.60	5.00
Al	9.22	11.30
Si	9.00	8.30
P	1.80	1.30
S	0.70	2.10
Cl	0.00	0.00
K	0.30	0.00
Ca	32.40	31.00
Ti	0.00	1.40
Cr	0.00	0.00
Fe	11.60	7.70
Ba	1.50	1.10
O	27.00	30.60

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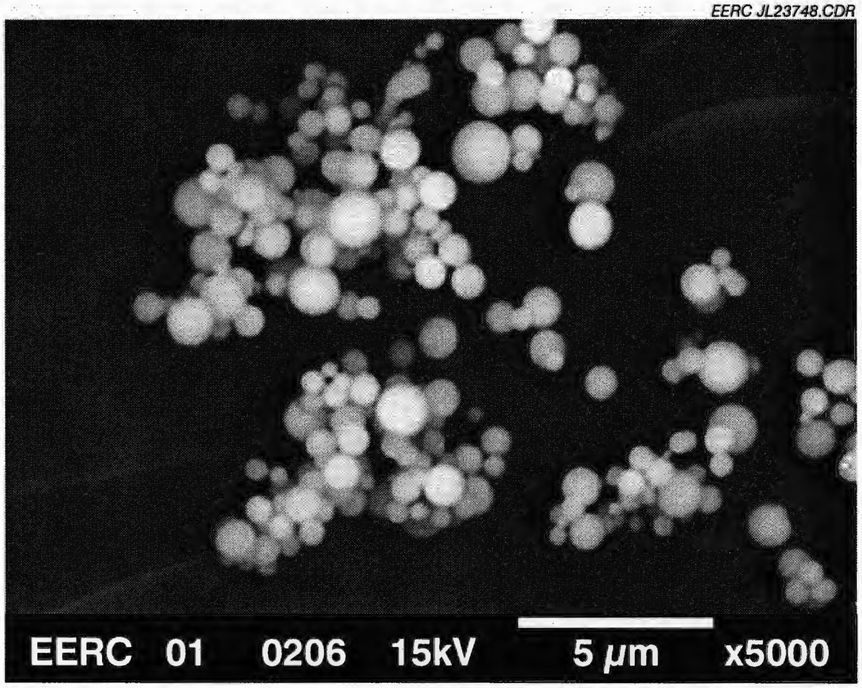

Figure 15. SEM micrograph of reaction products from Nanticoke PRB–LSUS blend.

Table 9. SEM/EDS Analysis Results from Nanticoke PRB–LSUS blend at 800°F

Element	Percent	Percent
Na	0.40	0.50
Mg	2.10	3.10
Al	15.90	12.60
Si	14.50	21.80
P	2.00	4.00
S	1.00	0.00
Cl	0.10	0.00
K	1.70	1.00
Ca	20.00	10.60
Ti	0.90	3.00
Cr	0.00	0.00
Fe	4.90	5.60
Ba	0.00	1.00
O	36.40	36.50

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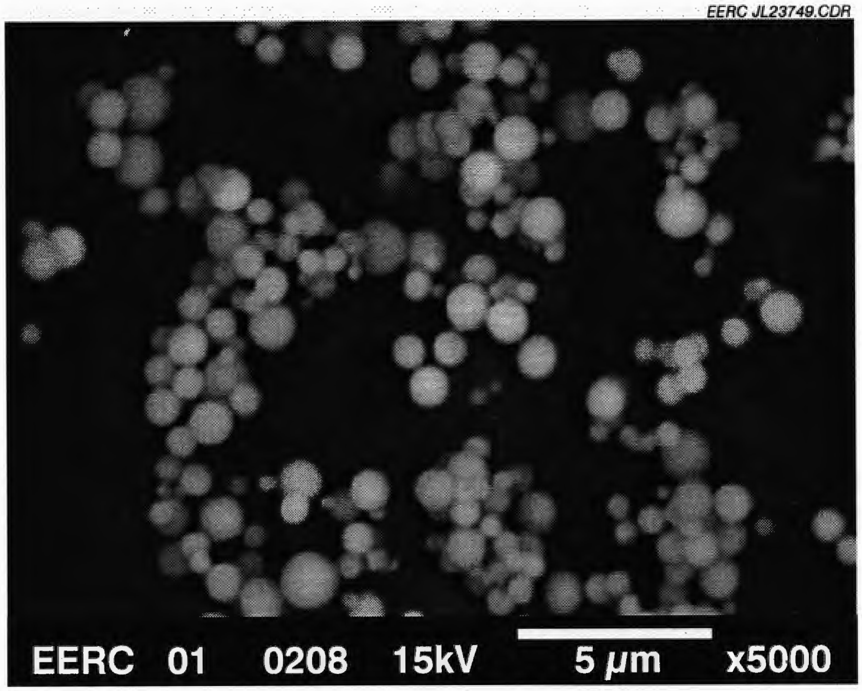

Figure 16. SEM micrograph of reaction products from Beulah lignite.

Table 10. SEM/EDS Analysis Results from Beulah Lignite at 800°F

Element	Percent	Percent
Na	1.60	1.00
Mg	4.00	5.30
Al	7.10	9.00
Si	22.70	18.10
P	0.00	0.00
S	1.60	2.80
Cl	0.00	0.00
K	1.40	0.50
Ca	17.10	25.00
Ti	0.00	1.50
Cr	0.10	0.00
Fe	5.40	4.00
Ba	5.90	4.60
O	33.00	28.00

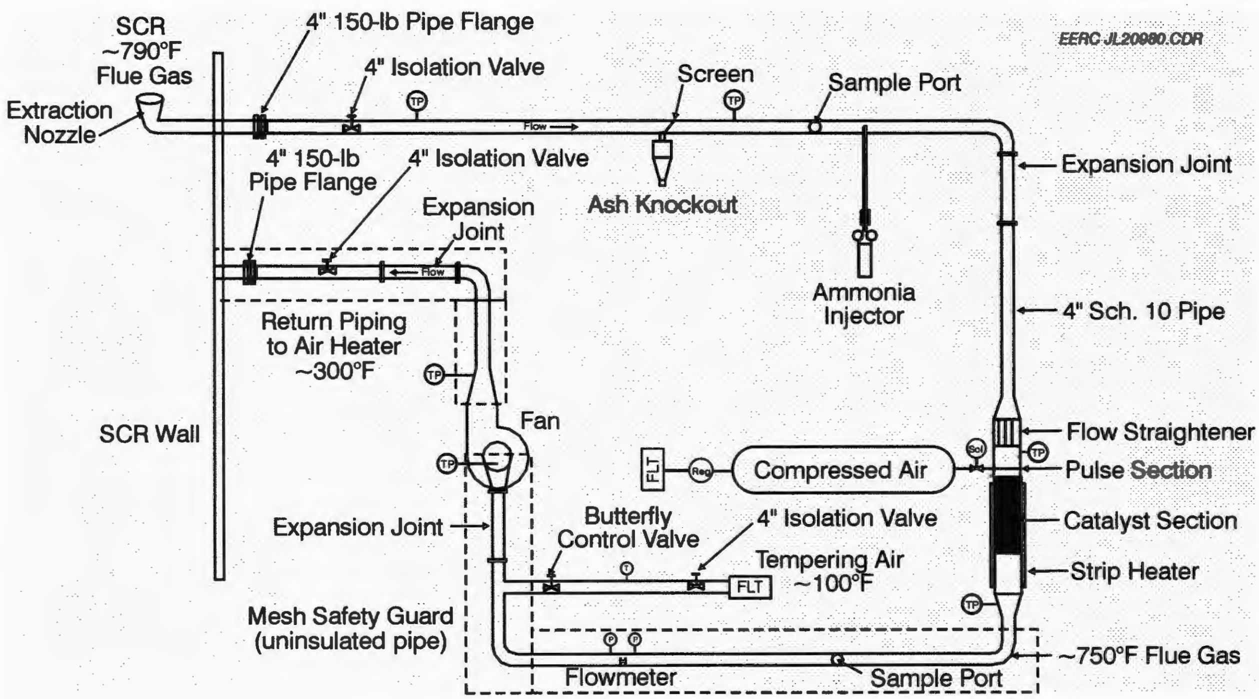

Figure 17. Conceptual schematic of the SCR reactor slipstream field test unit.

reactor section. The reactor consists of a steel housing that is approximately 8.5 inches square and 8 feet long. The reactor section illustrated in Figure 18 has three components, including a flow straightener, a pulse section or sootblower, and a catalyst test section. A metal honeycomb is used as a flow straightener upstream of the catalyst section and is about 6 inches long. A purge section was installed ahead of the catalyst test section to remove accumulated dust and deposits. The catalyst test section is located downstream of the purge section. The entire catalyst section is insulated and equipped with strip heaters for temperature control. The catalyst test section is 1 m (3.28 ft) in length and houses three catalyst sections. Thermocouple and pressure taps are located in the purge sections for measurements before and after each section.

The induced-draft fan is used to extract approximately 5.6 scmm (200 scfm) of flue gas from the convective pass of the utility boiler to achieve an approach velocity of 5.2 m/s (17.0 ft/s). The total gas flow through the reactor represents a thermal load of approximately 300 kW.

The range of operating conditions for the reactor is listed below:

- Gas temperature: ~371°–426°C (700°–800°F)
- Gas flow rate: 11.3–14.2 acmm (400–500 acfm)
- Approach velocity range: 5.0–5.5 m/sec (16.4–18 ft/s)
- NH_3 injection rate: 0.5:1 with NO_x level
- Tempering air for fan: ~1.4–5.7 scmm (50–200 scfm)
- Catalyst dP: 0.5–1.0 inches water column
- Fan sized for up to 30 inches water column

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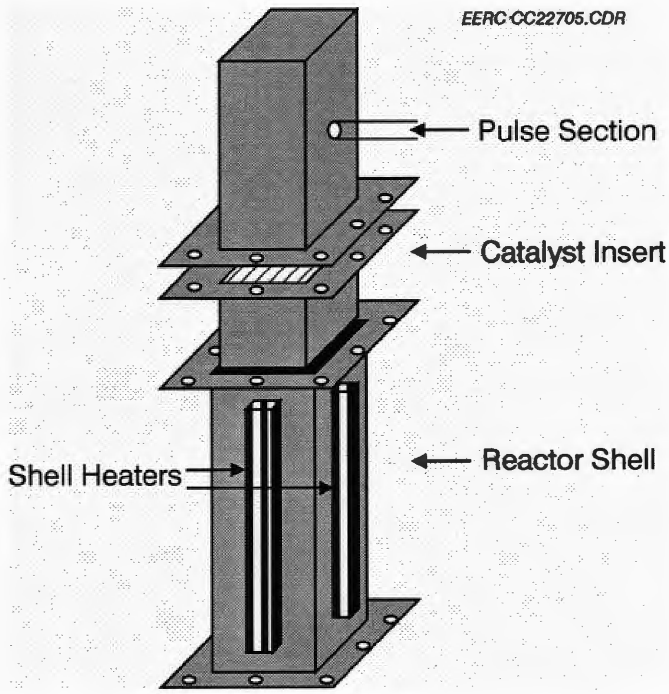

Figure 18. SCR catalyst section.

For catalyst inspection or replacement, the catalyst section can be unbolted and slid out from the reactor (support brackets hold the remaining reactor pieces in place). Once a catalyst reactor section is removed, the top catalyst holder can be removed, and the section(s) of interest removed by pushing it up from the bottom and out the top. A new section is then inserted from the top to replace the piece removed.

Task 4 – SCR Test Chamber Installation and Data Collection at Utility Host Sites

The catalyst installed at the Baldwin and Coyote Stations was the Haldor Topsoe catalyst. Topsoe's DNX-series of catalysts comprises SCR DENOX catalysts tailored to suit a comprehensive range of process requirements. DNX-series catalysts are based on a corrugated, fiber-reinforced TiO_2 carrier impregnated with the active components V_2O_5 and tungsten trioxide (WO_3). The catalyst is shaped to a monolithic structure with a large number of parallel channels. The unique catalyst design provides a highly porous structure with a large surface area and an ensuing large number of active sites. Figure 19 is an image of the Haldor Topsoe SCR catalyst. The pitch of the catalyst was approximately 6 mm.

The catalyst installed at the Columbia Station was a Babcock Hitachi plate-type catalyst. This catalyst is a TiO_2-based plate catalyst, developed and manufactured by Hitachi. Figure 20 shows the design of the catalyst. The pitch of the catalyst was approximately 10 mm.

Upon installation at each utility boiler unit, flue gas temperature, composition, and velocity measurements were obtained using portable equipment. Shakedown testing of the unit was conducted to ensure that all components were operating properly and that data were being logged

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Figure 19. Haldor Topsoe SCR catalyst showing the gas flow passages.

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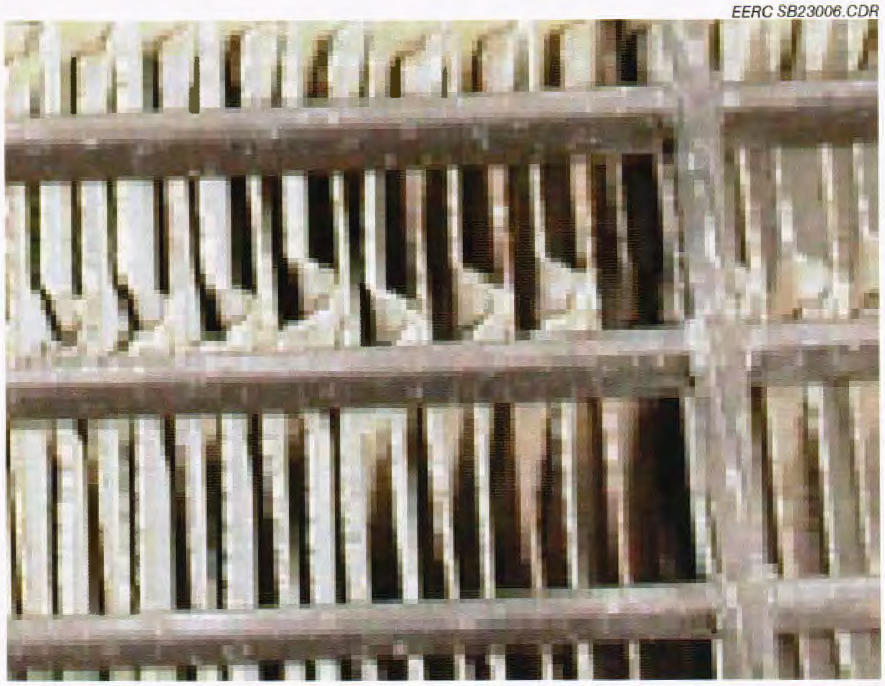

Figure 20. Babcock Hitachi SCR catalyst showing the gas flow passages.

and could be retrieved. After installation and shakedown were completed, the reactor was operated in a computer-controlled, automated mode and monitored on a daily basis to ensure proper operation and data quality. During operation of the SCR slipstream system, catalyst temperature, sootblowing frequency, and pressure drop across the catalyst were monitored and logged. Samples of the exposed SCR catalyst and associated deposits were obtained after exposure to flue gas and particulate for 2, 4, and 6 months. The samples of the catalyst were analyzed to determine the components that were bonding and filling pores, resulting in decreased reactivity.

The characteristics of ash that accumulated on the catalyst were examined using SEM–x-ray microanalysis and XRD (18). Correlations between the physical and chemical characteristics of any ash deposits on the SCR test section and entrained-ash sample collected at the chamber inlet and the coal inorganic composition will be made to discern mechanisms of SCR blinding. Entrained ash was collected at Columbia Station only and characterized as to composition and size.

Baldwin Station Data

The data presented in the following section represent a small portion of the operational data collected. The remainder of the data can be found in a database attached as an appendix to this report. The reactor was installed at the Baldwin Station and operated for a 6-month time period on the Haldor Topsoe catalyst. The information obtained from testing included pressure drop, sootblowing cycles, and reactor temperatures. Table 11 summarizes the operating conditions of the reactors during the testing periods at all plants. Figures 21–23 show the pressure drop across the catalyst test periods from 0 to 2 months, 2 to 4 months, and 4 to 6 months, respectively. During the first 2 months of operation, the pressure shown in Figure 21 was about 0.5 inches of water; at the end of 2 months, the pressure drop was about 0.8 inches of water, indicating plugging had occurred. The air was pulsed a minimum of every 8 hours in an attempt to maintain cleanliness. The reactor was monitored on a daily basis, and adjustments in pulsing cycles were made in order to minimize deposit accumulation. However, for the first 2 months, the pressure drop steadily increased. During several periods when the unit was taken off-line, the temperature of the catalyst was maintained. At 2-month intervals, a section of catalyst was removed and replaced with a new one.

Table 11. Selected Operating Conditions of the SCR Catalysts

Plant Name	Average SCR Inlet Temp., °F	Average SCR Outlet Temp., °F	Air Pulse Frequency	Flue Gas Flow Rate, acfm
Baldwin	645	549	Once a day and on demand	393
Columbia	672	662	Once a day and on demand	385
Coyote	675	667	Once a day and on demand	385

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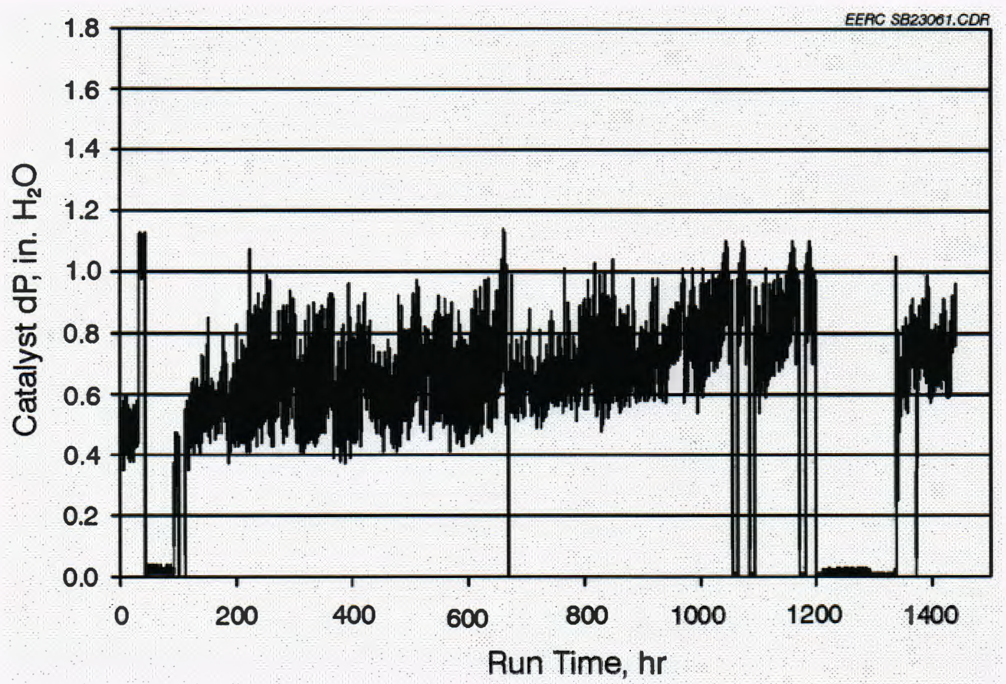

Figure 21. Catalyst pressure drop at Baldwin Station at 0 to 2 months of operation.

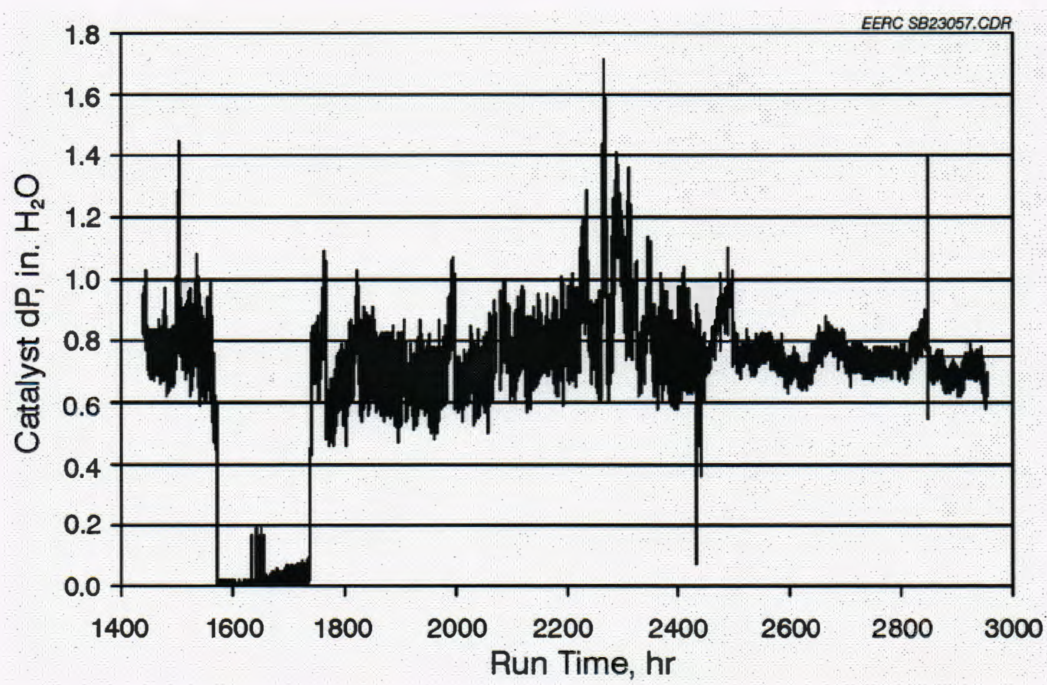

Figure 22. Catalyst pressure drop at Baldwin Station at 2 to 4 months of operation.

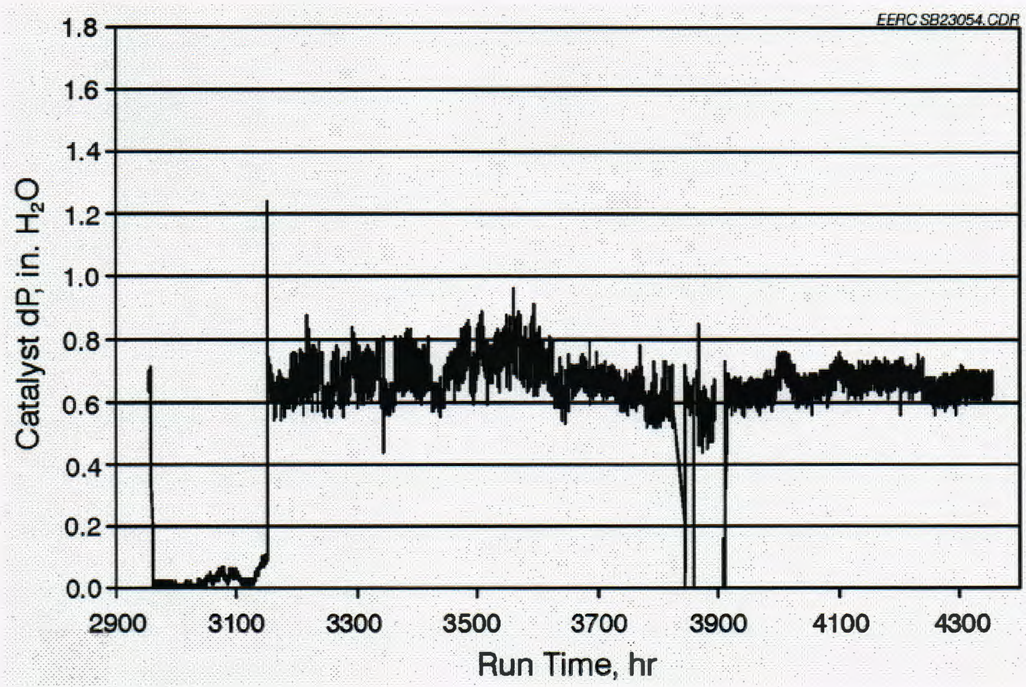

Figure 23. Catalyst pressure drop at Baldwin Station at 4 to 6 months of operation.

For Months 2 through 4, the pressure drop was highly variable initially but was about 0.8 inches of water. From Months 4 through 6, the pressure drop was maintained between 0.6 and 0.8 inches of water. This is due to the installation of a fresh catalyst section and leaving two-thirds of the catalysts in place that were partially plugged. The gas velocity in the single section of new, clean catalyst was high because of channeling, and the result of the high gas flow was less deposition and accumulation. Gas velocity has a significant impact on the potential for deposits to form. However, at high gas velocity, low NO_x conversion is likely.

Columbia Station Data

The reactor was installed at the Columbia Station and operated for a 6-month period of time for the Babcock Hitachi catalyst. The information obtained from the testing included pressure drop information, sootblowing cycles, and reactor temperature. Table 11 shows the reactor temperature, air-pulsing cycles, and airflow rates. Figures 24–26 show the test periods from 0 to 2 months, 2 to 4 months, and 4 to 6 months, respectively. The pressure drop across the SCR upon installation was about 0.4 inches of water and increased to an average of about 0.5 inches of water, but ranged from less than 0.4 to greater than 0.8 inches of water. Figure 25 shows the pressure drop for Months 2 to 4. The pressure drop increased from about 0.5 to 0.7 inches of water because of accumulation of ash. Figure 26 shows a rapid increase in pressure drop across the catalyst at about 3000 hours of operation, and aggressive pulsing brought it down to 0.4 inches of water until the catalyst section was changed out at about 3200 hours. After the reactor was cleaned and one catalyst section was replaced, the pressure drop was about 0.3 but increased to over 0.6 inches of water up to about 4100 hours. There was an outage at the plant,

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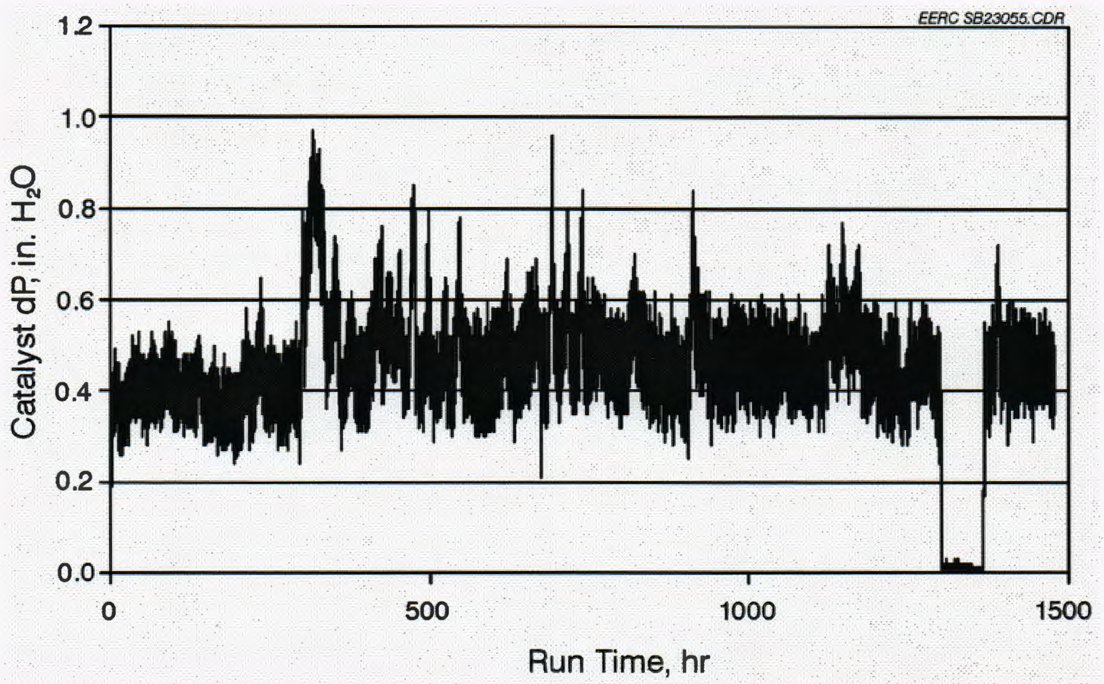

Figure 24. Catalyst pressure drop at Columbia Station at 0 to 2 months of operation.

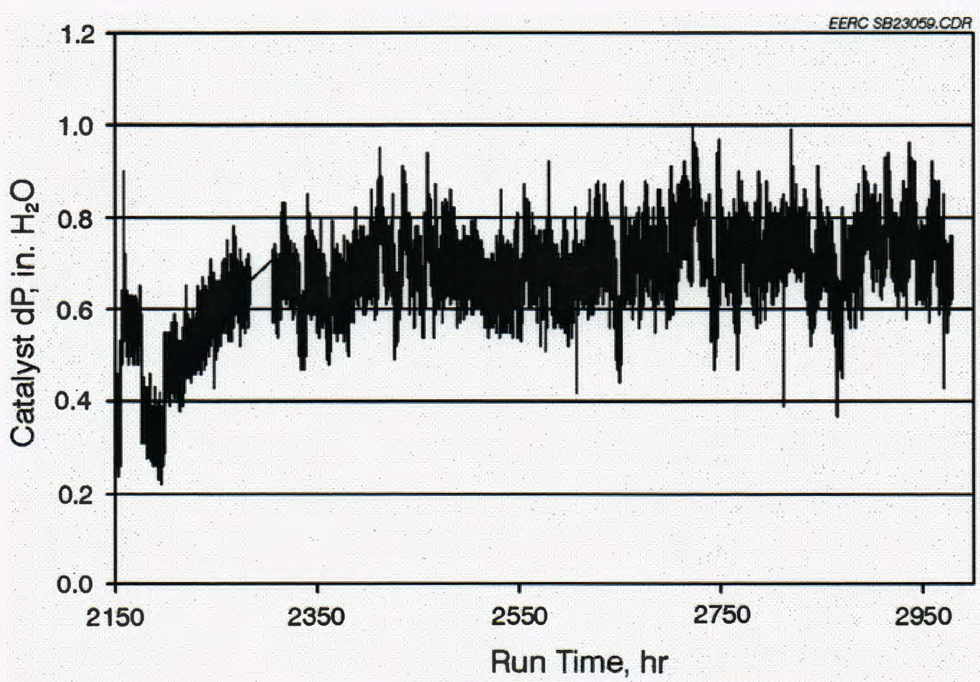

Figure 25. Catalyst pressure drop at Columbia Station at 2 to 4 months of operation.

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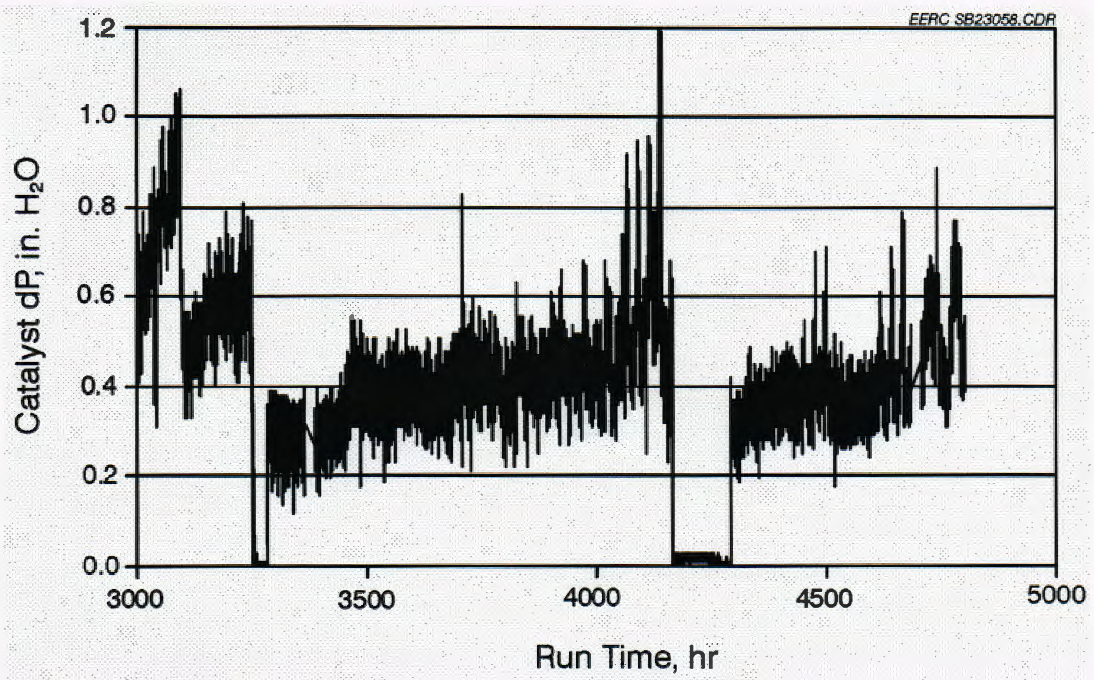

Figure 26. Catalyst pressure drop at Columbia Station at 4 to 6 months of operation.

and aggressive pulsing of the reactor was conducted; the pressure drop was brought back down to 0.3 but rapidly increased to over 0.5 inches of water within 500 hours.

Coyote Station Data

The same reactor that was installed at the Baldwin Station was moved and installed at the Coyote Station. In addition, the same Haldor Topsoe catalyst was used in the reactor. The cleaning cycles, temperatures, and gas flow rates are listed in Table 11. The reactor was operated for a 6-month period of time. Figures 27–29 show the test periods from 0 to 2 months, 2 to 4 months, and 4 to 6 months, respectively. The pressure drop across the catalyst upon installation was about 0.4 inches of water. After only 750 hours, the pressure drop was 1.5 inches of water, indicating significant plugging and blinding. Very aggressive air pulsing was conducted, with little success in removing the deposits. The pressure drop for the catalyst was over two times greater than the pressure drop observed for the Baldwin Station utilizing the same reactor and same catalyst. At about 1700 hours, the reactor was cleaned, and a section of catalyst was removed for characterization. The pressure drop after cleaning was about 0.8 to 1.0 inches of water. The pressure drop did not increase as rapidly because of the higher velocities through the clean section of the catalyst. Figure 29 shows the pressure drop for 4 to 6 months of operation. The pressure drop during the last two months of testing was highly variable and at times reached values over 2 inches of water.

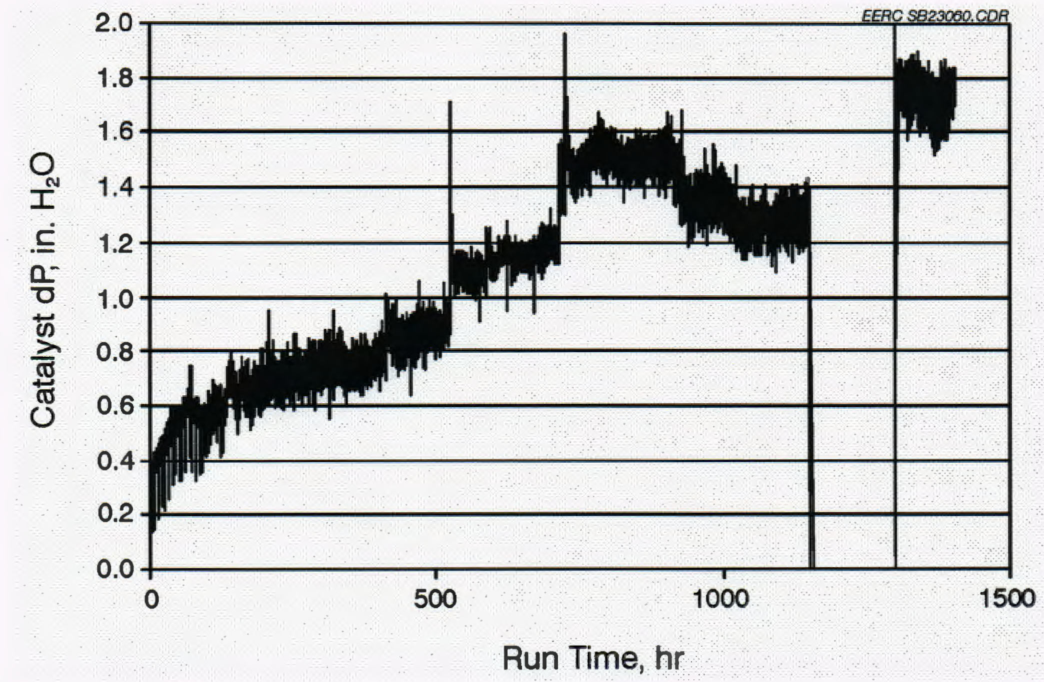

Figure 27. Catalyst pressure drop at Coyote Station at 0 to 2 months of operation.

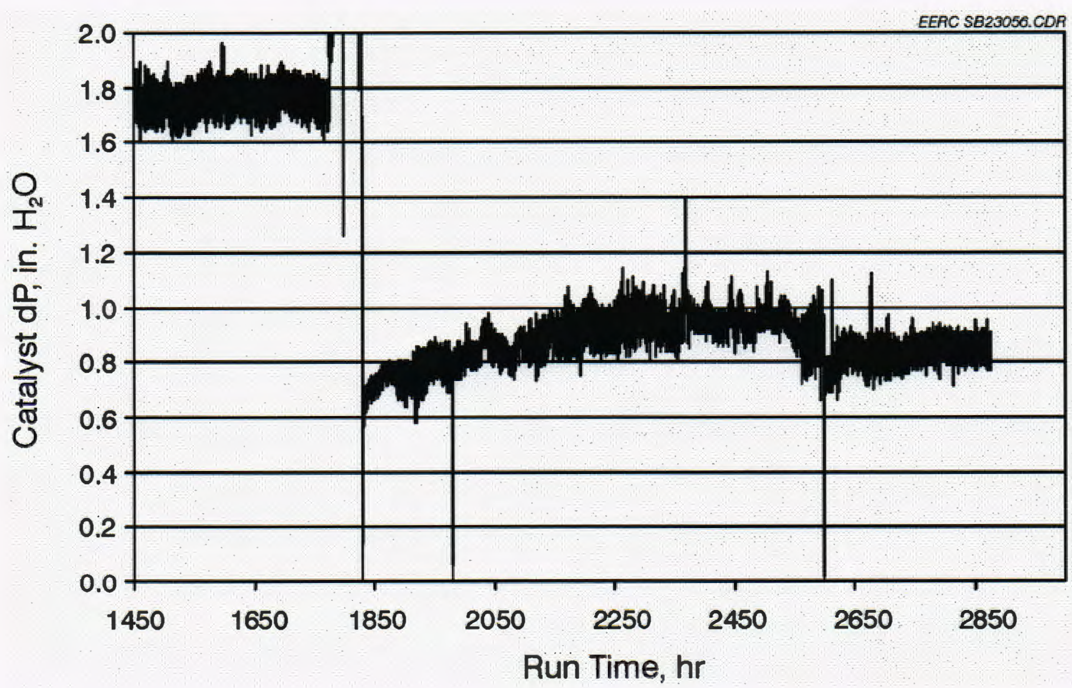

Figure 28. Catalyst pressure drop at Coyote Station at 2 to 4 months of operation.

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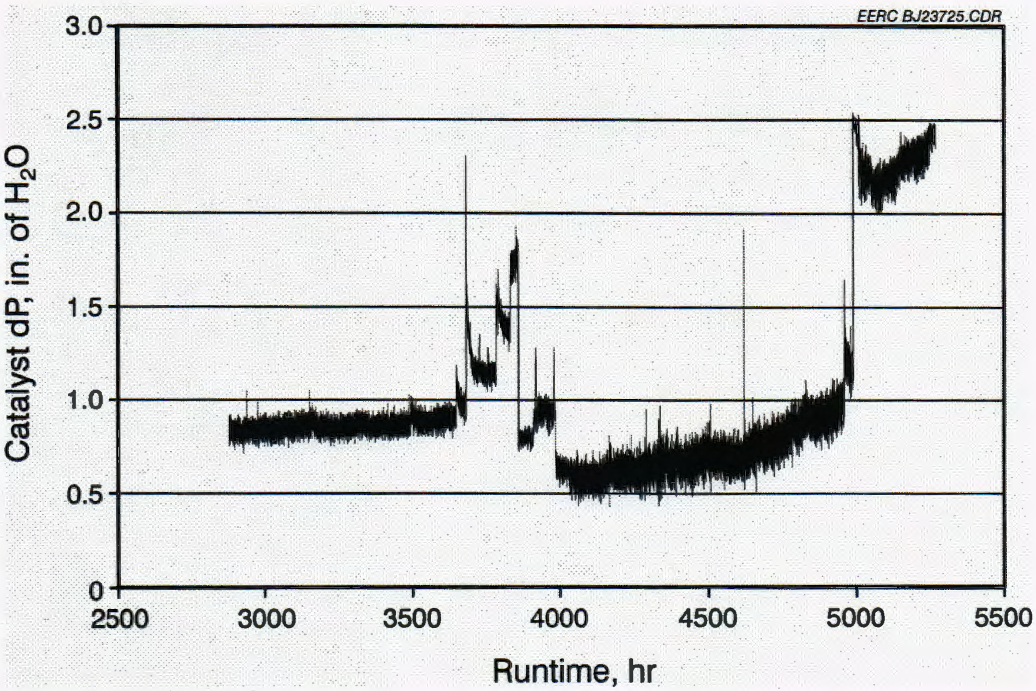

Figure 29. Catalyst pressure drop at Coyote Station at 4 to 6 months of operation.

Visual Observations

The tops of the catalysts were photographed during inspection and sampling of the catalyst sections. Figure 30 shows the ash materials that accumulated on the catalyst inlet after 2 months of operation. The most significant accumulation was noted for the Coyote Station, followed by Columbia and Baldwin. The Coyote Station had some larger pieces of ash deposit material on the surface as well as plugging of the catalyst passages. The Baldwin Station showed some obvious deposition along the walls of the reactor and some accumulation on the inlet sections. The Columbia Station showed more significant accumulation and plugging than the Baldwin Station. After 4 months, the tops of the catalysts were photographed during inspection and sampling of the catalyst sections, as shown in Figure 31. The most significant accumulation was noted for the Coyote Station and some accumulation for the Baldwin Station.

The characteristics of the ash materials that collected on the catalyst surfaces and pores were characterized by SEM and x-ray microanalysis, and in selected cases, XRD was used to determine the crystalline phases present. The catalysts were sampled after 2, 4, and 6 months. The sections were sampled, and approximately 2.5-cm squares were mounted for SEM analysis on double-stick tape and in epoxy resin. The double-stick tape samples allowed for characterization of the external morphology of the particles and catalyst surface. The samples mounted in resin were cross-sectioned and polished, which allowed for more detailed and quantitative analysis of the bonding materials and materials that accumulated in the pores of the catalyst. The data presented in the following section represent a small portion of the data collected by SEM analysis. The remainder of the data can be found in a database attached as an appendix to this report.

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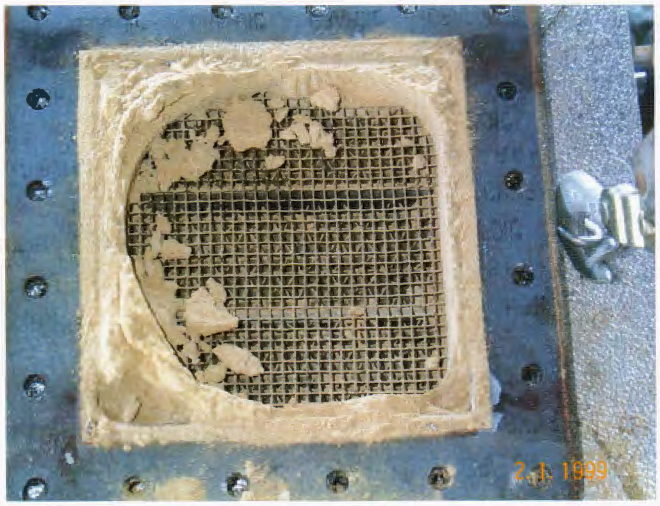
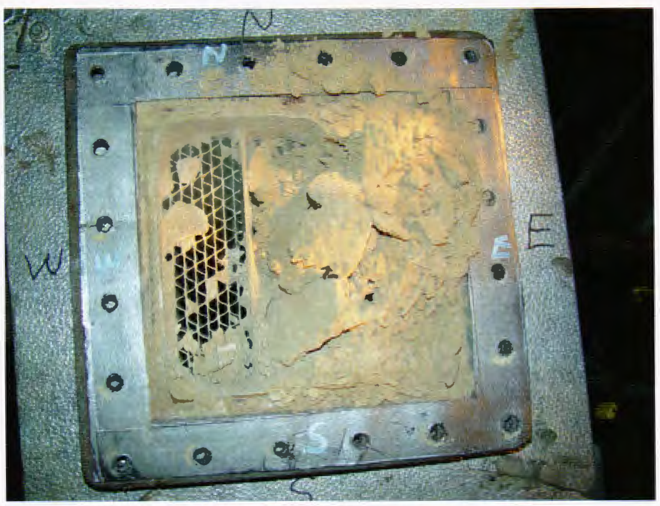


Baldwin Station after 2 months



Coyote Station after 2 months

Columbia Station after 2 months

Figure 30. Pictures of catalyst inlet after about 2 months of testing at each plant.

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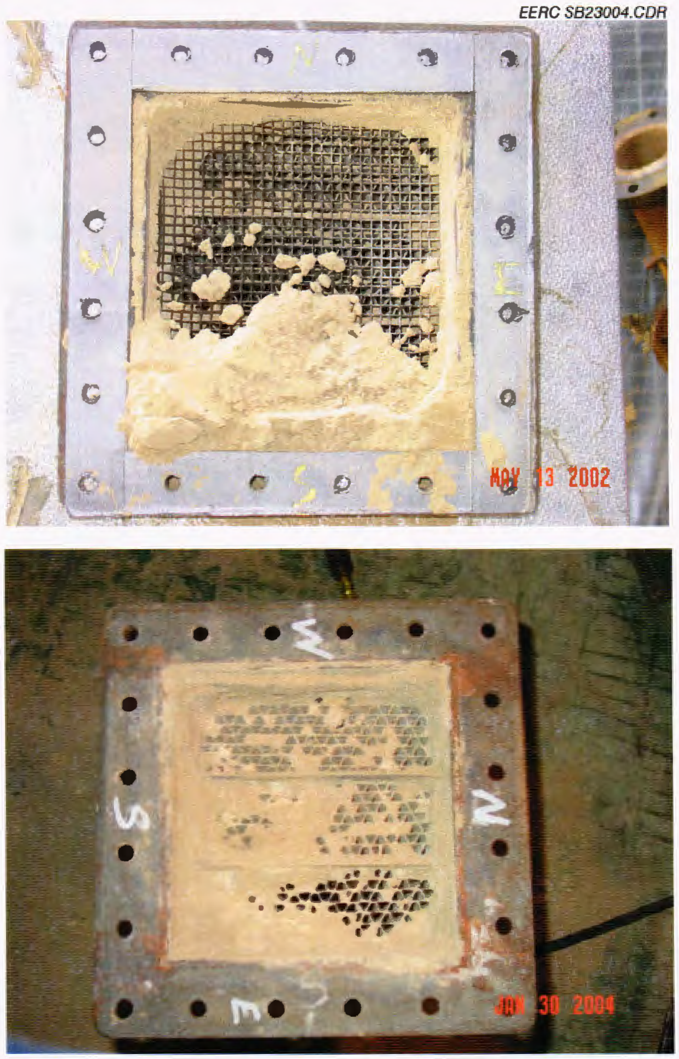

Baldwin Station after 4 months

Coyote Station after 4 months

Figure 31. Pictures of catalyst inlet after about 4 months of exposure to flue gas and particulate.

Baldwin Station Deposits

Samples of catalyst were removed from the Baldwin Station after exposure to flue gas and particulate after 2, 4, and 6 months. Figure 32 shows the characteristics of the ash deposit material on the SCR catalyst after 2 months of exposure. This is a polished cross section of a deposit on the surface of the catalyst. Figure 32a shows particles on the surface of the catalyst that range in size from <1 to 15 μm. The larger particles range from oxides of solely silicon and iron to complex mixtures rich in aluminum and calcium; aluminum, silicon, and calcium; aluminum, calcium, and iron; and sodium, calcium, aluminum, and silicon. Chemical analysis of selected particles is summarized in Table 12. The samples of ash mounted on double-stick tape allow for the characterization of the external surfaces of the particles. The surface of a typical particle that is accumulating on the surface of the catalyst is shown in Figure 32b. The blebs on the surface are composed of calcium and sulfur, with some iron and minor amounts of sodium and potassium. Figure 32c shows a cross section of the deposited particles showing calcium- and

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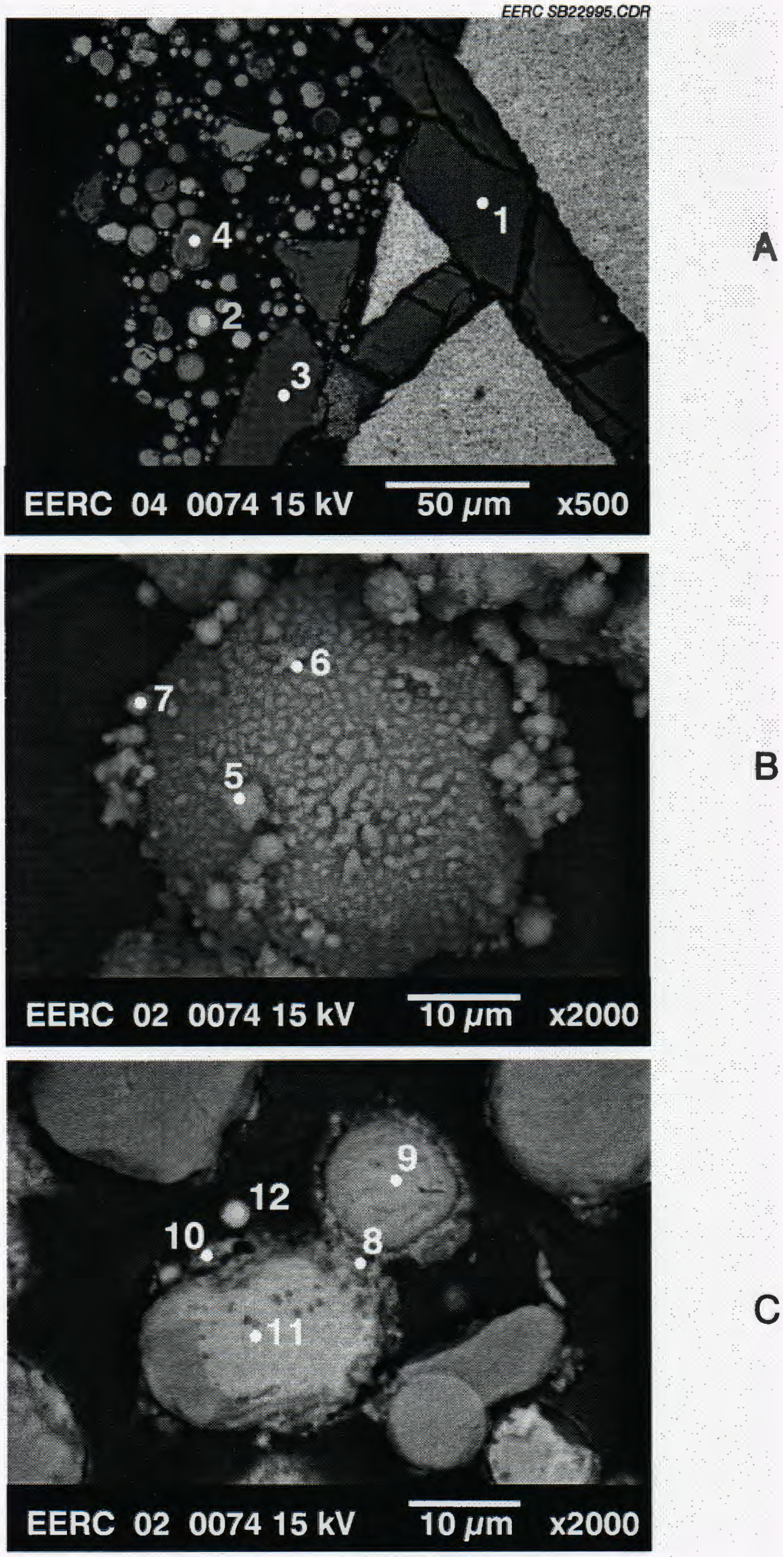

Figure 32. SEM images of ash collected on catalyst surface at the Baldwin Station after 2 months of exposure: A) low-magnification image of ash deposit on catalyst surface, B) high-magnification image of coated ash particle, and C) high-magnification image of polished cross section showing coatings on particles.

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Table 12. Chemical Composition of Selected Points and Areas in Figure 32

	Element, wt%					
	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6
Oxide						
Na_2O	0.2	0.0	0.2	2.3	2.5	3.0
MgO	0.0	6.3	0.0	3.1	3.0	1.3
Al_2O_3	3.6	17.9	6.9	29.6	8.4	5.5
SiO_2	92.1	5.9	86.5	39.9	3.4	53.2
P_2O_5	0.1	0.4	0.0	0.0	1.8	0.0
SO_3	3.3	0.4	5.2	0.1	51.8	18.1
K_2O	0.0	0.0	0.0	0.6	0.4	0.5
CaO	0.0	49.4	0.1	18.6	16.4	14.6
TiO_2	0.7	4.5	0.4	1.0	0.0	0.0
Fe_2O_3	0.0	14.6	0.7	3.6	12.3	3.8
BaO	0.0	0.6	0.0	1.1	0.0	0.0
Total	100	100	100	100	100	100
	Point 7	Point 8	Point 9	Point 10	Point 11	Point 12
Oxide						
Na_2O	3.6	0.7	0.6	1.6	0.4	0.9
MgO	1.6	2.5	4.5	3.0	3.6	3.5
Al_2O_3	4.4	5.4	22.7	12.2	21.2	14.2
SiO_2	15.7	3.4	16.1	1.0	8.1	2.3
P_2O_5	1.5	0.3	0.5	2.3	0.0	4.6
SO_3	52.4	53.0	0.0	46.4	0.0	19.7
K_2O	0.7	0.2	0.0	0.1	0.0	0.0
CaO	13.0	28.8	41.5	27.1	51.1	39.2
TiO_2	0.0	0.0	0.0	0.0	0.0	0.0
Fe_2O_3	7.1	5.7	14.2	6.5	15.6	15.6
BaO	0.0	0.0	0.0	0.0	0.0	0.0
Total	100	100	100	100	100	100

aluminum-rich particles bonded together with a calcium- and sulfur-rich phase. This phase is in the form of calcium sulfate based on XRD analysis conducted on the deposited ash samples.

The 4-month sample from the Baldwin Station showed more extensive sulfation of the alkaline-earth elements present in the deposits. Figure 33 shows the images of a polished cross section of an ash deposit on the surface of the catalyst. The deposit formed both on the surface of the catalyst and within the catalyst pores, as shown in Figure 33a. Figure 33b shows a higher-magnification view of the deposit on the catalyst surface. The deposit consists of particles of fly ash bonded together by a matrix of calcium- and sulfur-rich material, likely in the form of calcium sulfate. The chemical composition of selected points shown in Table 13 shows high levels of calcium and sulfur. There is much more extensive bonding of the materials with the sulfate matrix as compared to the 2-month sample.

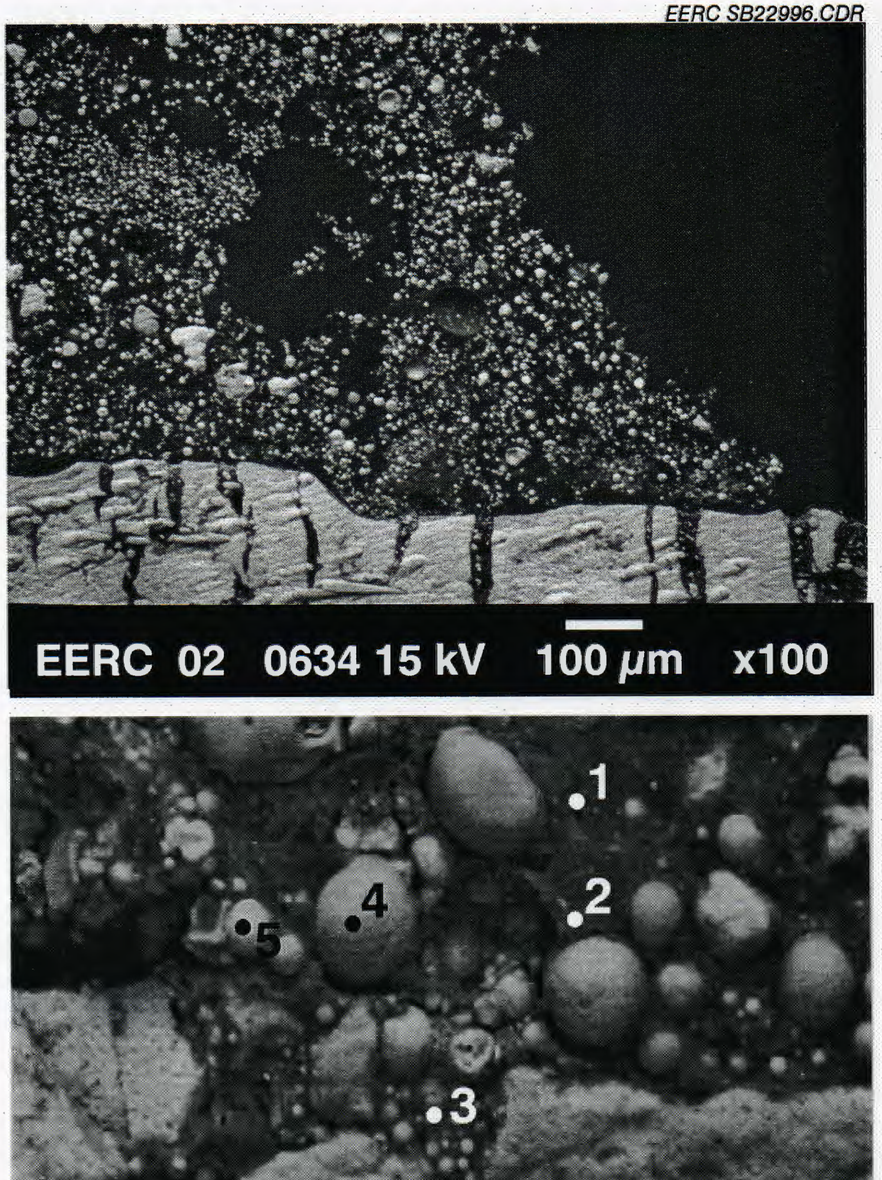

Figure 33. SEM images of ash collected on catalyst surface at the Baldwin Station after 4 months of exposure: A) low-magnification image of ash deposit on catalyst surface and B) high-magnification image of polished cross section showing particles in a matrix of calcium- and sulfur-rich materials.

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Table 13. Chemical Composition of Selected Points and Areas in Figure 33

	Element, wt%				
	Point 1	Point 2	Point 3	Point 4	Point 5
Oxide					
Na_2O	1.7	2.3	0.0	0.3	1.0
MgO	5.9	3.0	1.2	1.8	3.8
Al_2O_3	3.7	2.5	3.3	5.7	6.3
SiO_2	9.7	31.5	13.3	70.0	18.5
P_2O_5	3.1	2.7	0.8	0.0	2.6
SO_3	48.1	31.0	35.8	0.0	32.1
K_2O	0.5	0.7	0.0	1.5	0.0
CaO	22.0	8.8	38.0	13.9	14.7
TiO_2	1.8	10.8	4.1	1.6	15.1
Fe_2O_3	2.1	6.6	3.4	4.2	5.9
BaO	1.4	0.0	0.0	0.9	0.0
Total	100	100	100	100	100

The 6-month sample from the Baldwin Station showed extensive sulfation of the alkaline-earth elements present in the deposits. Figures 34a and 34b show regions of the catalyst where all the pores were blocked and a minimal amount of deposit on the surface of the catalyst. Figure 34c shows a higher-magnification view of the deposit that is filling the catalyst pore. The deposit consists of particles of fly ash bonded together by a matrix of calcium- and sulfur-rich material, likely in the form of calcium sulfate. The chemical compositions of selected points that indicate the presence of high levels of calcium and sulfur are listed in Table 14. There is much more extensive bonding of the materials with the sulfate matrix as compared to the 2-month sample. In addition, there are some regions of high levels of calcium, aluminum, and sulfur present. The calcium aluminum materials are likely derived from the calcium aluminum phosphate minerals found in the coal fired at this plant.

Columbia Station Deposits

The 2-month sample from the Columbia Station showed particles adhering to the surface and filling pores in the catalyst, as shown in Figure 35. Figure 35a shows the external morphology of the catalyst surface showing particles trapped in the pores of the catalysts. Chemical compositions of selected points are shown in Table 15. The 2-month sample shows significant evidence of sulfation after only 2 months of exposure. It appears to be more significant than that observed for the Baldwin 2-month sample. Figures 35b and 35c show a higher-magnification view of the deposit that is filling the catalyst pore. The deposit consists of particles of fly ash bonded together by a matrix of calcium- and sulfur-rich material, likely in the form of calcium sulfate.

The 4-month sample from the Columbia Station showed particles adhering to the surface and filling pores in the catalyst, as shown in Figure 36. Figure 36a shows the external morphology of the catalyst surface showing particles trapped in the pores of the catalysts. Chemical compositions of selected points are shown in Table 16. It appears to be more

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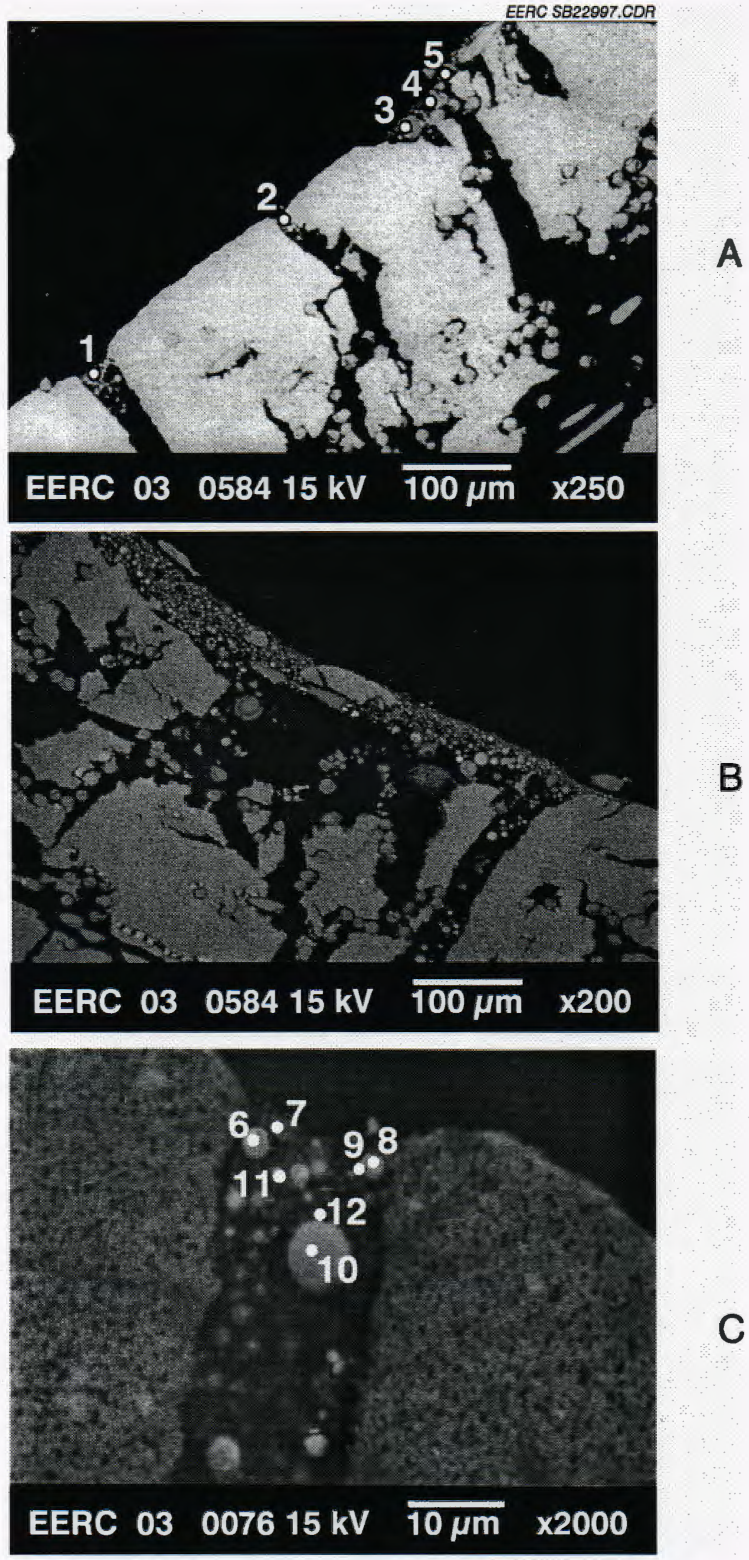

Figure 34. SEM images of ash collected on catalyst surface at the Baldwin Station after 6 months of exposure: A) low-magnification image of ash deposit on catalyst surface, and C) high-magnification image of polished cross section showing particles in a matrix of calcium- and sulfur-rich materials.

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Table 14. Chemical Composition of Selected Points and Areas in Figure 34

Element, wt%						
	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6
Oxide						
Na_2O	0.6	1.0	2.1	0.3	0.5	2.7
MgO	4.3	2.5	6.3	0.7	1.6	7.6
Al_2O_3	14.8	16.0	15.6	15.5	14.7	0.9
SiO_2	3.3	7.8	18.8	57.7	7.7	47.3
P_2O_5	2.3	2.1	0.5	0.6	1.8	0.0
SO_3	30.7	20.4	17.7	0.0	29.0	0.8
K_2O	0.7	0.0	1.0	0.4	0.9	0.9
CaO	28.8	28.7	28.1	22.5	34.9	28.4
TiO_2	2.0	7.2	2.2	0.3	1.3	1.1
Fe_2O_3	11.4	12.9	6.2	0.0	7.6	7.9
BaO	1.1	1.4	1.4	2.0	0.0	2.5
Total	100	100	100	100	100	100
	Point 7	Point 8	Point 9	Point 10	Point 11	Point 12
Oxide						
Na_2O	1.7	0.4	0.5	2.2	1.3	1.7
MgO	4.5	6.4	5.9	5.0	3.4	6.4
Al_2O_3	5.0	2.4	3.0	19.2	10.8	3.8
SiO_2	8.4	18.4	18.5	31.0	17.9	16.7
P_2O_5	1.8	0.9	1.0	0.0	1.7	1.2
SO_3	37.9	1.7	5.3	0.0	22.5	13.9
K_2O	0.4	0.0	0.0	0.9	0.8	0.0
CaO	31.4	52.6	49.0	28.9	30.6	45.4
TiO_2	1.9	6.9	7.4	2.4	2.0	1.1
Fe_2O_3	7.1	5.7	6.0	6.3	6.1	6.5
BaO	0.0	4.6	3.5	4.2	2.9	3.3
Total	100	100	100	100	100	100

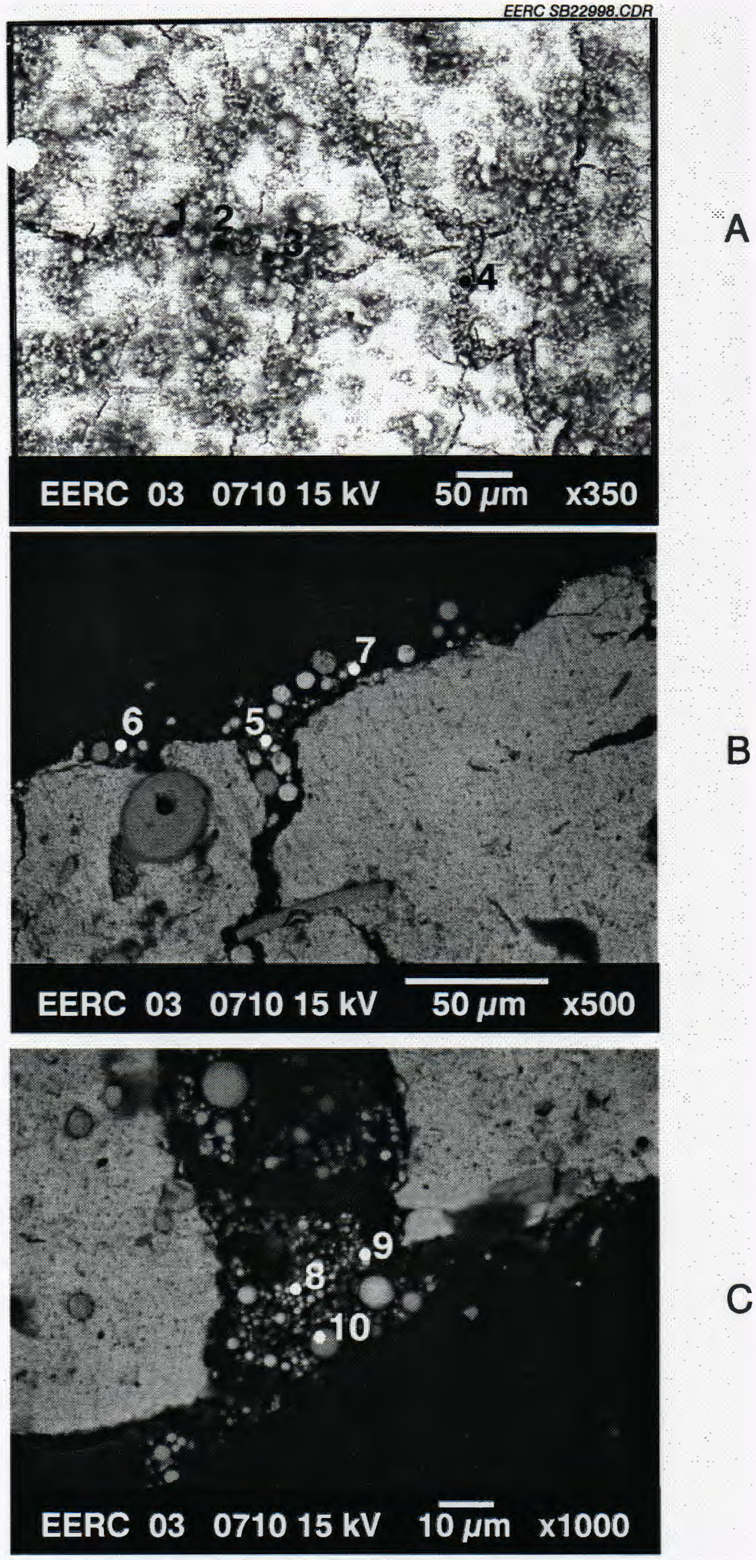

Figure 35. SEM images of ash collected on catalyst surface at the Columbia Station after 2 months of exposure: A) low-magnification image of ash deposit on catalyst surface, B) low-magnification image of polished cross section showing particles in a matrix of calcium- and sulfur-rich materials, and C) higher-magnification image of bonding.

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Table 15. Chemical Composition of Selected Points and Areas in Figure 35

	Element, wt%				
	Point 1	Point 2	Point 3	Point 4	Point 5
Oxide					
Na_2O	0.0	0.9	1.3	0.1	0.3
MgO	0.7	1.5	3.2	3.9	0.9
Al_2O_3	12.2	17.6	20.9	12.2	5.9
SiO_2	10.8	4.1	23.3	7.3	6.3
P_2O_5	0.9	0.1	0.0	1.4	2.6
SO_3	15.2	17.6	16.8	17.1	32.3
K_2O	0.2	0.0	0.5	0.0	0.1
CaO	14.1	43.1	25.0	42.0	34.9
TiO_2	44.8	2.8	1.1	10.5	5.2
Fe_2O_3	1.1	12.3	3.9	5.5	11.5
BaO	0.0	0.0	4.2	0.0	0.0
Total	100	100	100	100	100
	Point 6	Point 7	Point 8	Point 9	Point 10
Oxide					
Na_2O	0.0	0.6	1.0	0.5	1.8
MgO	0.0	1.5	2.9	1.4	0.7
Al_2O_3	5.5	12.4	13.6	9.0	20.7
SiO_2	9.4	6.1	15.4	7.9	61.8
P_2O_5	1.2	0.6	1.7	3.1	0.2
SO_3	33.3	22.0	19.5	30.7	0.0
K_2O	0.0	0.0	0.1	0.2	2.5
CaO	44.1	48.5	34.1	38.3	4.4
TiO_2	0.5	4.4	2.4	2.6	2.2
Fe_2O_3	3.1	2.3	6.0	6.3	4.4
BaO	2.8	1.6	3.3	0.0	1.3
Total	100	100	100	100	100

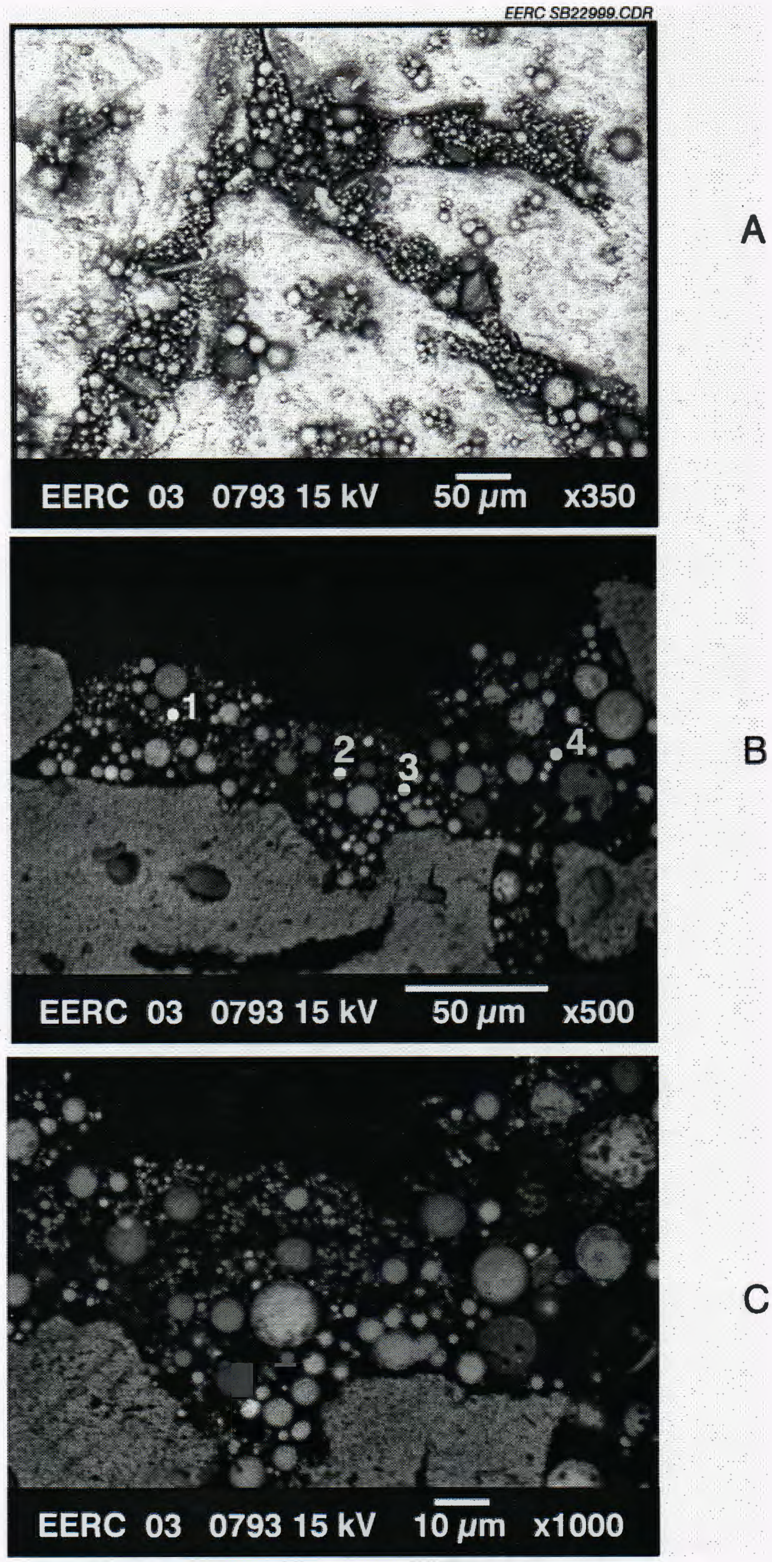

Figure 36. SEM images of ash collected on catalyst surface at the Columbia Station after 4 months of exposure: A) low-magnification image of ash deposit on catalyst surface, B) low-magnification image of polished cross section showing particles in a matrix of calcium- and sulfur-rich materials, and C) higher-magnification image of bonding.

Table 16. Chemical Composition of Selected Points and Areas in Figure 36

	Element, wt%			
	Point 1	Point 2	Point 3	Point 4
Oxide				
Na_2O	0.5	0.0	0.6	0.3
MgO	3.3	1.9	3.2	2.4
Al_2O_3	13.1	10.2	13.0	6.3
SiO_2	12.4	8.4	8.4	3.6
P_2O_5	1.3	0.5	2.1	0.6
SO_3	27.7	29.9	32.2	47.4
K_2O	0.2	0.6	0.1	0.8
CaO	32.1	38.1	28.9	33.2
TiO_2	1.0	2.7	1.3	0.0
Fe_2O_3	6.3	6.3	7.6	2.6
BaO	2.0	1.4	2.5	2.6
Total	100	100	100	100

significant than that observed for the Baldwin 2-month sample. Figures 36b and 36c show a higher-magnification view of the deposit that is filling the catalyst pore. The deposit consists of particles of fly ash bonded together by a matrix of calcium- and sulfur-rich material, likely in the form of calcium sulfate.

The 6-month sample from the Columbia Station showed particles adhering to the surface and filling pores in the catalyst, as shown in Figure 37. Figure 37a shows the external morphology of the catalyst surface showing particles trapped in the pores of the catalysts. Chemical compositions of selected points are shown in Table 17. Figures 37b and 37c show a higher-magnification view of the deposit that is filling the catalyst pore. The deposit consists of particles of fly ash bonded together by a matrix of calcium- and sulfur-rich material, likely in the form of calcium sulfate. The 6-month samples show the most extensive degree of sulfation of the Columbia Station samples.

Coyote Station Deposits

The 2-month sample from the Coyote Station showed particles adhering to the surface and filling pores in the catalyst, as shown in Figure 38. Figure 38a shows the external morphology of the catalyst surface showing particles trapped in the pores of the catalysts. Chemical compositions of selected points are shown in Table 18. The 2-month sample shows significant evidence of sulfation after only 2 months of exposure and was much more pronounced than the 2-month samples for the Baldwin and Columbia Stations that are fired on PRB coals. Figures 38b and 38c show a higher-magnification view of the deposit that is filling the catalyst pores. The deposit consists of particles of fly ash bonded together by a matrix of calcium- and sulfur-rich material, likely in the form of calcium sulfate. The presence of sodium enhances the bonding and sulfation of the particles to form a strongly bonded matrix.

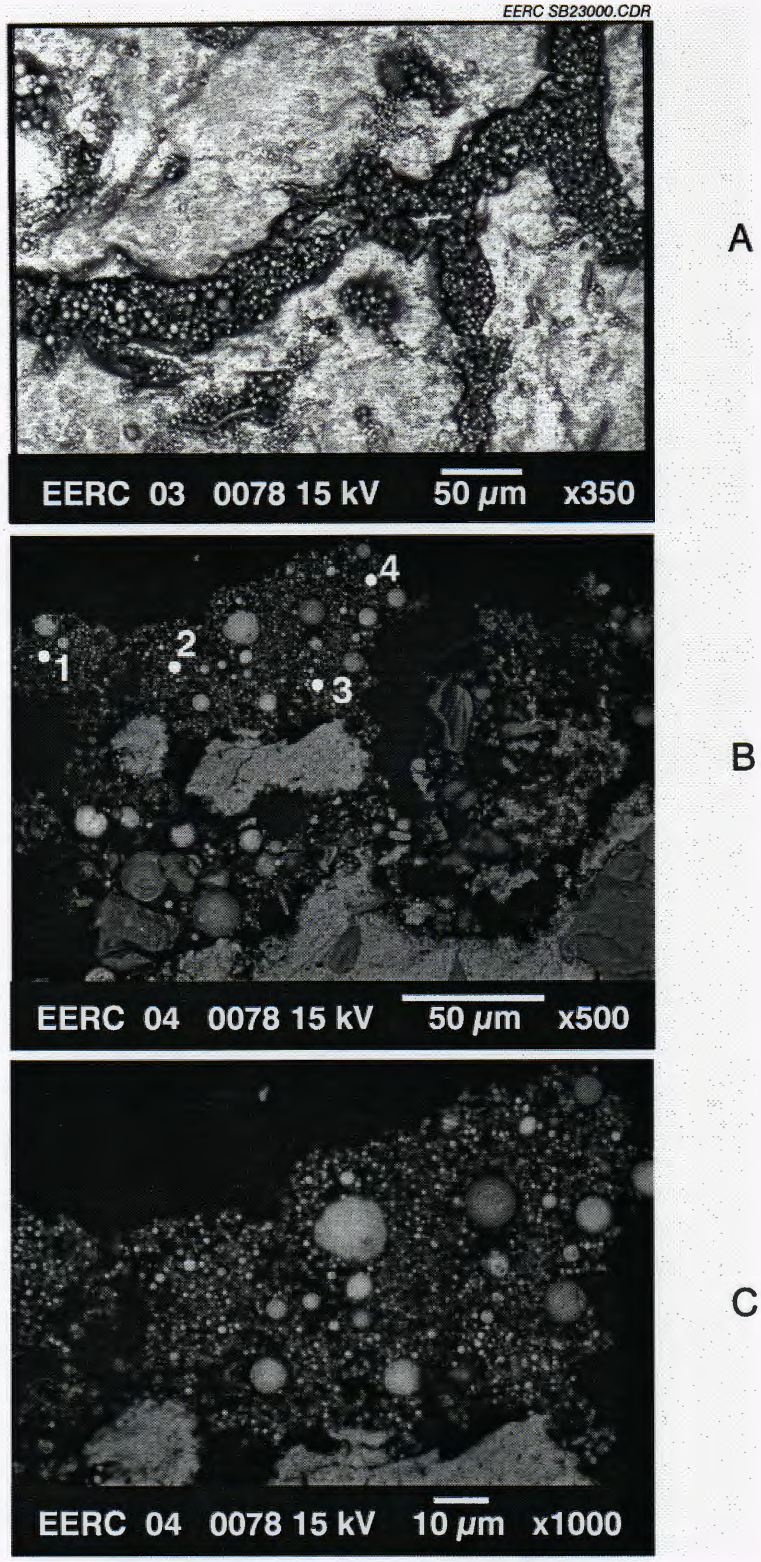

Figure 37. SEM images of ash collected on catalyst surface at the Columbia Station after 6 months of exposure: A) low-magnification image of ash deposit on catalyst surface, B) low-magnification image of polished cross section showing particles in a matrix of calcium- and sulfur-rich materials, and C) higher-magnification image of bonding.

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Table 17. Chemical Composition of Selected Points and Areas in Figure 37

	Element, wt%			
	Point 1	Point 2	Point 3	Point 4
Oxide				
Na_2O	0.1	0.0	0.3	0.6
MgO	1.8	0.7	1.7	2.2
Al_2O_3	10.9	9.6	6.2	11.3
SiO_2	13.1	11.3	12.4	19.5
P_2O_5	3.9	4.8	0.2	2.1
SO_3	27.6	34.0	35.5	30.0
K_2O	0.5	0.3	0.1	1.2
CaO	33.0	25.9	39.8	25.8
TiO_2	0.8	2.5	1.6	3.3
Fe_2O_3	6.1	9.7	1.9	2.9
BaO	2.1	1.2	0.0	1.1
Total	100.00	100.00	100.00	100.00

The 4-month sample from the Coyote Station showed particles adhering to the surface and completely filling and masking the pores in the catalyst as shown in Figure 39. Figure 39a shows the external morphology of the catalyst surface showing the masking of the catalyst surface. Chemical compositions of selected points are shown in Table 19. The 4-month sample shows more sulfation than the 2 months of exposure samples. Figures 39b and 39c show a higher-magnification view of the deposit that is filling the catalyst pores. The deposit consists of particles of fly ash bonded together by a matrix of sodium-, calcium-, and sulfur-rich material, likely in the form of calcium sulfate. The presence of sodium and potassium enhances the bonding and sulfation of the particles to form a strongly bonded matrix. Significant sodium was found in the deposits, as shown in Table 19.

The 6-month sample from the Coyote Station showed particles adhering to the surface and filling pores in the catalyst, as shown in Figure 40. Figure 40a shows the external morphology of the catalyst surface showing particles trapped in the pores of the catalysts. Chemical compositions of selected points are shown in Table 20. Figures 40b and 40c show a higher-magnification view of the deposit that is filling the catalyst pore. The deposit consists of particles of fly ash bonded together by a matrix of sodium-, calcium- and sulfur-rich material, likely in the form of sulfate. The 6-month samples show the most extensive degree of sulfation of the Coyote Station samples.

Reactivity Testing

Samples of the catalyst from 2, 4, and 6 months of operations were submitted to the appropriate catalyst vendor for reactivity testing. The results of only the samples from the Baldwin installation are available at the time of this report. An addendum to this report will be sent when the results from Coyote and Columbia are made available to the EERC.

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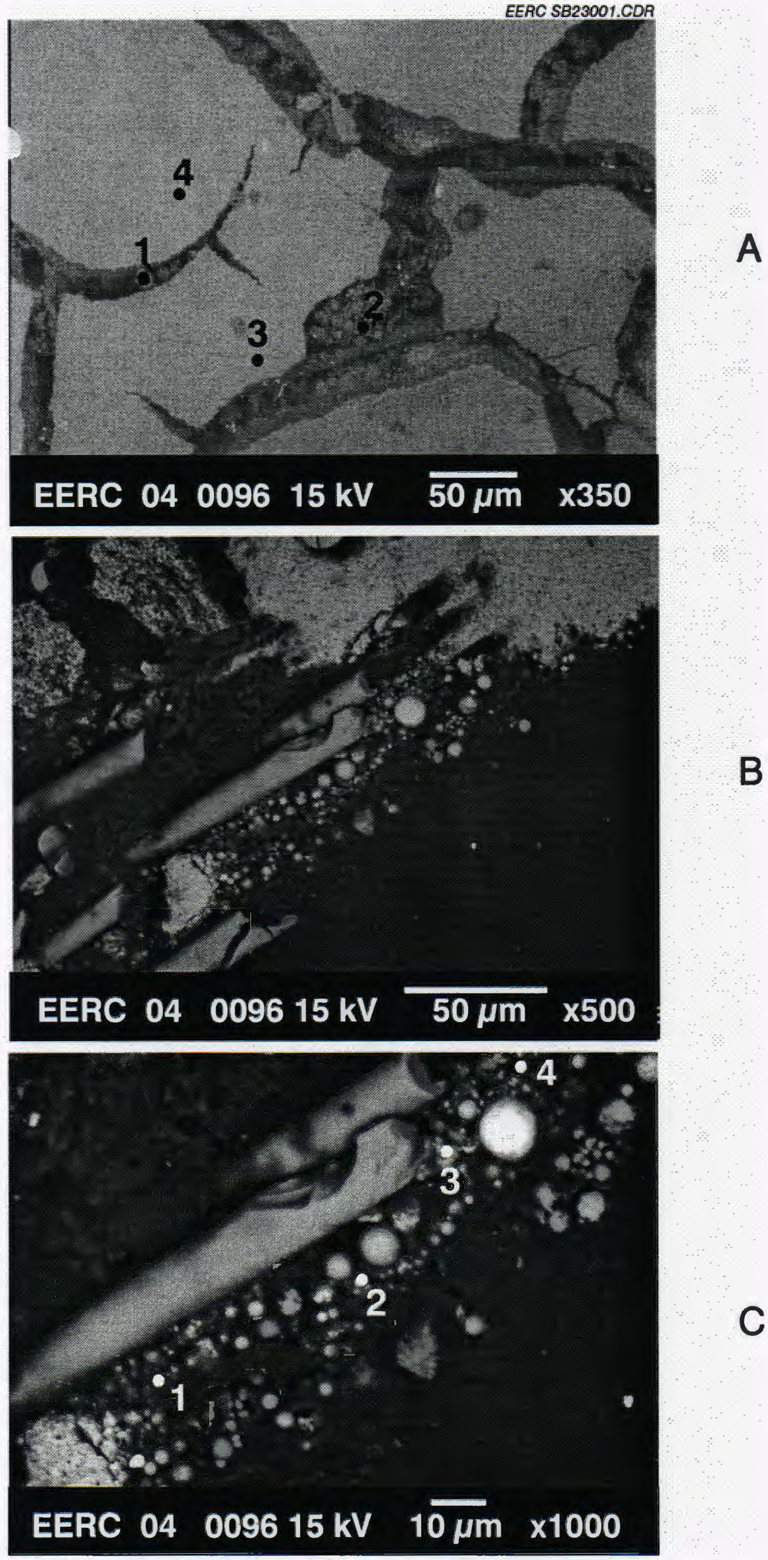

Figure 38. SEM images of ash collected on catalyst surface at the Coyote Station after 2 months of exposure: A) low-magnification image of ash deposit on catalyst surface, B) low-magnification image of polished cross section showing particles in a matrix of calcium- and sulfur-rich materials, and C) higher-magnification image of bonding.

Table 18. Chemical Composition of Selected Points and Areas in Figure 38c

	Point 1	Point 2	Point 3	Point 4
Oxide				
Na_2O	0.9	0.7	1.2	1.0
MgO	5.0	1.6	5.6	1.7
Al_2O_3	12.3	5.8	11.9	5.5
SiO_2	24.6	3.1	21.1	2.6
P_2O_5	0.7	0.0	0.5	0.0
SO_3	23.5	44.0	17.4	31.8
K_2O	0.5	0.3	0.8	0.4
CaO	14.9	36.4	19.6	46.9
TiO_2	7.2	1.9	8.0	2.1
Fe_2O_3	9.2	5.5	11.8	6.9
BaO	1.3	0.7	2.1	1.1
Total	100	100	100	100

Table 21 contains the results of the reactivity analysis on the 2-, 4-, and 6-month samples from the Baldwin Station. After 2 months of operation, the catalyst had no noticeable loss of reactivity when compared to the reference catalyst. After 4 months, the reactivity was 96% of the reference, and after 6 months, the reactivity had dropped to 84% of the reference catalyst.

Task 5 – Determination of SCR Blinding Mechanisms

The mechanism for the formation of deposits that blind SCR catalysts involves the transport of very small particles rich in alkali and alkaline-earth elements, the surface of the catalyst, and reactions with SO_2/SO_3 to form sulfates. The formation of SO_3 from SO_2 is catalyzed by the SCR; this, in turn, increases the reaction rate of SO_3 to form sulfates. In some cases, the alkali and alkaline-earth elements will also react with CO_2 to form carbonates. XRD analysis shown in Figure 41 identified $CaSO_4$ as a major phase and $Ca_3Mg(SiO_4)_2$ and $CaCO_3$ as minor phases.

Lignite and subbituminous coals contain high levels of organically associated alkali and alkaline-earth elements, including sodium, magnesium, calcium, and potassium, in addition to mineral phases. The primary minerals present in these coals include quartz, clay minerals, carbonates, sulfates, sulfides, and phosphorus-containing minerals (18).

During combustion, the inorganic components in the coal are partitioned into various size fractions based on the type of inorganic component, their association in the coal, and combustion system design and operating conditions. Significant research has been conducted on ash formation mechanisms and relationships and their resulting impacts on power plant performance (18–34). Typically, during combustion the inorganic components associated with western subbituminous and lignite coal are distributed into various size fractions of ash, as shown in Figure 42. The results shown in Figure 42 were obtained from isokinetic sampling, aerodynamically size-fractionating ash particles from a full-scale pc-fired boiler firing subbituminous coal, and analyzing each size fraction. The results show that the smaller-sized

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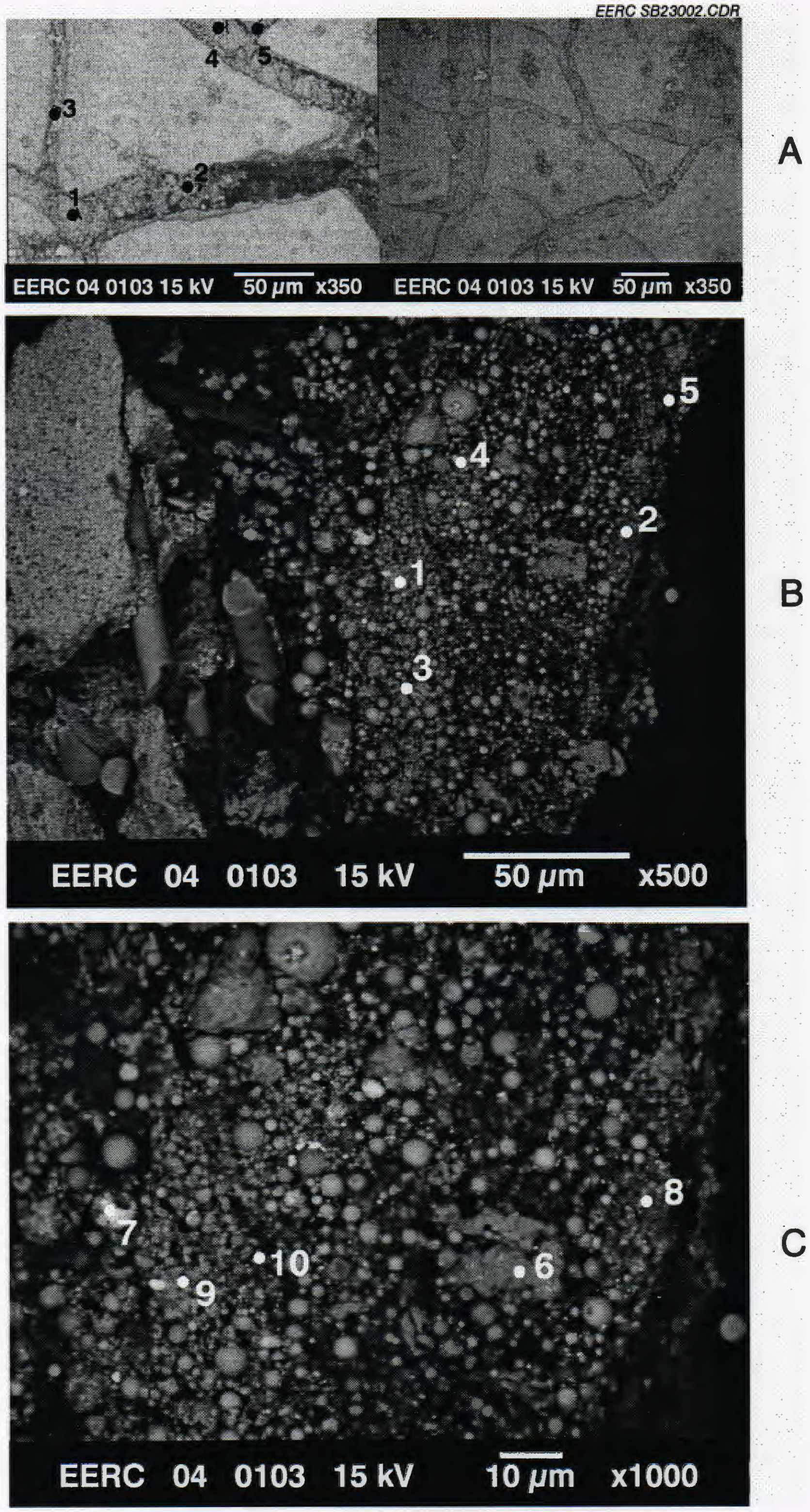

Figure 39. SEM images of ash collected on catalyst surface at the Coyote Station after 4 months of exposure: A) low-magnification image of ash deposit on catalyst surface, B) low-magnification image of polished cross section showing particles in a matrix of calcium- and sulfur-rich materials, and C) higher-magnification image of bonding.

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Table 19. Chemical Composition of Selected Points and Areas in Figure 39b and 39c

	Element, wt%				
	Point 1	Point 2	Point 3	Point 4	Point 5
Oxide					
Na_2O	6.7	1.9	7.1	6.2	3.1
MgO	1.1	1.7	1.1	2.6	3.2
Al_2O_3	2.6	8.8	4.0	4.8	10.5
SiO_2	7.0	21.1	11.3	5.6	32.2
P_2O_5	0.2	2.4	0.0	0.2	0.9
SO_3	54.7	38.5	56.4	57.5	30.4
K_2O	2.0	2.8	0.7	2.8	2.4
CaO	18.0	3.4	15.8	9.3	2.3
TiO_2	0.6	0.8	1.1	1.3	1.5
Fe_2O_3	5.8	5.1	2.1	6.5	9.8
BaO	1.4	13.5	0.5	3.4	3.6
Total	100	100	100	100	100
	Point 6	Point 7	Point 8	Point 9	Point 10
Oxide					
Na_2O	9.5	2.6	10.4	8.9	4.4
MgO	1.2	1.9	1.3	3.0	3.7
Al_2O_3	2.6	8.6	4.2	4.9	10.6
SiO_2	6.3	18.2	10.5	5.0	28.9
P_2O_5	0.1	1.9	0.0	0.1	0.7
SO_3	41.8	28.4	44.9	44.5	23.4
K_2O	3.2	4.3	1.2	4.4	3.8
CaO	24.5	4.4	22.5	12.8	3.1
TiO_2	0.6	0.8	1.3	1.5	1.8
Fe_2O_3	7.7	6.6	2.9	8.9	13.2
BaO	2.4	22.3	0.9	5.9	6.3
Total	100	100	100	100	100

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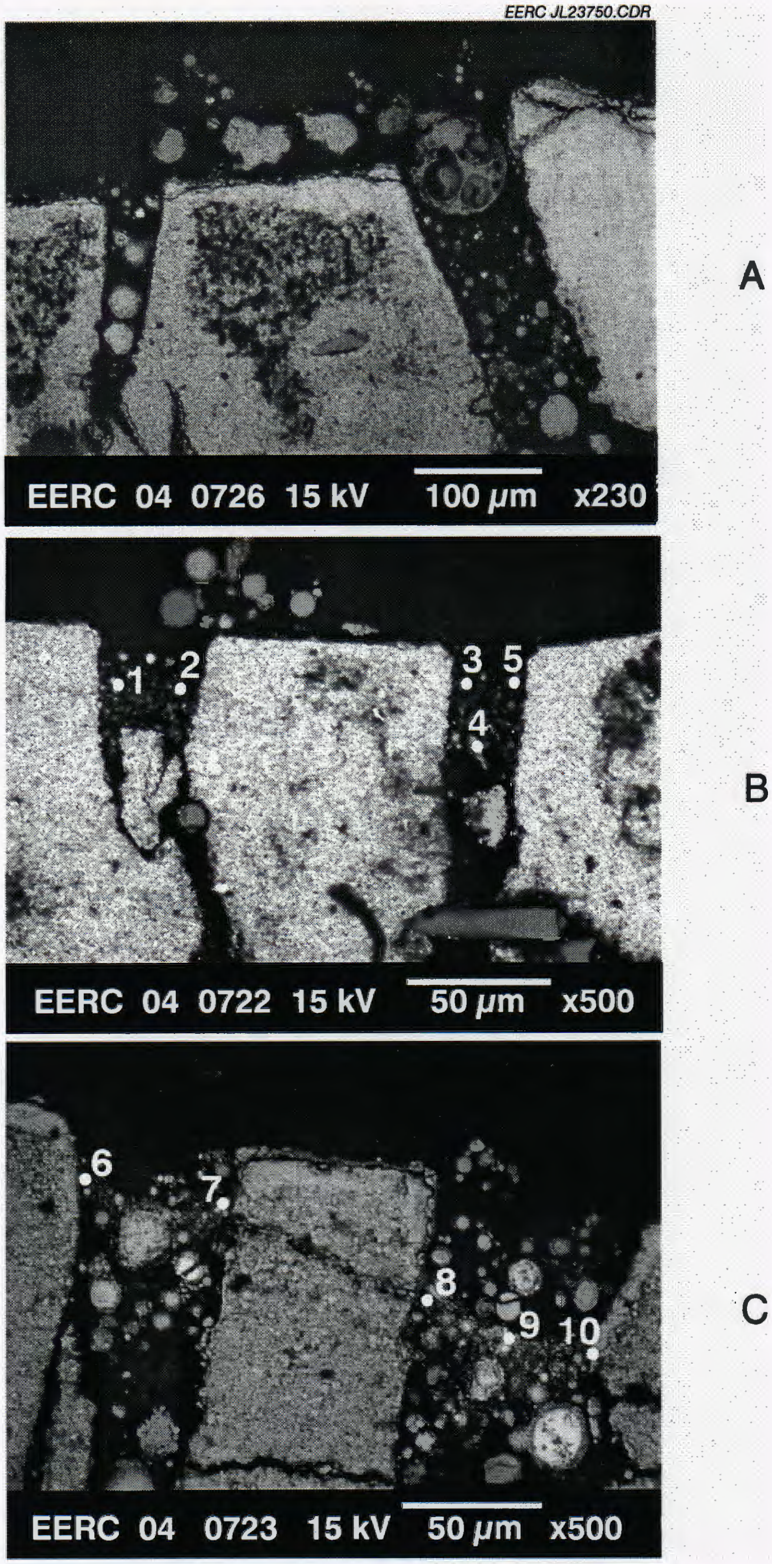

Figure 40. SEM images of ash collected on catalyst surface at the Coyote Station after 6 months of exposure: A) low-magnification image of ash deposit on catalyst surface, B) low-magnification image of polished cross section showing particles in a matrix of calcium- and sulfur-rich materials, and C) higher-magnification image of bonding.

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Table 20. Chemical Composition of Selected Points and Areas in Figure 40

	Element, wt%				
	Point 1	Point 2	Point 3	Point 4	Point 5
Oxide					
Na_2O	5.0	3.2	6.6	5.8	4.1
MgO	1.6	0.0	0.0	7.6	1.4
Al_2O_3	2.1	3.3	0.6	0.8	1.7
SiO_2	10.7	12.8	3.6	2.6	14.4
P_2O_5	0.0	0.0	0.0	0.0	0.0
SO_3	57.9	40.7	67.0	71.0	52.7
K_2O	0.5	0.8	0.8	1.3	0.4
CaO	13.7	6.2	12.7	7.7	16.3
TiO_2	2.0	33.0	0.0	1.7	2.1
Fe_2O_3	6.5	0.0	8.8	1.4	7.0
BaO	0.0	0.0	0.0	0.0	0.0
Total	100	100	100	100	100
	Point 6	Point 7	Point 8	Point 9	Point 10
Oxide					
Na_2O	6.5	4.1	5.7	8.1	6.7
MgO	4.6	3.1	4.4	7.5	3.7
Al_2O_3	3.3	10.2	1.6	5.4	2.4
SiO_2	11.5	2.3	4.1	10.1	9.6
P_2O_5	2.2	0.5	0.0	0.9	7.2
SO_3	52.5	48.2	61.4	53.1	56.7
K_2O	1.9	1.0	10.0	3.0	0.9
CaO	13.6	23.9	2.6	8.6	10.5
TiO_2	2.7	3.7	0.7	0.0	0.0
Fe_2O_3	1.2	3.0	9.5	3.3	2.3
BaO	0.0	0.0	0.0	0.0	0.0
Total	100	100	100	100	100

Table 21. Results of Reactivity Tests for the Baldwin Station

Catalyst	K–NO_x 350°C (662°F) (scfh/ft^3)	K/K_o 350°C (662°F)
Reference	22,808	—
2 month	23,400	1.03
4 month	21,361	0.96
6 month	19,510	0.84

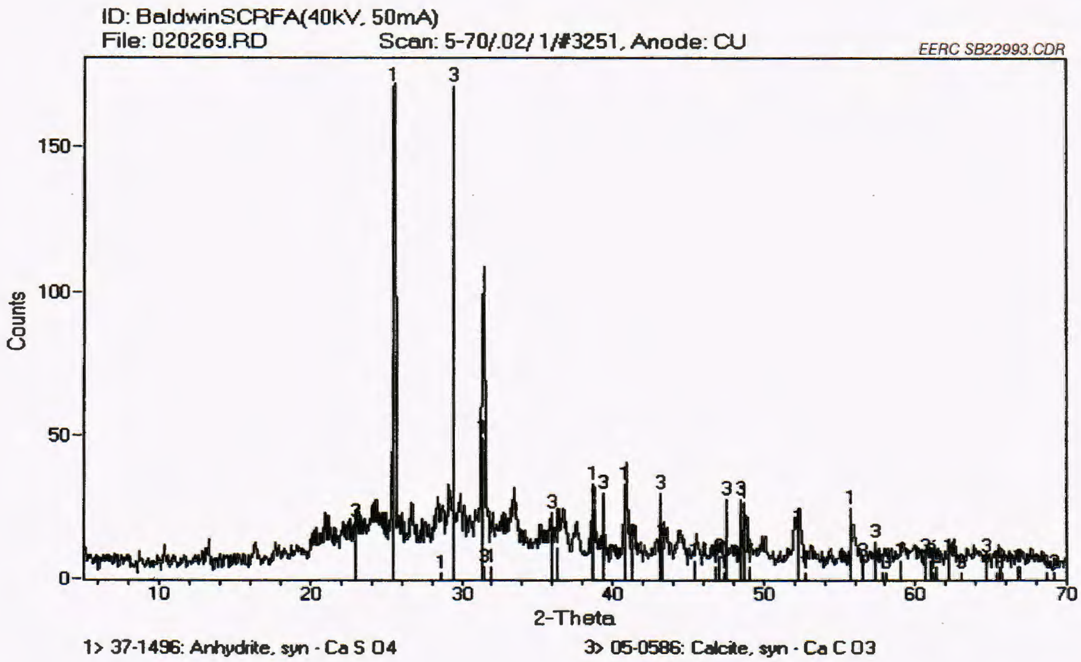

Figure 41. X-ray diffraction of ash collected on SCR catalyst (1 – $CaSO_4$, 2 – $Ca_3Mg(SiO_4)_2$, and 3 – $CaCO_3$).

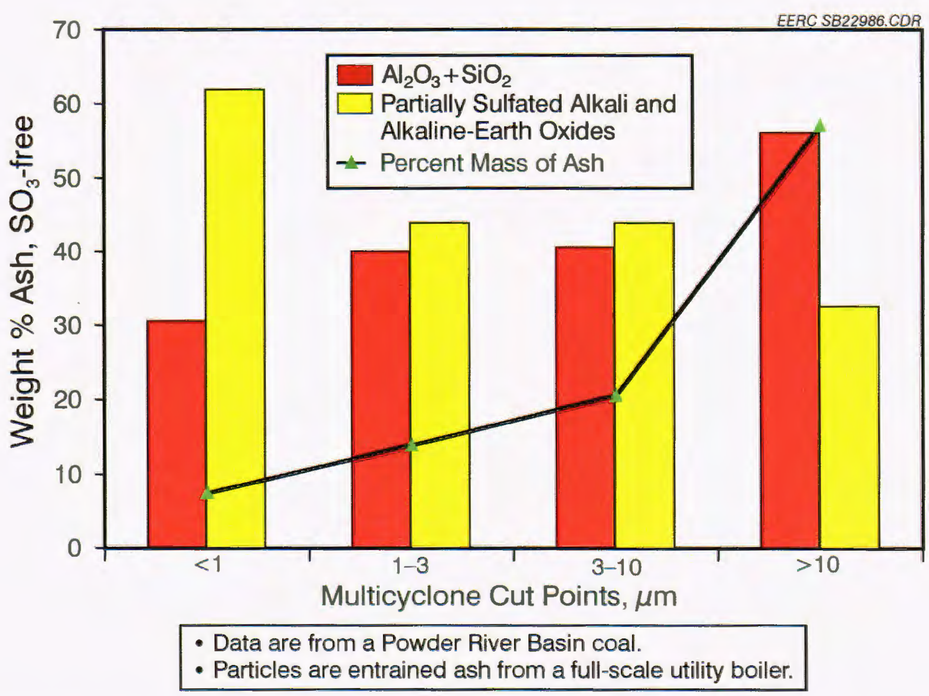

Figure 42. Simplified illustration of ash partitioning in combustion systems (18).

fractions of ash are dominated by partially sulfated alkali and alkaline-earth elements. These ash particles are largely derived from the organically associated cations in the coal. The larger-sized fraction has higher levels of aluminum and silicon derived from the mineral fraction of the ash-forming component of the coal.

Entrained ash was extracted from the Columbia Station at the point of the inlet to the SCR reactor and was aerodynamically classified and analyzed. The composition of the size fractions was compared to the chemical composition of the ash deposited on and in the catalyst, as shown in Figure 43. The comparison shows that the composition of the particle captured in the SCR catalyst is very similar to the <5-μm size fraction. The deposited material shows significantly more sulfation than the entrained-ash size fraction, indicating that the sulfation process occurs after the particles are deposited in the catalyst.

The mechanism of SCR catalyst blinding when lignite or subbituminous coals are fired is shown in Figure 44 (35). The requirements for the formation of deposits that blind SCR catalyst include firing a coal that produces significant levels of <5-μm-sized particles. The particles are transported into the pores of the catalyst and subsequently react with SO_3 to form sulfates. The sulfate forms a matrix that bonds other ash particles. The SCR catalyzes the formation of SO_3 and thereby increases the rate of sulfation (9, 15). The sulfation of CaO increases the molar volume, resulting in the filling of the pore. For coals that have high sodium contents, formation of low melting point phases such as pyrosulfates are possible (36). Pyrosulfate materials can melt at temperatures as low as 279°C (535°F) in coal-fired power systems.

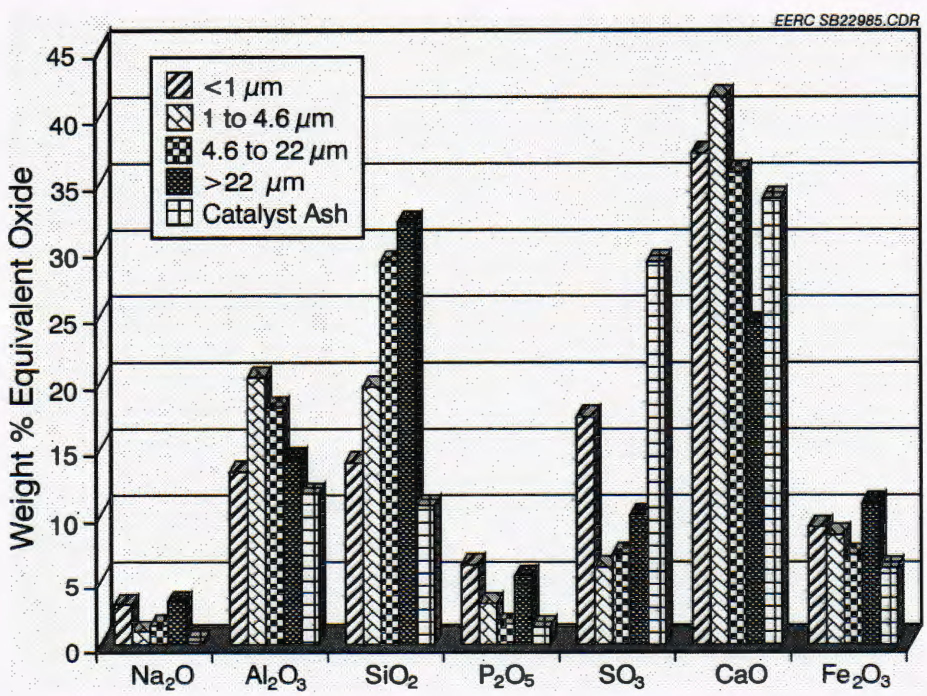

Figure 43. Comparison of entrained ash and deposited ash on catalyst for Columbia Station.

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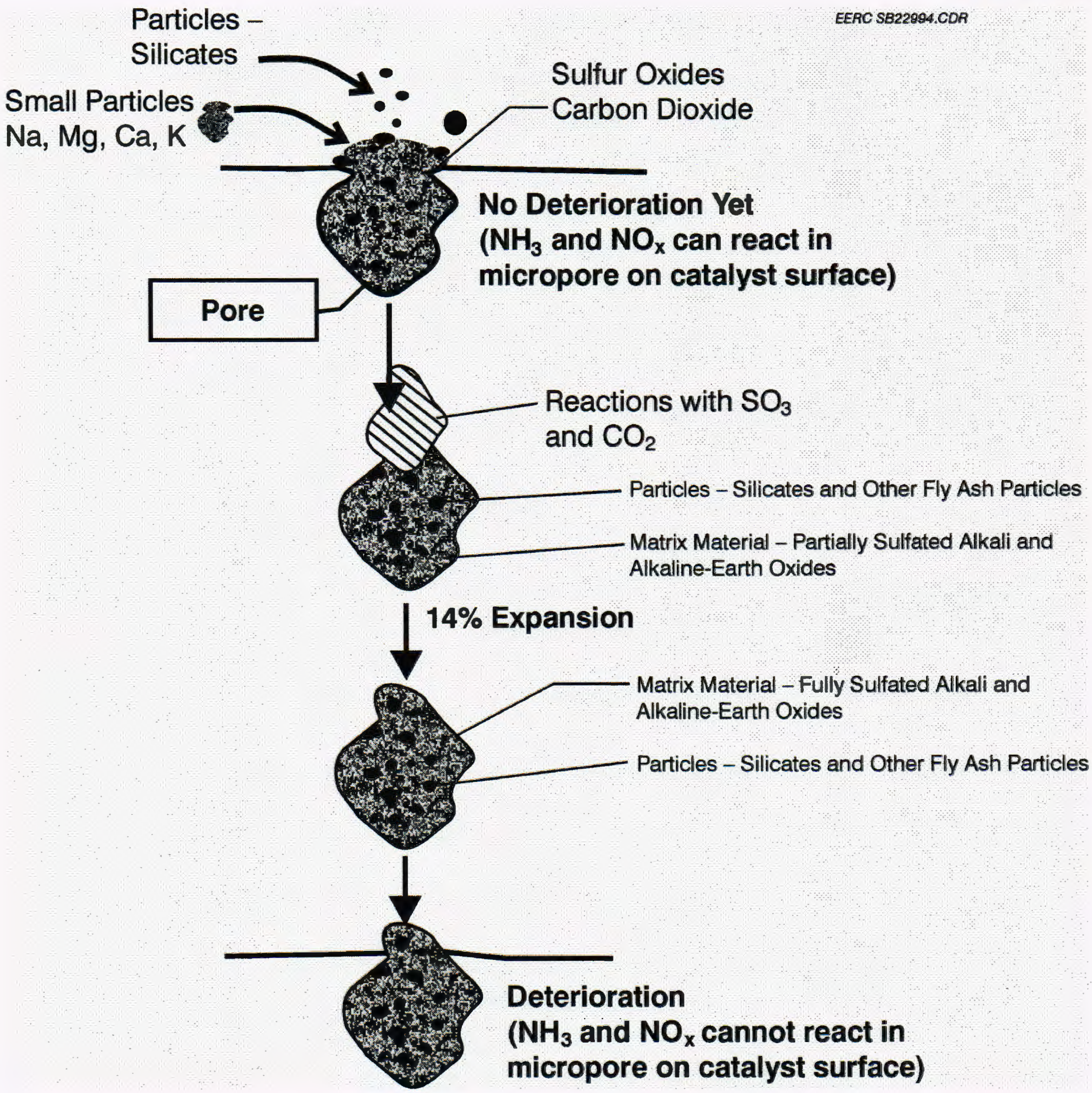

Figure 44. Mechanism of SCR catalyst blinding via the formation of sulfates and carbonates (modified after Pritchard and others [35]).

Add-On Task – Characterization of Mercury Transformations Across SCR Catalysts for a Lignite Coal-Fired Boiler

The ability of mercury to be oxidized across the SCR catalyst was investigated at the Coyote Station. The Coyote Station is fired on North Dakota lignite, and the flue gas is dominated by elemental mercury. Measurement of mercury speciation was conducted using the OH method at the inlet and the outlet of the SCR catalyst. The measurements were made upon installation of the catalyst and after 2 and 4 months of operation. The results of the mercury speciation measurement at the inlet and outlet of the SCR catalyst conducted upon installation are shown in Figure 45. The inlet and outlet measurements were repeated three times and are shown in Figure 45. The level of elemental mercury at the inlet was approximately 76% to 92%, with the remaining in the oxidized form ranging from 8% to 24%. Very little was in the form of particulate mercury at the inlet. Measurement of mercury speciation was conducted with the NH_3 on and off. The results with the NH_3 off showed an increase in the oxidized mercury to 43% of the total mercury occurring across the SCR catalyst. However, when the NH_3 was introduced into the SCR catalyst, the amount of mercury oxidation decreased from 43% to 19%. There was an increase in the particulate mercury from 1.0% to 7.2%.

The mercury oxidation after the SCR catalyst was exposed to flue gas and particulate for 2 months is shown in Figure 46. The level of oxidized mercury at the inlet ranges from 7.5% to 11.1% of the total mercury. The level of oxidized mercury at the outlet ranged from 7.6% to 14% of the total mercury. The level of particulate mercury increased from a negligible level to 3% of the total mercury at the outlet.

The results of mercury oxidation across the SCR catalyst after 4 months of exposure to flue gas and particulate are shown in Figure 47. The results show a higher level of oxidized mercury at the inlet as compared to testing conducted at installation and after 2 months. The level of oxidized mercury at the inlet ranges from 32% to 38% of the total, with about 5% of the total in the particulate form. The outlet levels of oxidized mercury decrease after passing through the catalyst to about 20% of the total. The level of particulate mercury remained about the same across the catalyst.

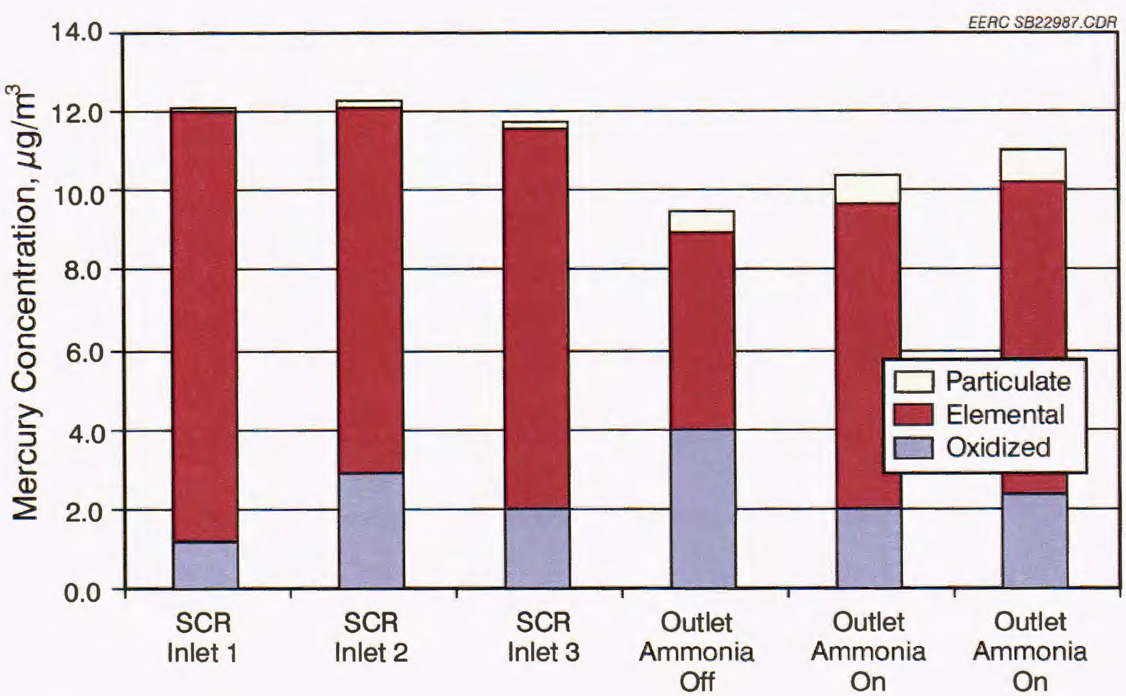

Figure 45. Mercury speciation measurement at the inlet and outlet of the SCR catalyst upon installation of the catalyst.

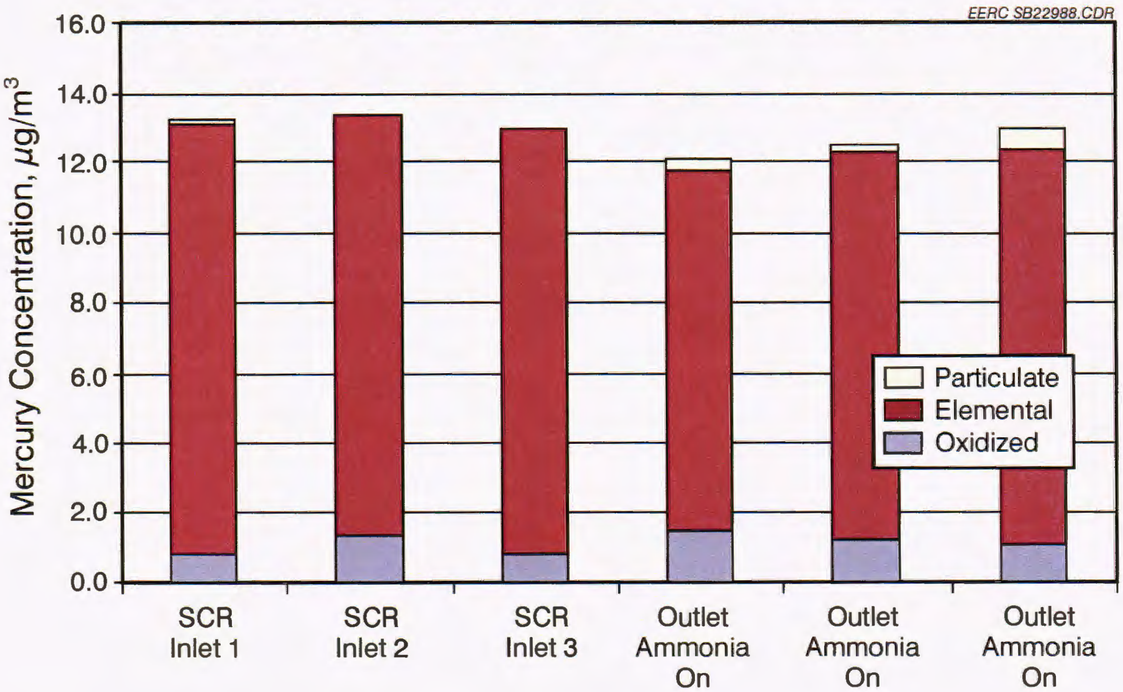

Figure 46. Mercury speciation measurement at the inlet and outlet of the SCR catalyst after exposure to flue gas and particulate for 4 months.

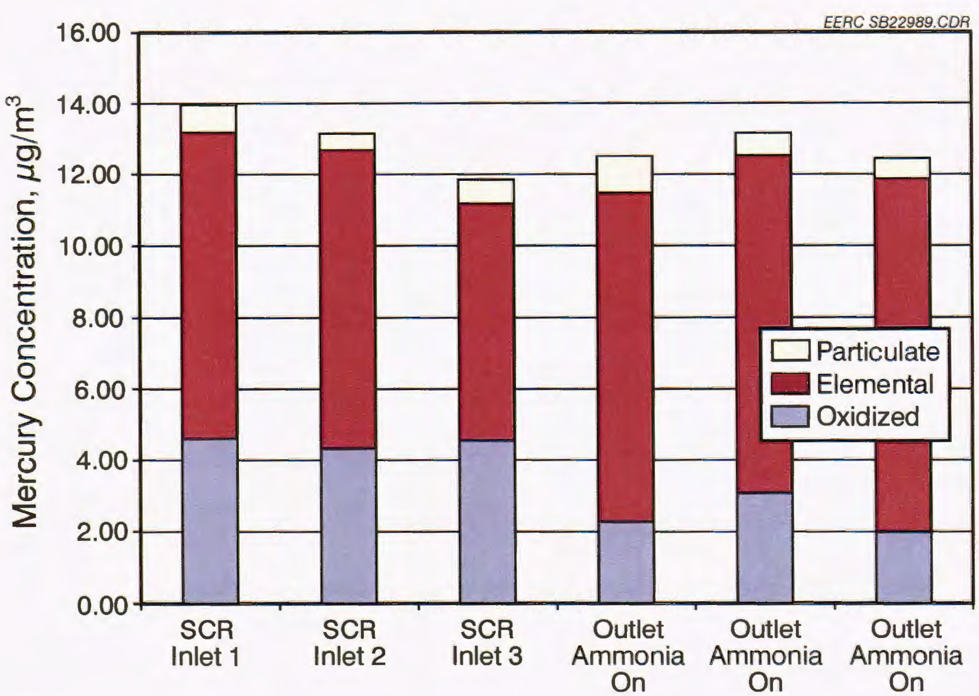

Figure 47. Mercury speciation measurement at the inlet and outlet of the SCR catalyst after exposure to flue gas and particulate for 2 months.

The results of mercury oxidation across the SCR catalyst after 6 months of exposure to flue gas are shown in Figure 48. The amount of oxidized mercury at the inlet ranges from 6.5% to 10.5% of the total with about 2.0% in the particulate form. The levels of oxidized mercury at the outlet increases slightly to 8.5% to 11.0% of the total mercury, while the particulate bound mercury also increases to as high as 12.0%.

Task 6 – Final Interpretation, Recommendations, and Reporting

Lignite and subbituminous coals contain high levels of organically bound alkali and alkaline-earth elements, including sodium, calcium, potassium, and magnesium. During combustion, partitioning of these elements occurs based on the size of particles, their association in the coal, and system configuration. This phenomenon, coupled with the fact that SCR catalyst increases the oxidation of SO_2 to SO_3, will lead to extensive blinding of SCR catalyst by the formation of alkali or alkaline-earth sulfates. The results of this study lead the authors to suggest careful evaluation of each SCR installation on applications using subbituminous coals and suggest no installations of SCRs on plants firing lignite coal until further evaluations or improvements to the current technology can be carried out. Installations involving lignite fuels will need advanced cleaning techniques to handle the high-sodium and high-dust loads associated with burning most lignite fuels.

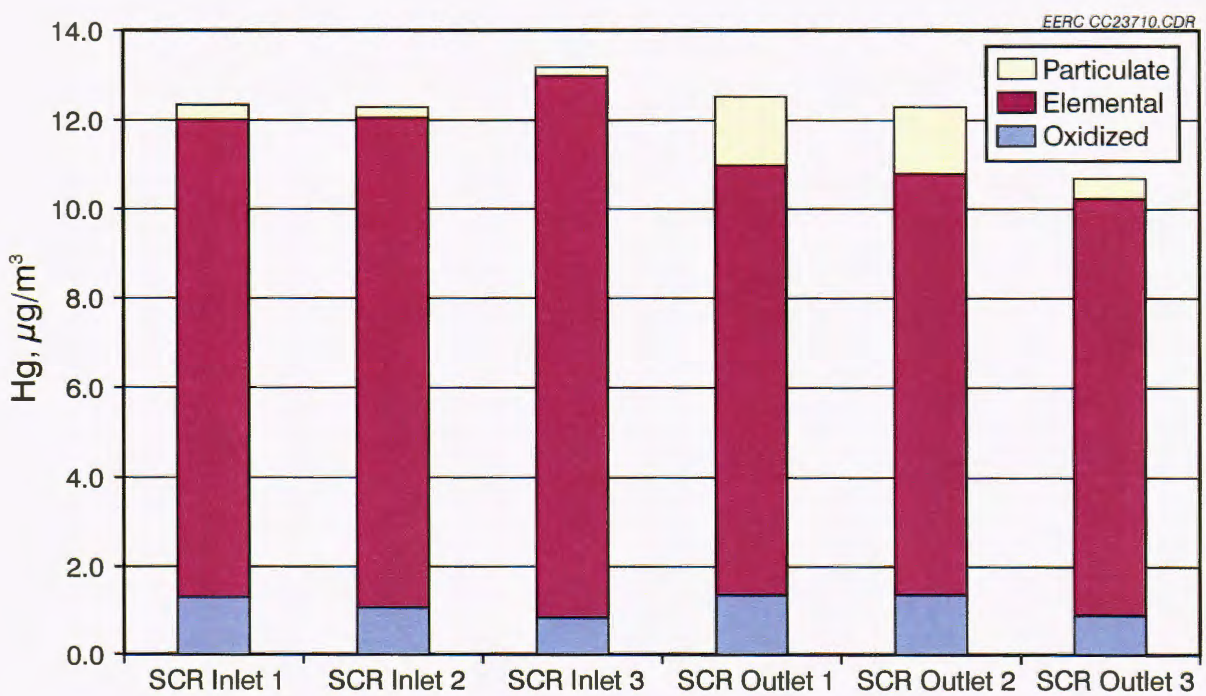

Figure 48. Mercury speciation measurement at the inlet and outlet of the SCR catalyst after exposure to flue gas and particulate for 6 months.

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CONCLUSIONS

A slipstream reactor is designed to expose SCR catalyst to coal combustion-derived flue gases and particulate. The system is computer-controlled and operates in an automated mode. The system can be operated and monitored remotely through a modem connection. SCR catalyst testing was conducted at two subbituminous-fired plants and one lignite-fired plant. The boiler configurations for the subbituminous-fired plants included a cyclone- and a tangentially fired boiler. The boiler configuration for the lignite plant was a cyclone-fired system.

The pressure drop across the catalyst was found to be the most significant for the lignite-fired plant as compared to the subbituminous-fired plants. Both coals had significant accumulations of ash on the catalyst, on both macroscopic and microscopic levels. On a macroscopic level, there were significant observable accumulations that plugged the entrance as well as the exit of the catalyst sections. On a microscopic level, the ash materials filled pores in the catalyst and, in many cases, completely masked the pores within 4 months of operation. After 6 months of operation, the reactivity of the catalyst from the Baldwin Station was 84% of a comparable reference value.

The deposits on the surfaces and within the pores of the catalyst consisted of mainly alkali and alkaline-earth element-rich phases that have been sulfated. The mechanism for the formation of the sulfate materials involves the formation of very small particles rich in alkali and alkaline-earth elements, transport of the particles to the surface of the catalyst, and reactions with SO_2/ SO_3 to form sulfates. XRD analysis identified $CaSO_4$ as a major phase and $Ca_3Mg(SiO_4)_2$ and $CaCO_3$ as minor phases.

Lignite and subbituminous coals contain high levels of organically associated alkali and alkaline-earth elements, including sodium, magnesium, calcium, and potassium in addition to mineral phases. During combustion, the inorganic components in the coal are partitioned into various size fractions based on the type of inorganic component and their association in the coal and combustion system design and operating conditions. The results of this testing found that the smaller-sized fractions of ash are dominated by partially sulfated alkali and alkaline-earth elements. The composition of the size fractions was compared to the chemical composition of the ash deposited on and in the catalyst. The comparison shows that the composition of the particle captured in the SCR catalyst is very similar to the <5-μm size fraction.

The results of this study lead the authors to suggest careful evaluation of each SCR installation on applications using subbituminous coals and suggest no installations of SCRs on plants firing lignite coal until further evaluations or improvements to the current technology can be carried out. Installations involving lignite fuels will need advanced cleaning techniques to handle the high-sodium and high-dust loads associated with burning most lignite fuels.

The ability of mercury to be oxidized across the SCR catalyst was investigated at the Coyote Station. The Coyote Station is fired on North Dakota lignite, and the flue gas is dominated by elemental mercury. Measurement of mercury speciation was conducted using the OH method at the inlet and the outlet of the SCR catalyst. These results show limited oxidation of mercury across the SCR catalyst when lignite coals are fired. The reasons for the lack of

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mercury oxidation include the following: no chlorine present in the coal and flue gas to catalytically enhance the oxidation of Hg^0, higher levels of alkali and alkaline-earth elements acting as sorbents for any chlorine present in the flue gas, and lower levels of acid gases present in the flue gas.

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INDUSTRIAL COMMISSION OF NORTH DAKOTA

John Hoeven
Governor

Wayne Stenehjem
Attorney General

Roger Johnson
Commissioner of Agriculture

Memorandum

TO: Karen Gutenkunst

FR: Karlene Fine
Executive Director and Secretary

DT: December 9, 2004

RE: GRANT PAYMENT

Please have a check(s) prepared in the following amount to the entity(s) listed below as per their contract.

UND - EERC $21,250
ATTN: GRANTS & CONTRACTS OFFICE
FY00-XXXVI-100 EVLUATION POTENTIAL SCR CATALYST BLINDING
PO BOX 9018
GRAND FORKS, ND 58202-9018 (Final Payment)
For work done: Final Report dated November 2004

UND - EERC $15,000
ATTN: GRANTS & CONTRACTS OFFICE
FY03-XLIX-119 IMPACT OF SCR CATALYST ON MERCURY OXIDATION
PO BOX 9018
GRAND FORKS, ND 58202-9018 (Third and Final Payments)
For work done: Draft Final and Final Report dated November 2004

GREAT RIVER ENERGY $30,000
ATTN: MARK STROHFUS
FY04-L-126 EVAL OF MERCAP FOR POWER PLANT MERCURY CONTROL
17845 EAST HIGHWAY 10
ELK RIVER MN 55330-0800 (Fourth & Fifth Payments)
For work done: 4-04 to 6-04 and 7-04 to 9-04

Please pay from the 2003-2005 biennium for FY05. If you have any questions, please call. Please forward the check(s) to the appropriate person(s) and make a copy for my files.

Thanks. KF

Karlene K. Fine, Executive Director and Secretary
State Capitol, 14th Floor - 600 E Boulevard Ave Dept 405 - Bismarck, ND 58505-0840
E-Mail: kfine@state.nd.us
Phone: (701) 328-3722 FAX: (701) 328-2820
"Your Gateway to North Dakota": discovernd.com

EVALUATION OF POTENTIAL SCR CATALYST BLINDING DURING COAL COMBUSTION AND ADD-ON: IMPACT OF SCR CATALYST ON MERCURY OXIDATION IN LIGNITE-FIRED COMBUSTION SYSTEMS

Final Report

(for the period of November 1, 2000 – June 30, 2004)

Prepared for:

Ms. Karlene Fine

Executive Director
North Dakota Industrial Commission
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Contract No. FY-00-XXXVI-100
Contract No. FY-03-XLIX-119

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04-EERC-11-09

November 2004

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JV 31 – EVALUATION OF POTENTIAL SCR CATALYST BLINDING DURING COAL COMBUSTION AND ADD-ON: IMPACT OF SCR CATALYST ON MERCURY OXIDATION IN LIGNITE-FIRED COMBUSTION SYSTEMS

ABSTRACT

Lignite and subbituminous coals from the United States of America have characteristics that impact the performance of catalysts used in selective catalyst reduction (SCR) for nitrogen oxide removal and mercury oxidation. Typically, these coals contain ash-forming components that consist of inorganic elements (sodium, magnesium, calcium, and potassium) associated with the organic matrix and mineral grains (quartz, clays, carbonates, sulfates, and sulfides). Upon combustion, the inorganic components undergo chemical and physical transformations that produce intermediate inorganic species in the form of inorganic gases, liquids, and solids. The alkali and alkaline-earth elements are partitioned between reactions with minerals and reactions to form alkali and alkaline-earth-rich oxides during combustion. The particles resulting from the reaction with minerals produce low-melting-point phases that cause a wide range of fireside deposition problems. The alkali and alkaline-earth-rich oxides consist mainly of very small particles ($<5\ \mu m$) that are carried into the backpasses of the combustion system and react with flue gas to form sulfates and, possibly, carbonates. These particles cause low-temperature deposition, blinding, and plugging problems in SCR systems. These coals also lack sufficient levels of chlorine needed to oxidize mercury. Slipstream testing was conducted at two subbituminous-fired power plants and one lignite-fired power plant to determine the impacts of ash on SCR plugging, blinding, and mercury oxidation. The results indicated a high potential for blinding and plugging because of the formation of sulfate-bonded deposits but no evidence of mercury oxidation.

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EXECUTIVE SUMMARY

The goal of this project by the Energy & Environmental Research Center (EERC) is to determine the potential of low-rank coal ash to cause blinding or masking of selective catalytic reduction (SCR) catalysts. The primary goal of the add-on is to determine the effects of new and aged catalyst on the oxidation of mercury at full-scale power plants.

Two SCR slipstream reactors were constructed to accomplish the goals of this project. The test chambers are approximately 19 cm (7.5 inches) square and are able to accommodate catalyst sections up to 1 meter (3.3 feet) in length. The chambers are electrically heated and fully instrumented to limit heat loss and to maintain a catalyst face velocity of 5 m/s (16.4 ft/s).

The SCR reactors were installed at three different plant locations and operated until the catalyst had 6 months of operating time. The units that were chosen for this study are the Columbia Station (pulverized coal-fired), the Baldwin Station (cyclone-fired), and the Coyote Station (cyclone-fired). The Coyote Station fires North Dakota lignite, while the other two stations burn Powder River Basin (PRB) coal. The catalyst was sampled every 2 months and analyzed with scanning electron microscopy (SEM).

Bench-scale and Facility for Analysis of Chemical Thermodynamics (FACT) modeling studies were also conducted in the laboratory prior to the reactors being installed at the host utilities. Experiments were carried out in a thermogravimetric analyzer (TGA) system at 315°C (600°F), 370°C (700°F), and 427°C (800°F) with simulated flue gas. Ash samples created from the test coals were placed on the TGA pan with and without catalyst. The rate of sample weight gain was then monitored. The ash was then analyzed with SEM techniques to identify the species that were present.

The results of the bench-scale analysis indicate that the rate of weight gain increases with increasing temperature, and calcium sulfates were the predominant species formed. The rate of sulfate formation could increase as much as tenfold with the addition of catalyst to the system. Low-sulfur bituminous and PRB blends exhibited a higher rate of sulfate formation and, therefore, would have a higher blinding potential than a 100% PRB or lignite. Results of the FACT modeling indicate that there is a high potential to form alkali and alkaline-earth sulfates, carbonates, and phosphates while SCRs are operated at utilities burning lignite and PRB coals.

The data collected during the three slipstream reactor tests indicate that the pressure drop across the catalyst was found to be the most significant for the lignite-fired plant as compared to the subbituminous-fired plants. Both lignite and PRB coals had significant accumulations of ash on the catalyst, on both macroscopic and microscopic levels. On a macroscopic level, there were significant observable accumulations that plugged the entrance as well as the exit of the catalyst

sections. On a microscopic level, the ash materials filled pores in the catalyst and, in many cases, completely masked the pores within 4 months of operation.

The deposits on the surfaces and within the pores of the catalyst consisted of mainly alkali and alkaline-earth element-rich phases that have been sulfated. The mechanism for the formation of the sulfate materials involves the formation of very small particles rich in alkali and alkaline-earth elements, transport of the particles to the surface of the catalyst, and reactions with SO_2/ SO_3 to form sulfates. X-ray diffraction analysis identified $CaSO_4$ as a major phase and $Ca_3Mg(SiO_4)_2$ and $CaCO_3$ as minor phases.

Lignite and subbituminous coals contain high levels of organically associated alkali and alkaline-earth elements, including sodium, magnesium, calcium, and potassium in addition to mineral phases. During combustion, the inorganic components in the coal are partitioned into various size fractions based on the type of inorganic component and their association in the coal and combustion system design and operating conditions. The results of this testing found that the smaller size fractions of ash are dominated by partially sulfated alkali and alkaline-earth elements. The composition of the size fractions was compared to the chemical composition of the ash deposited on and in the catalyst. The comparison shows that the composition of the particle captured in the SCR catalyst is very similar to the <5-μm size fraction.

This study suggests the careful evaluation of each SCR installation on applications using subbituminous and lignite coals. Improvements are needed to ensure technical feasibility, especially with lignite-fired units. Installations involving lignite fuels will need advanced cleaning techniques to handle the high sodium and high dust loads associated with burning most lignite fuels.

The ability of mercury to be oxidized across the SCR catalyst was investigated at the Coyote Station. The Coyote Station is fired on North Dakota lignite, and the flue gases are dominated by elemental mercury. Measurement of mercury speciation was conducted using the Ontario Hydro (American Society for Testing and Materials D6784-02) method at the inlet and the outlet of the SCR reactor. These results show limited oxidation of mercury across the SCR catalyst when lignite coals are fired. The reasons for the lack of mercury oxidation include the following: no chlorine present in the coal and flue gas to catalytically enhance the oxidation of Hg^0, higher levels of alkali and alkaline-earth elements acting as sorbents for any chlorine present in the flue gas, and lower levels of acid gases present in the flue gas.

JV 31 – EVALUATION OF POTENTIAL SCR CATALYST BLINDING DURING COAL COMBUSTION AND ADD-ON: IMPACT OF SCR CATALYST ON MERCURY OXIDATION IN LIGNITE-FIRED COMBUSTION SYSTEMS

INTRODUCTION

The Energy & Environmental Research Center (EERC) investigated selective catalytic reduction (SCR) for NO_x control and mercury oxidation using a slipstream reactor at power plants firing subbituminous and lignite coals to determine the potential for ash plugging and blinding and mercury oxidation. SCR units lower NO_x emissions by reducing NO_x to N_2 and H_2O. Ammonia (NH_3) is the most common reducing agent used for the SCR of NO_x. The SCR process involves the use of a metal oxide catalyst such as titanium dioxide (TiO_2)-supported vanadium pentoxide (V_2O_5). These units are operated at about 340°–370°C (650°–700°F). Subbituminous and lignitic coals are known for their ability to produce alkali and alkaline-earth sulfate-bonded deposits at low temperature (<1000°C) in utility boilers. The mechanisms of the formation of low-temperature sulfates have been extensively examined and modeled by the EERC in work termed Project Sodium and Project Calcium in the early 1990s (1, 2). Deposit buildup of this type blinds or masks the catalyst, diminishing its reactivity for converting NO_x to N_2 and water and potentially creating increased NH_3 slip (3). Elemental mercury oxidation has been observed in laboratory-, pilot-, and full-scale testing using SCR catalysts (4–6). In these studies, the metal oxides, V_2O_5 and TiO_2, have been shown to promote the conversion of elemental mercury to oxidized and/or particulate-bound mercury. Full-scale tests in Europe (7) and the United States (8) have indicated that the V_2O_5 and TiO_2 catalyst may promote the formation of oxidized mercury. The ability to oxidize mercury is largely dependent on the composition of the coal (8).

Lignite and subbituminous coals produce ash that plug and blind catalysts (9–12). The problems currently being experienced on SCR catalysts include the formation of sulfate- and phosphate-based blinding materials on the surface of catalysts and the carrying of deposit fragments, or popcorn ash, from other parts of the boiler and depositing them on top of the SCR catalysts (3). The most significant problem that limits the successful application of SCR catalysts to lignite coal is the formation of low-temperature sodium–calcium–magnesium sulfates, phosphates and, possibly, carbonates on the surfaces of catalysts and the carryover of deposits that will plug the catalyst openings, resulting in increased pressure drop and decreased efficiency (3, 11–14). The degree of the ash-related impacts on SCR catalyst performance depends upon the composition of the coal, the type of firing systems, flue gas temperature, and catalyst design (11, 12, 14, 15).

Licata and others (13) conducted tests on a South African and a German Ruhr Valley coal and found that the German Ruhr Valley coal significantly increased the pressure drop across the catalyst because of the accumulation of ash. They found that the German coal produced a highly adhesive ash consisting of alkali (K and Na) sulfates. In addition, they reported that the alkali elements are in a water-soluble form and highly mobile and will migrate throughout the catalyst material, reducing active sites. The water-soluble form is typical of organically associated alkali elements in coals. The German Ruhr Valley coal has about 9.5% ash and 0.9% S on an as-received basis, and the ash consists mainly of Si (38.9%), Al (23.2%), Fe (11.6%), and Ca (9.7%), with lower levels of K (1.85%) and Na (0.85%) (13). Cichanosicz and Muzio (14) summarized the experience in Japan and Germany and indicated that the alkali elements (K and Na) reduced the acidity of the catalyst sites for total alkali content (K + Na + Ca + Mg) of 8%–15% of the ash in European power plants. Licata et al. also found that alkaline-earth elements such as calcium react with SO_3 on the catalyst, resulting in plugging of pores and a decrease in the ability of NH_3 to bond to catalyst sites. The levels of calcium in the coals that caused blinding ranged from 3% to 5% of the ash. Studies conducted on the impact of alkali elements associated with biomass found that, when biomass is fired, poisoning and blinding of SCR catalysts occurred (16, 17).

This study took a three-pronged approach to solve the issues involving low-rank fuels and the SCR catalyst. Studies were conducted at both the pilot and bench scales and were compared to a thermodynamic equilibrium model. In order to facilitate the pilot-scale study, two slipstream SCR systems were constructed. The slipstream reactors were installed at three power plants. Two of the plants were cyclone-fired: one with lignite and one with subbituminous coal. The third plant was a pulverized-coal (pc), tangentially fired unit using subbituminous coal. The slipstream reactors were designed to expose SCR catalysts to flue gas and particulate matter under conditions that simulate gas velocities, temperatures, and NH_3 injection of a full-scale pilot plant. The control system maintains catalyst temperature, pulse air to remove accumulated deposits, and a constant gas flow across the catalyst; it logs pressure drops and temperatures. The reactor was operated in an automated mode and could be remotely controlled via modem. Testing at each power plant was conducted over 6 months. The reactor was inspected and cleaned at 2-month intervals, and a catalyst section was removed for analysis. The catalysts and associated ash deposits were analyzed to determine the characteristics of the ash on the surface and in the pores. In addition, mercury speciation in the flue gas upstream and downstream of the catalyst was conducted at 2-month intervals during the testing at the lignite-fired plant. The ability of the SCR catalyst to catalyze gaseous elemental mercury (Hg^0[g]) to more soluble and chemically reactive $Hg^{2+}X$(g) forms was evaluated, along with the potential increase in particle-associated mercury (Hg[p]). Increasing the oxidized and particulate fractions of mercury has the potential to increase the efficiency of mercury capture by conventional control devices such as wet flue gas desulfurization scrubbers and electrostatic precipitators.

EXPERIMENTAL

Thermochemical Equilibrium Modeling

The Facility for the Analysis of Chemical Thermodynamics (FACT) is a digital thermodynamic equilibrium model that assesses fuel quality effects on ash behavior in a boiler. It predicts molar fractions (partial pressures) of all gas, liquid, and solid stable components in a system by using the principle of Gibbs free energy minimization. FACT output includes quantities, compositions, and viscosities of liquid and solid mineral phases; the model accurately predicts the behavior of fuel ash, including biomass-derived ash, for different boiler temperature regimes.

In this study, the bulk ash composition and the atmosphere used in the thermogravimetric analyzer (TGA) testing were input to the FACT model. In this model, each reaction is considered independent of all other reactions. For example, the FACT model may predict that species X will dominate while the empirical results show that species Y tends to form (i.e., selectivity and kinetics are not considered by the model).

Bench-Scale TGA Study

Fuels were first combusted in the EERC's conversion and environmental process simulator. Ash resulting from the combustion of these fuels was collected and size-fractionated. Tests were carried out on the size-fractionated ash in a TGA under atmospheric conditions that mimic a combustion environment. The simulated flue gas atmosphere consisted of CO_2, SO_2, NH_3, N_2, O_2, H_2O, and P_2O_5. The flue gas makeup is presented in Table 1. The weight gain of the ash or ash–catalyst mixtures was measured as a function of time and temperature. The tests were conducted at 316°, 371°, and 427°C (600°, 700°, and 800°F). The resulting mixtures were analyzed to determine the influence of SCR catalysts on ash behavior.

Table 1. Flue Gas Makeup

N_2	74%
H_2O	8%
CO_2	14%
O_2	4%
NH_3	100–300 ppm
SO_2	0.04%
P	1–1000 ppm

Slipstream Reactor Installation and Operation

Upon installation at each utility boiler unit, flue gas temperature, composition, and velocity measurements were obtained using portable equipment. Shakedown testing of the unit was conducted to ensure that all components were operating properly and that data were being logged and could be retrieved. After installation and shakedown were completed, the reactor was operated in a computer-controlled, automated mode and monitored on a daily basis to ensure proper operation and data quality. During operation of the SCR slipstream system, catalyst temperature, sootblowing frequency, and pressure drop across the catalyst were monitored and logged. Samples of the exposed SCR catalyst and associated deposits were obtained after exposure to flue gas and particulate for 2, 4, and 6 months. The samples of the catalyst were analyzed to determine the components that were bonding and filling pores, resulting in decreased reactivity.

SEM Ash Characterization

The characteristics of the ash that accumulated on the catalyst were examined using scanning electron microscopy (SEM)–x-ray microanalysis and x-ray diffraction (XRD) (18). The samples were either placed on double-stick tape for surface analysis or mounted in epoxy for cross-section analysis. Correlations between the physical and chemical characteristics of any ash deposits on the SCR test section and entrained-ash sample collected at the chamber inlet and the coal inorganic composition will be made to discern mechanisms of SCR blinding. Entrained ash was collected at the Columbia Station only and characterized with respect to composition and size.

Mercury Measurement

At the Coyote Station, the Ontario Hydro (OH) mercury speciation sampling train was used to determine mercury forms across the SCR test section. The OH extractive mercury speciation sampling technique was used to measure potential mercury conversion across the SCR system over a period of several hours after fresh installation of the SCR test chamber and again just prior to removal of SCR catalyst sections.

The procedure used to conduct the mercury speciation sampling was American Society for Testing and Materials Method D6784-02 entitled "Standard Test Method for Elemental, Oxidized, Particle-Bound and Total Mercury in Flue Gas Generated from Coal-Fired Stationary Sources (Ontario Hydro method)" (19).

The OH method follows standard U.S. Environmental Protection Agency (EPA) methods for isokinetic flue gas sampling (EPA Methods 1–3 and EPA Method 5/17). A sample is withdrawn from the flue gas stream isokinetically through the filtration system, which is followed by a series of impingers in an ice bath. Particulate-bound mercury is collected on the filter; Hg^{2+} is collected in impingers containing 1 N potassium chloride solution; and elemental mercury is collected in one impinger containing a 5% nitric acid and 10% peroxide solution and in three impingers containing a solution of 10% sulfuric acid and 4% potassium permanganate. An impinger containing silica gel collects any remaining moisture. The filter media is quartz fiber filters. The filter holder is glass or Teflon-coated. An approximate 2-hour sampling time was used, with a target sample volume of 1 standard cubic meter.

RESULTS AND DISCUSSION

Task 1 – Identification of Test Coals and Utility Host Sites

Three host utility sites were chosen for the installation of the SCR reactors. The utilities were chosen based on their ability to provide all of the necessary support and hardware for the operation of the SCR reactors. The electric utility units selected for testing are shown in Table 2. The plants where the SCR slipstream system was installed included Alliant Energy's Columbia Station, Dynegy's Baldwin Station, and Otter Tail Power Company's Coyote Station.

Table 2 describes the plants, and Table 3 summarizes the characteristics and selection criteria. The selection criteria that were most important to the success of this project were geographic location, a base load plant, and a consistent supply of one fuel for the duration of the study.

Table 2. Description of Power Plants Tested

	Baldwin	Columbia	Coyote
Unit No.	1	2	1
Utility	Dynegy	Alliant	Otter Tail
Boiler Type	Cyclone	T-fired	Cyclone
Fuel type	Antelope – subbituminous	Caballo – subbituminous	Beulah – Zap lignite
Load	Base	Base	Base
Location	Baldwin, IL	Portage, WI	Beulah, ND
MW	600	520	425

Table 3. Key Selection Criteria

Field Test 1 – Columbia Station

- Tangentially fired boiler to show differences in ash partitioning as compared to cyclone-fired systems.
- High-potential-blinding coal in Caballo, which can be burned nearly 100% for the entire test.

Field Test 2 – Baldwin Station

- Plant is cyclone fired.
- Units already are equipped to do slipstream testing.
- Plant currently fires a blend of Antelope coal and tires; plant is willing to fire 100% Antelope.
- High-potential-blinding coal in Antelope.

Field Test 3 – Coyote Station

- Cyclone-fired with lignite.
- High-potential-blinding coal with high alkali and alkaline-earth elements. Coal can have very high sodium content and is known to cause significant low-temperature deposition.

The units tested were selected based on the fuels fired, boiler type, and availability of the unit for sampling. The average composition of the coals fired during the testing is listed in Tables 4 and 5. The subbituminous coals were typically low ash, nominally 4.5%–5.5% with very high levels of calcium in the ash. In comparison, the lignite contains higher levels of ash and lower calcium but higher levels of sodium. The alkali and alkaline-earth elements are primarily associated with the organic matrix of the coal as salts of carboxylic acid groups (18). The portion of the ash-forming components that are associated with the organic matrix of the coal for subbituminous coal ranges from 30% to 60% (18); for the lignite coal, the portion is about 20% to 40%. The remaining ash-forming components consist of mineral grains. For these coals, the percentage organically associated is 29% for the Antelope, 36% for Caballo, and 19% for Beulah. The minerals present in the coals as determined by computer-controlled scanning electron microscopy (CCSEM) analyses are listed in Table 6. The primary minerals present in the subbituminous coals include quartz and various clay minerals with some pyrite and a mineral that is rich in Ca, Al, and P. This mineral has been identified in some coals as crandalite. The primary minerals found in the Beulah coal include clay minerals (kaolinite), pyrite, and quartz.

Table 4. Ultimate Analysis Results (dry basis), wt%

	Antelope	Caballo	Beulah
Ash Content	7.28	6.59	11.62
Total Sulfur	0.33	0.51	1.49
Carbon	69.97	67.88	61.50
Hydrogen	4.77	4.83	3.96
Nitrogen	1.05	1.24	1.08
Oxygen (by difference)	16.61	18.96	20.35

Table 5. Ash Composition (wt% equivalent oxide)

Oxide	Antelope	Caballo	Beulah
SiO_2	24.82	26.70	16.50
Al_2O_3	13.55	16.60	13.30
TiO_2	1.39	1.10	0.80
Fe_2O_3	7.52	5.10	16.60
CaO	26.68	25.10	19.50
MgO	7.14	8.00	7.40
K_2O	0.17	0.30	0.20
Na_2O	1.47	1.00	5.20
P_2O_5	0.90	1.70	0.00
SO_3	16.33	14.40	19.80

Task 2 – Bench-Scale Testing and FACT Modeling

Bench-Scale Testing

The goal of the bench-scale testing was to determine the effect catalyst would have on the conversion of SO_2 to SO_3 and the resulting increase in catalyst blinding. Tests were conducted with and without catalyst on the following fuels: Nanticoke Powder River Basin (PRB), Beulah lignite, and Nanticoke PRB and a low-sulfur U.S. (LSUS) bituminous blend.

The results of the study indicate that the addition of the catalyst to the ash and increased temperature increased the rate of weight gain by as much as tenfold. The weight gain can be directly linked to the rate of sulfation. The test results in Figures 1–3 were compiled using the gas concentrations noted in Table 1 minus the NH_3 and phosphorus compounds (baseline tests). Table 7 contains the ash analysis of the coals used in the bench-scale testing. Figure 1 contains the weight gain curves for the Nanticoke PRB test. The rate of weight gain increased as the temperature increased from 316° to 427°C (600° to 800°F).

Figure 2 contains the weight gain curve for the Beulah lignite. Again the weight gain increased as the temperature was increased from 316° to 427°C (600° to 800°F). The rate of weight gain was similar to what was seen with the Nanticoke PRB test.

Table 6. CCSEM Analysis Results for Beulah, Antelope, and Caballo (values are wt% on a mineral basis)

	Caballo	Antelope	Beulah
Total Mineral wt% on a Coal Basis:	2.8	3.2	8.4
Quartz	40.4	31.5	11.0
Iron Oxide	0.0	2.4	4.4
Periclase	0.0	0.0	0.0
Rutile	2.4	0.3	0.0
Alumina	0.0	0.0	1.1
Calcite	0.0	0.4	0.1
Dolomite	0.0	0.5	0.0
Ankerite	0.0	0.0	0.2
Kaolinite	23.7	17.1	4.9
Montmorillonite	0.4	6.5	6.6
K Al-Silicate	0.0	1.6	7.2
Fe Al-Silicate	0.0	0.8	9.0
Ca Al-Silicate	0.1	1.0	2.6
Na Al-Silicate	0.0	0.0	0.1
Aluminosilicate	0.7	3.3	3.2
Mixed Al-Silicate	0.0	1.0	5.5
Fe Silicate	0.0	0.0	0.0
Ca Silicate	0.0	0.4	0.0
Ca Aluminate	0.0	0.0	0.0
Pyrite	16.2	0.0	0.8
Pyrrhotite	0.0	4.8	18.4
Oxidized Pyrrhotite	0.0	0.5	0.5
Gypsum	0.4	0.0	0.5
Barite	0.8	0.5	3.0
Apatite	0.0	0.2	0.0
Ca Al-P	8.5	13.5	0.1
KCl	0.0	0.0	0.0
Gypsum/Barite	0.0	0.1	0.0
Gypsum/Al-Silicate	0.1	0.9	4.0
Si-Rich	0.3	3.7	4.9
Ca-Rich	0.0	0.0	0.0
Ca-Si-Rich	0.0	0.1	0.0
Unclassified	3.2	8.7	11.9
Totals	100.0	100.0	100.0

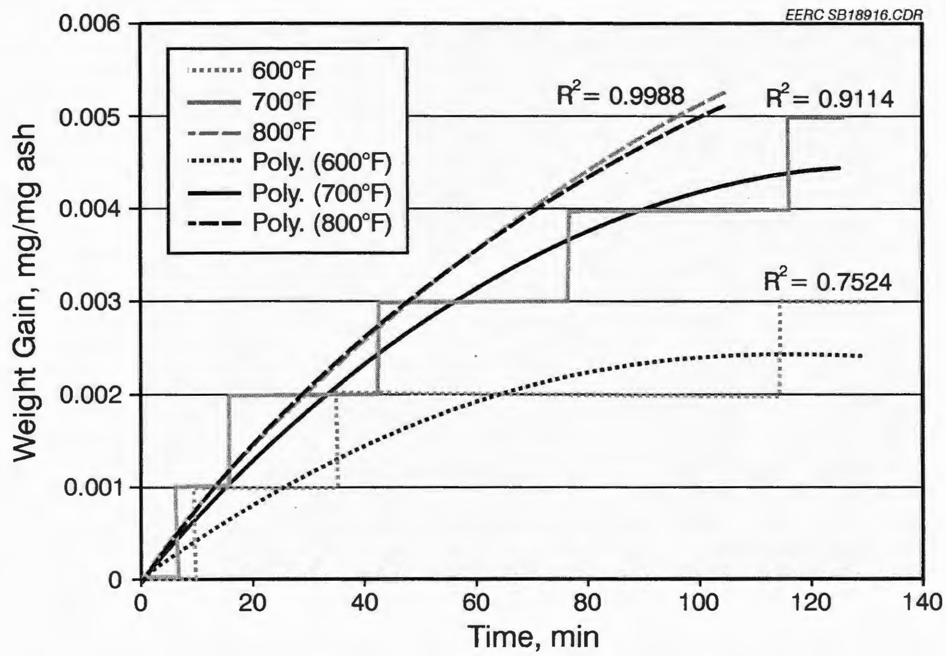

Figure 1. Weight gain curves for Nanticoke PRB (less than 3 μm), no catalyst.

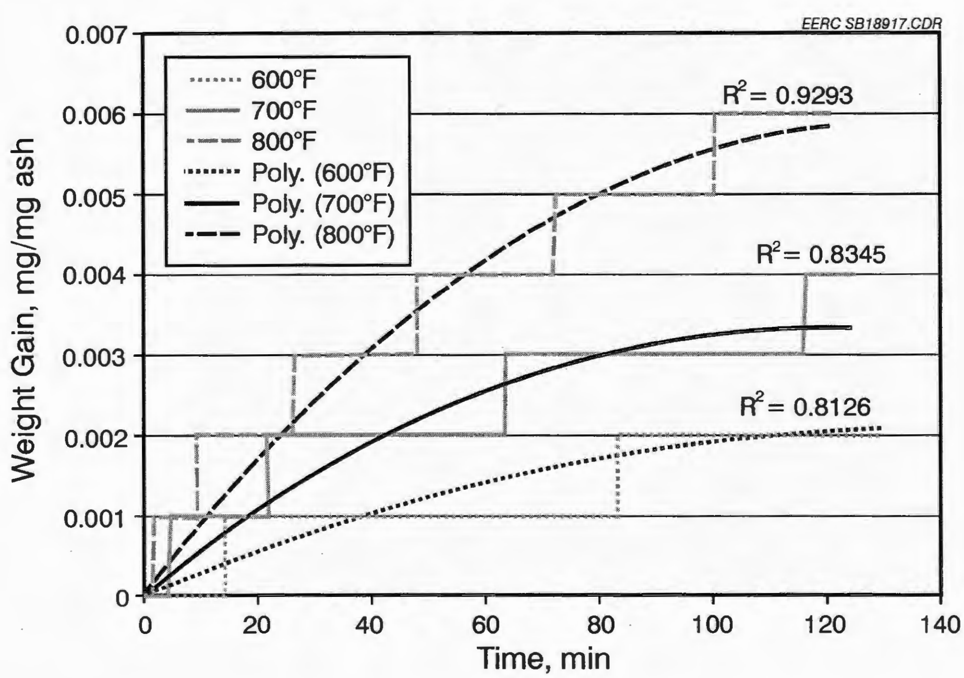

Figure 2. Weight gain curves for Beulah lignite (less than 3 μm), no catalyst.

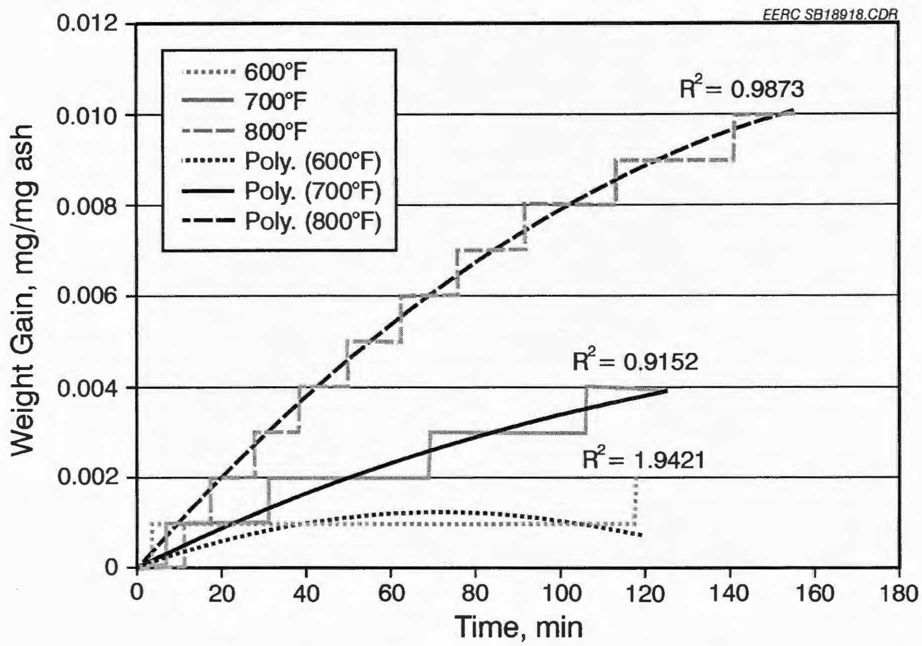

Figure 3. Weight gain curves for Nanticoke PRB–LSUS blend (less than 3 μm), no catalyst.

Table 7. Composition of Coal Ashes Used in Bench-Scale Testing

Oxides, wt%	Nanticoke 100% PRB (a)[1]	Nanticoke 100% PRB (b)[2]	Nanticoke 52% PRB–48% LSUS (a)	Nanticoke 52% PRB–48% LSUS (b)	Beulah (a)	Beulah (b)
SiO_2	27.9	32.0	43.4	48.4	31.5	39.7
Al_2O_3	17.7	20.3	26.7	29.7	14.2	17.9
Fe_2O_3	6.2	7.1	4.8	5.3	7.3	9.2
TiO_2	1.5	1.8	1.6	1.8	0.8	1.0
P_2O_5	1.0	1.2	0.4	0.4	0.2	0.2
CaO	24.8	28.5	8.5	9.4	15.8	19.9
MgO	6.6	7.6	2.6	2.9	5.8	7.3
Na_2O	1.0	1.2	0.7	0.7	3.1	3.9
K_2O	0.4	0.5	1.2	1.3	0.8	1.0
SO_3	12.9	—	10.2	—	20.6	—

[1] Oxide concentrations normalized to a closure of 100%.
[2] Oxide concentrations renormalized to an SO_3-free basis.

A blend of the Nanticoke PRB and an LSUS bituminous coal was tested at a 52–48 blend (PRB–LSUS). The weight gain curves for this test are in Figure 3. The results of this experiment are again similar to those obtained in the previous two cases, with the exception of the 427°C (800°F) test. The 427°C (800°F) test in this case gains slightly more weight than the previous two experiments. At high temperatures, this blend had almost double the weight gain from the straight PRB case. This indicates that there is likely more sulfur available from the bituminous coal.

More testing was completed on the Nanticoke PRB and the PRB–LSUS blend. In Figures 4–5, the gas used in the study now contains the NH_3 and phosphorus compounds in addition to the gas used in the previous three tests. Figure 4 contains the data for the Nanticoke PRB test with NH_3 and phosphorus. The addition of the NH_3 and phosphorus compounds increased the rate of weight gain in the 427°C (800°F) test. The difference in rates as temperature was increased became less pronounced.

Figure 5 contains the weight gain curves for the PRB–LSUS test. The rate of weight gain was also increased; however, the temperature effect was still present (increased weight gain with increased temperature).

The baseline tests (without NH_3 and phosphorus compounds) were repeated with the addition of SCR catalyst to the mixture. The results of these tests are in Figures 6–7. Figure 6 contains the weight gain curves for the Nanticoke PRB test with catalyst and the Nanticoke PRB test at baseline conditions and 427°C (800°F). The rate of weight gain with the addition of catalyst at 427°C (800°F) increased approximately 7-fold in this case. The addition of the catalyst will increase the amount of SO_2 that is oxidized to a more reactive form (SO_3), which will in turn increase the rate of sulfate formation.

Figure 7 contains the weight gain curves for the PRB–LSUS blend with catalyst. In this test, the rate of weight gain increased almost tenfold. Again, the increased rate can be attributed to more SO_3 in the system.

FACT Modeling

FACT thermodynamic equilibrium modeling was conducted on each of the ash and flue gas systems tested in the bench-scale screening. The FACT modeling will give an indication of what chemical species are thermodynamically favored at the temperature present in the SCR. Figures 8–13 contain the results of the FACT modeling on the Nanticoke PRB, Beulah lignite, and the Nanticoke PRB–LSUS blend. The gas composition used for the modeling is the same as what was used for the bench-scale analysis in Table 1.

Figures 8–10 have the results for the Nanticoke PRB, Nanticoke PRB–LSUS blend, and the Beulah lignite with 300 ppm NH_3 and 1000 ppm phosphorus pentoxide added. The model predicts that in all three cases the alkali/alkaline-earth phosphates and sulfates will be the predominant species formed. Trace amounts of phosphoric and sulfuric acid will also be present at lower temperatures (232°C [450°F]).

Figures 11–13 have the results for the Nanticoke PRB, the Nanticoke PRB–LSUS blend, and the Beulah lignite with 100 ppm NH_3 and 1 ppm phosphorus pentoxide added. With less phosphorus present, the model predicts that sulfates will dominate. In the case of the Nanticoke PRB, the formation of carbonate compounds is also predicted.

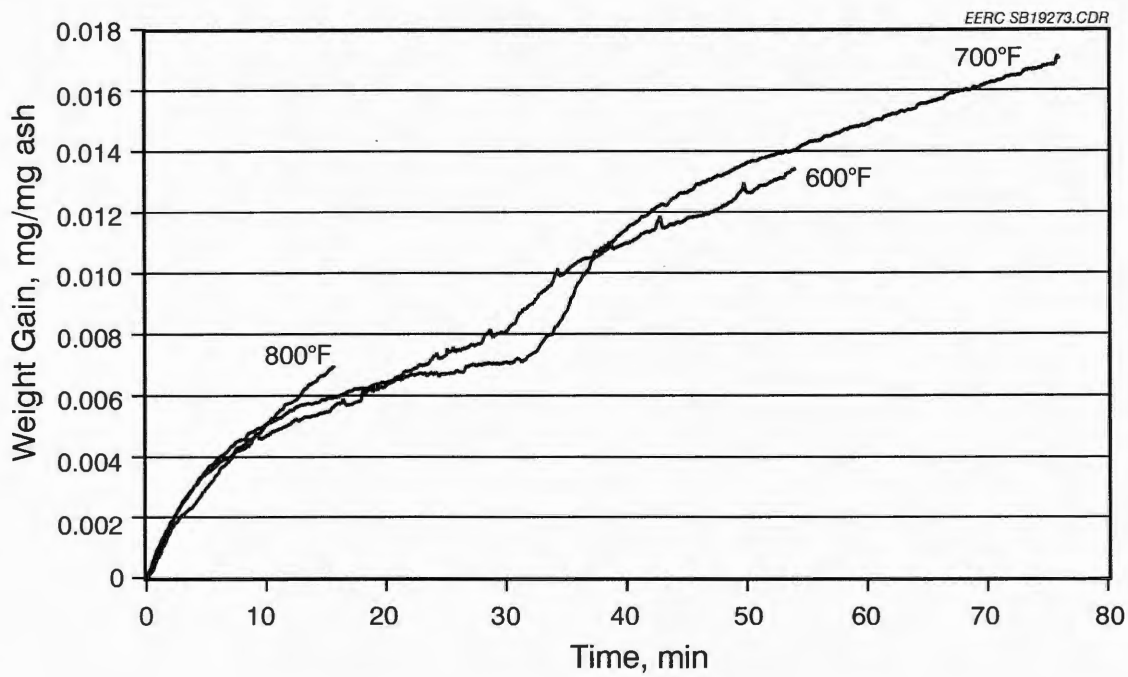

Figure 4. Weight gain curves for Nanticoke PRB (less than 3 μm) with ammonia and phosphorus compounds, no catalyst.

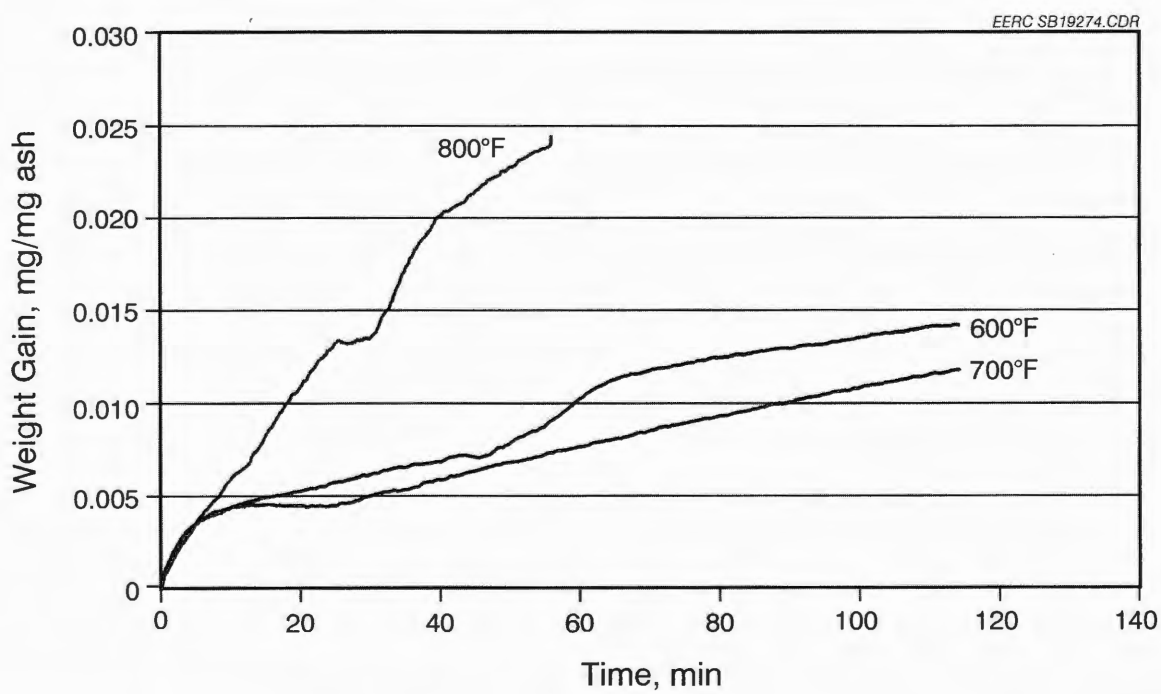

Figure 5. Weight gain curves for Nanticoke PRB–LSUS blend (less than 3 μm) with ammonia and phosphorus compounds, no catalyst.

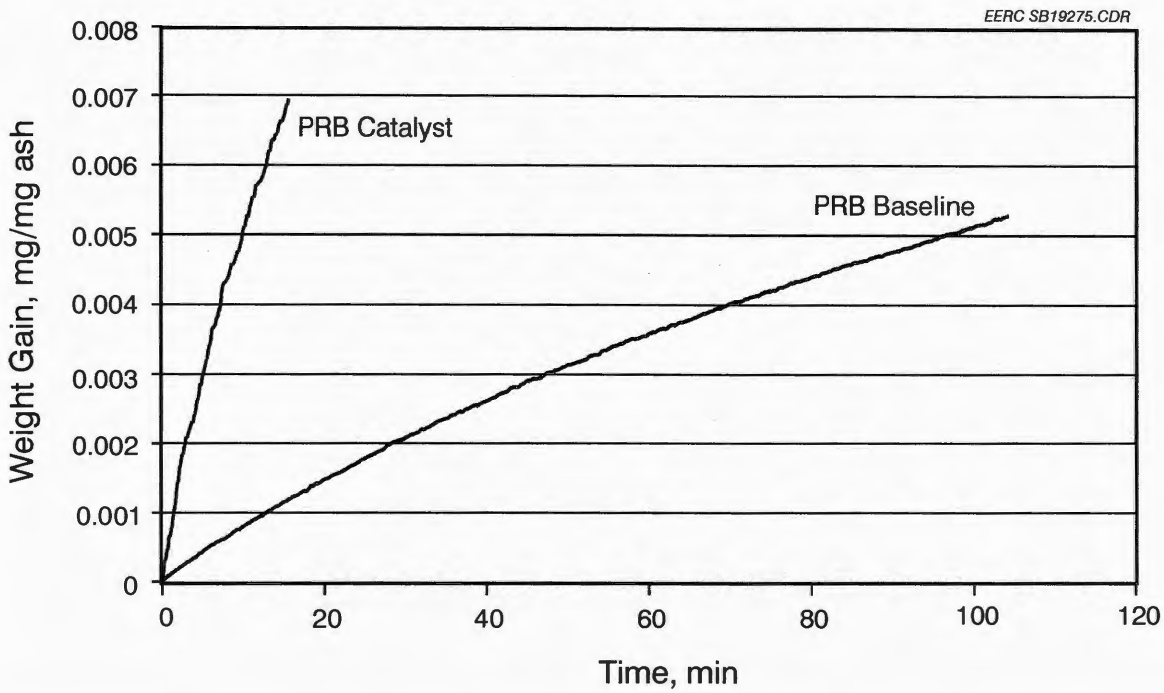

Figure 6. Weight gain curves for baseline Nanticoke PRB and Nanticoke PRB with catalyst.

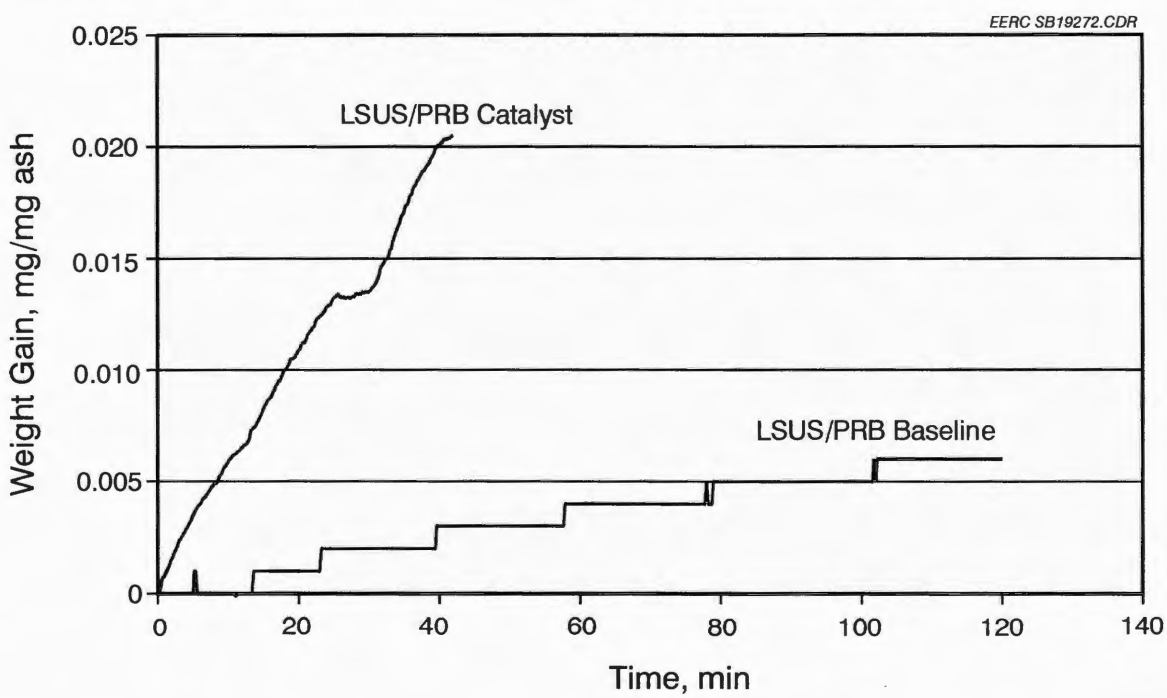

Figure 7. Weight gain curves for baseline LSUS–Nanticoke PRB blend and LSUS–Nanticoke PRB blend with catalyst.

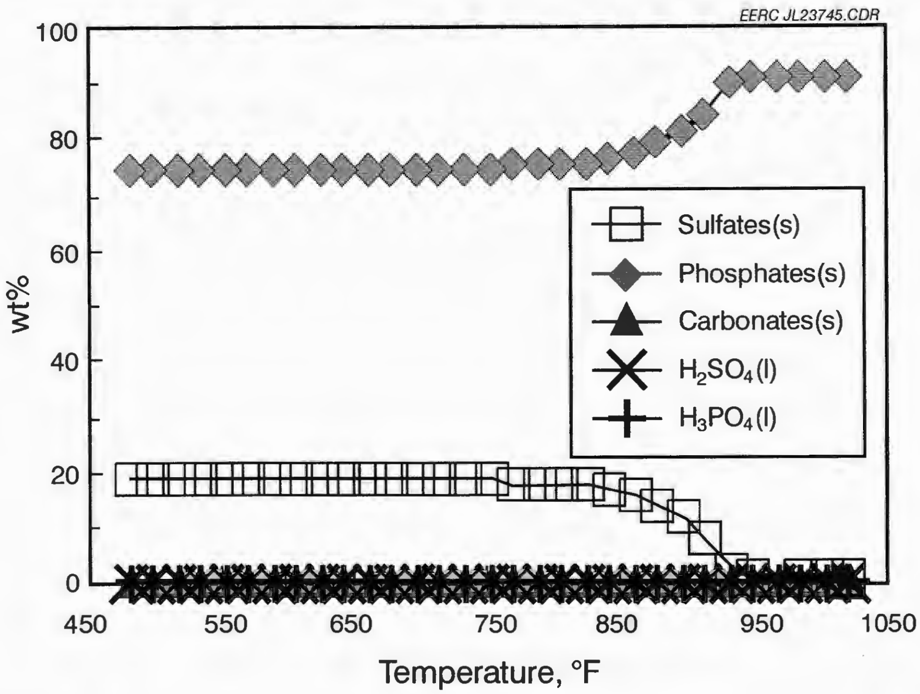

Figure 8. FACT modeling results for Nanticoke PRB with 300 ppm ammonia and 1000 ppm P_2O_5.

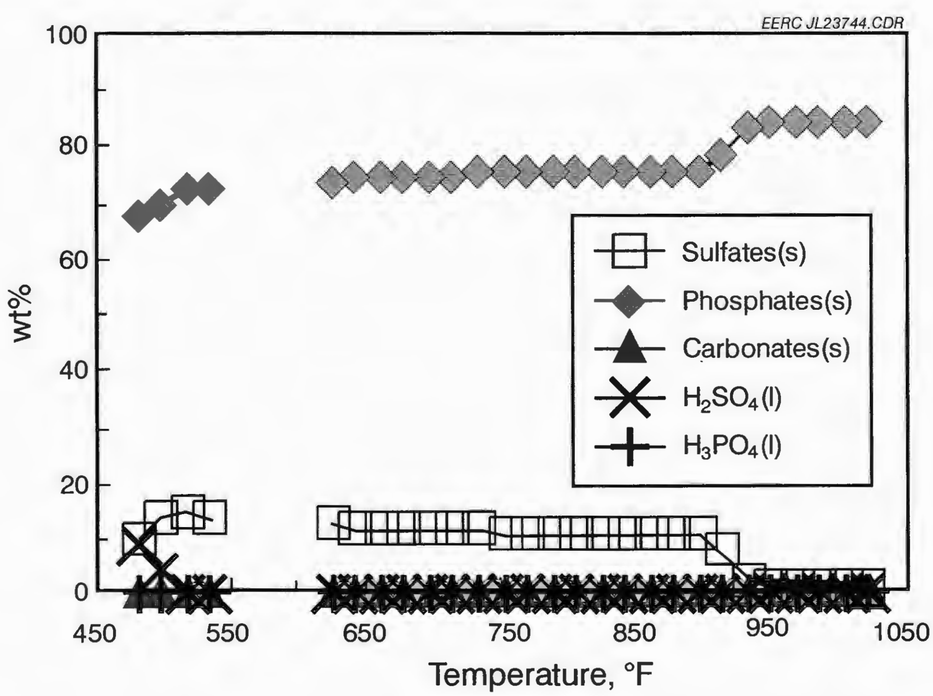

Figure 9. FACT modeling results for Nanticoke PRB–LSUS blend with 300 ppm ammonia and 1000 ppm P_2O_5.

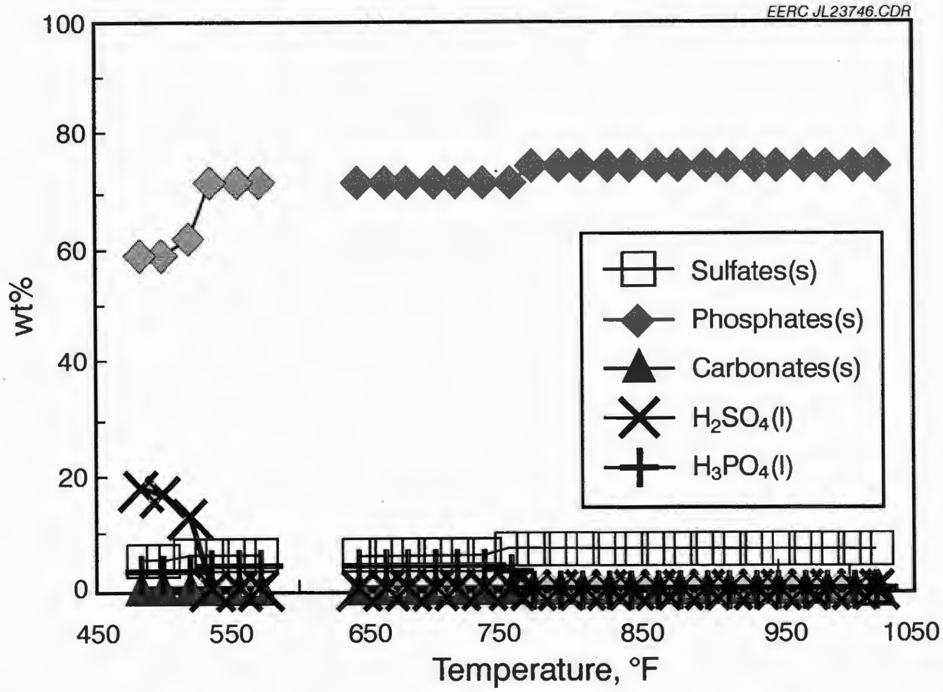

Figure 10. FACT modeling results for Beulah with 300 ppm ammonia and 1000 ppm P_2O_5.

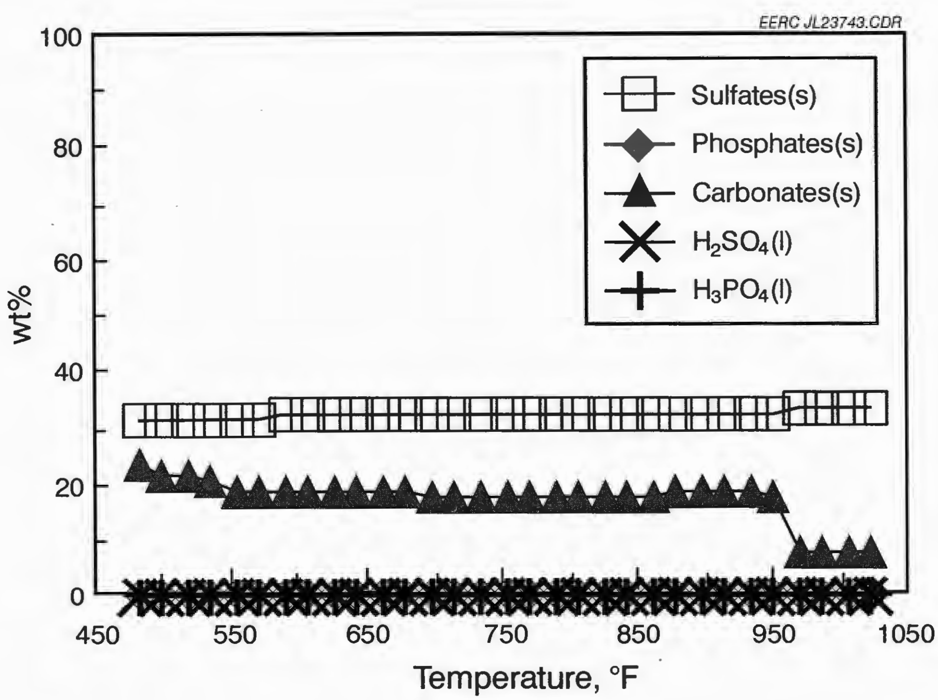

Figure 11. FACT modeling results for Nanticoke PRB with 100 ppm ammonia and 1 ppm P_2O_5.

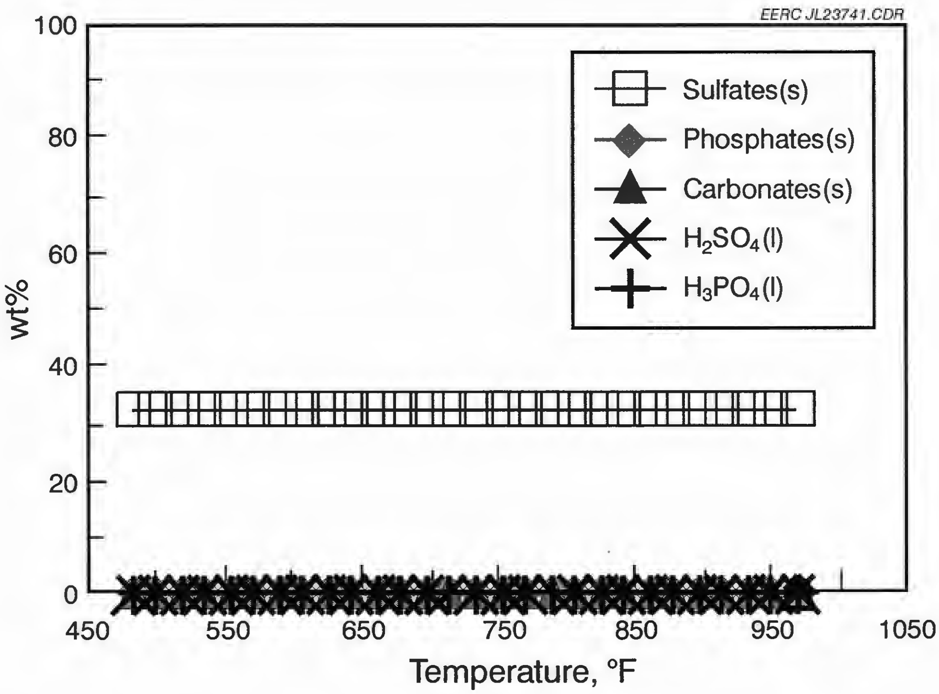

Figure 12. FACT modeling results for Nanticoke PRB–LSUS blend with 100 ppm ammonia and 1 ppm P_2O_5.

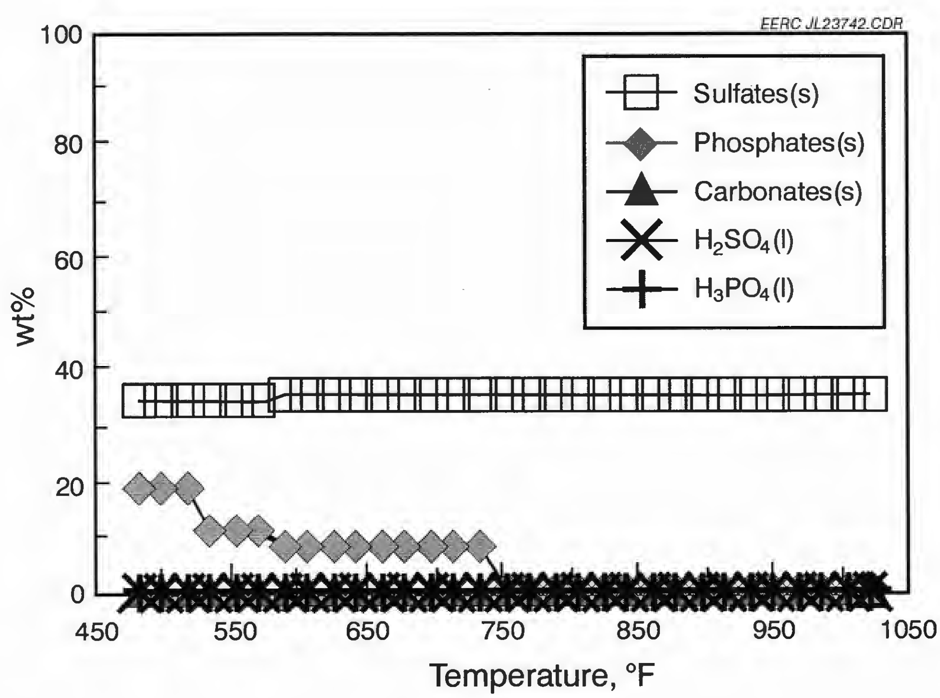

Figure 13. FACT modeling results for Beulah with 100 ppm ammonia and 1 ppm P_2O_5.

Characterization of Reaction Products from Bench-Scale Tests

The reaction products from three of the bench-scale tests were analyzed with SEM to validate the FACT modeling and to determine that the material gained during the tests was indeed a sulfate. Figures 14–16 are SEM micrographs of the fly ash from the Nanticoke PRB, Nanticoke PRB–LSUS blend, and the Beulah lignite. Corresponding Tables 8–10 contain the chemical analysis of several fly ash particles. Sulfur is present in almost all analyses and increases along with calcium. This indicates that most of the sulfur is present as calcium sulfate. These results are also consistent with the FACT modeling predictions. One exception may be that phosphates were not present in large quantities.

Task 3 – Design and Construction of the SCR Slipstream Test Chamber

The SCR slipstream system consists of two primary components: the control room and the SCR reactor. The reactor section consists of a catalyst section, an NH_3 injection system, and sampling ports for NO_x at the inlet and exit of the catalyst section. The control room houses a computer system that logs data and controls the gas flow rates, temperatures, pressure drop across the catalyst, and sootblowing cycles. The computer was programmed to maintain constant temperature of the catalyst, gas flow rates, sootblowing cycles, and NH_3 injection. The computer is equipped with a modem that allowed for downloading of data and modification of the operation of the reactor from a remote computer located at the EERC.

A schematic diagram of the SCR slipstream system is shown in Figure 17. Flue gas is isokinetically extracted from the convective pass of the boiler upstream of the air heater. The temperature is typically about 790°F. The flue gases pass through a 4-inch pipe equipped with sampling, thermocouple, and pressure ports. NH_3 is injected into the piping upstream of the reactor section. The reactor consists of a steel housing that is approximately 8.5 inches square and 8 feet long. The reactor section illustrated in Figure 18 has three components, including a flow straightener, a pulse section or sootblower, and a catalyst test section. A metal honeycomb is used as a flow straightener upstream of the catalyst section and is about 6 inches long. A purge section was installed ahead of the catalyst test section to remove accumulated dust and deposits. The catalyst test section is located downstream of the purge section. The entire catalyst section is insulated and equipped with strip heaters for temperature control. The catalyst test section is 1 m (3.28 ft) in length and houses three catalyst sections. Thermocouple and pressure taps are located in the purge sections for measurements before and after each section.

The induced-draft fan is used to extract approximately 5.6 scmm (200 scfm) of flue gas from the convective pass of the utility boiler to achieve an approach velocity of 5.2 m/s (17.0 ft/s). The total gas flow through the reactor represents a thermal load of approximately 300 kW.

The range of operating conditions for the reactor is listed below:

- Gas temperature: ~371°–426°C (700°–800°F)
- Gas flow rate: 11.3–14.2 acmm (400–500 acfm)
- Approach velocity range: 5.0–5.5 m/sec (16.4–18 ft/s)

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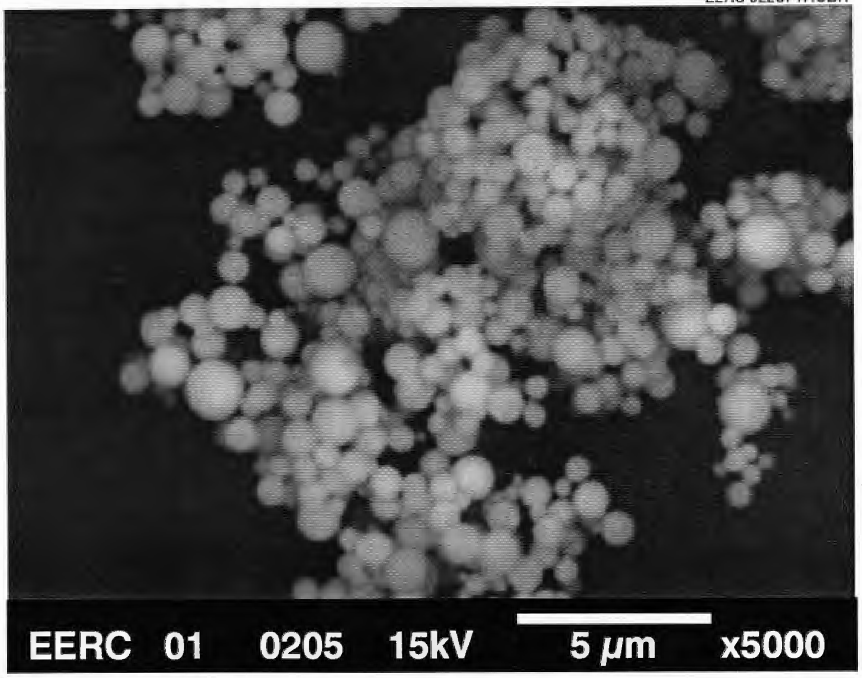

Figure 14. SEM micrograph of reaction products from Nanticoke PRB.

Table 8. SEM/Energy-Dispersive Spectroscopy (EDS) Analysis Results from Nanticoke PRB at 800°F

Element	Percent	Percent
Na	0.50	0.00
Mg	5.60	5.00
Al	9.22	11.30
Si	9.00	8.30
P	1.80	1.30
S	0.70	2.10
Cl	0.00	0.00
K	0.30	0.00
Ca	32.40	31.00
Ti	0.00	1.40
Cr	0.00	0.00
Fe	11.60	7.70
Ba	1.50	1.10
O	27.00	30.60

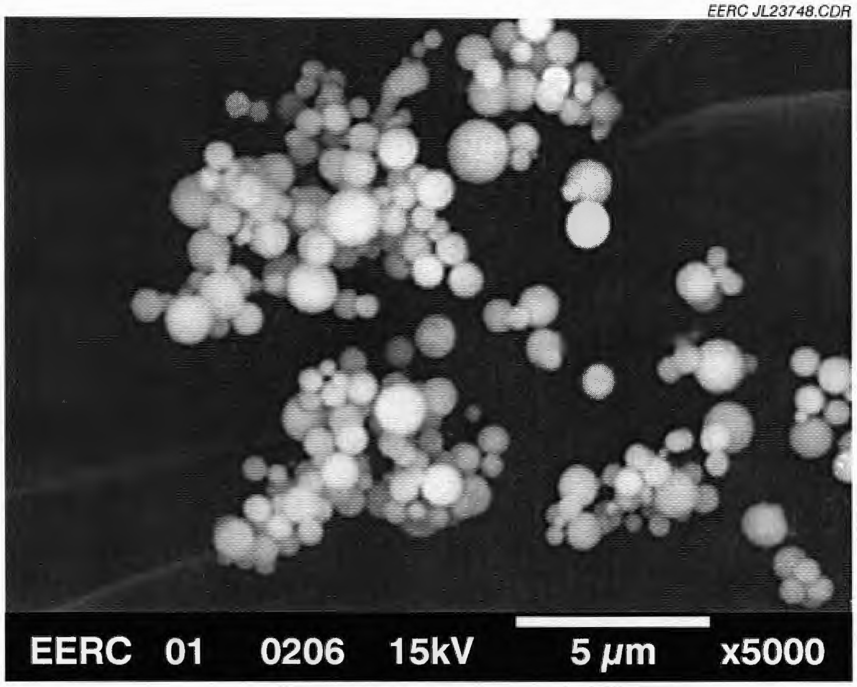

Figure 15. SEM micrograph of reaction products from Nanticoke PRB–LSUS blend.

Table 9. SEM/EDS Analysis Results from Nanticoke PRB–LSUS blend at 800°F

Element	Percent	Percent
Na	0.40	0.50
Mg	2.10	3.10
Al	15.90	12.60
Si	14.50	21.80
P	2.00	4.00
S	1.00	0.00
Cl	0.10	0.00
K	1.70	1.00
Ca	20.00	10.60
Ti	0.90	3.00
Cr	0.00	0.00
Fe	4.90	5.60
Ba	0.00	1.00
O	36.40	36.50

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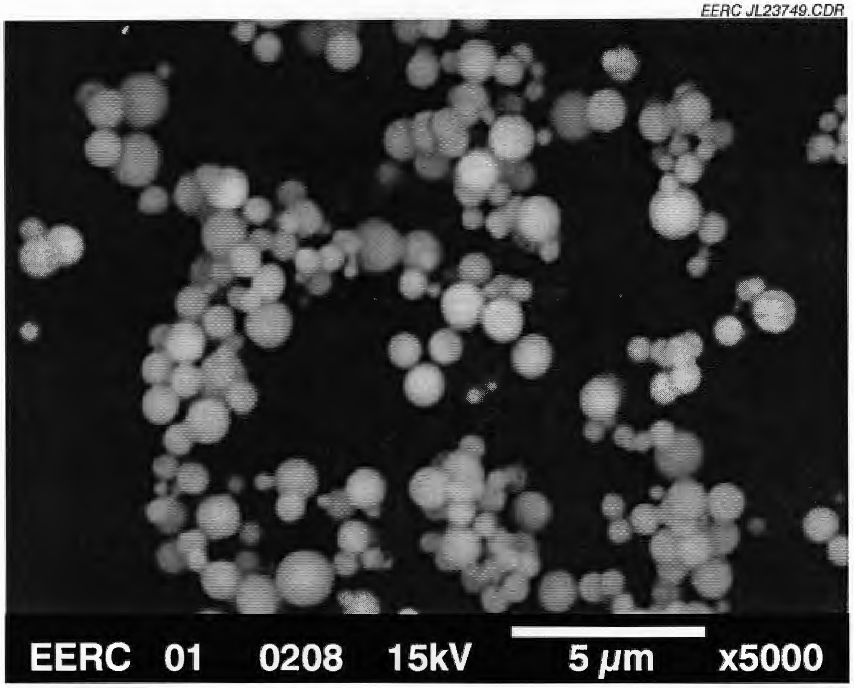

Figure 16. SEM micrograph of reaction products from Beulah lignite.

Table 10. SEM/EDS Analysis Results from Beulah Lignite at 800°F

Element	Percent	Percent
Na	1.60	1.00
Mg	4.00	5.30
Al	7.10	9.00
Si	22.70	18.10
P	0.00	0.00
S	1.60	2.80
Cl	0.00	0.00
K	1.40	0.50
Ca	17.10	25.00
Ti	0.00	1.50
Cr	0.10	0.00
Fe	5.40	4.00
Ba	5.90	4.60
O	33.00	28.00

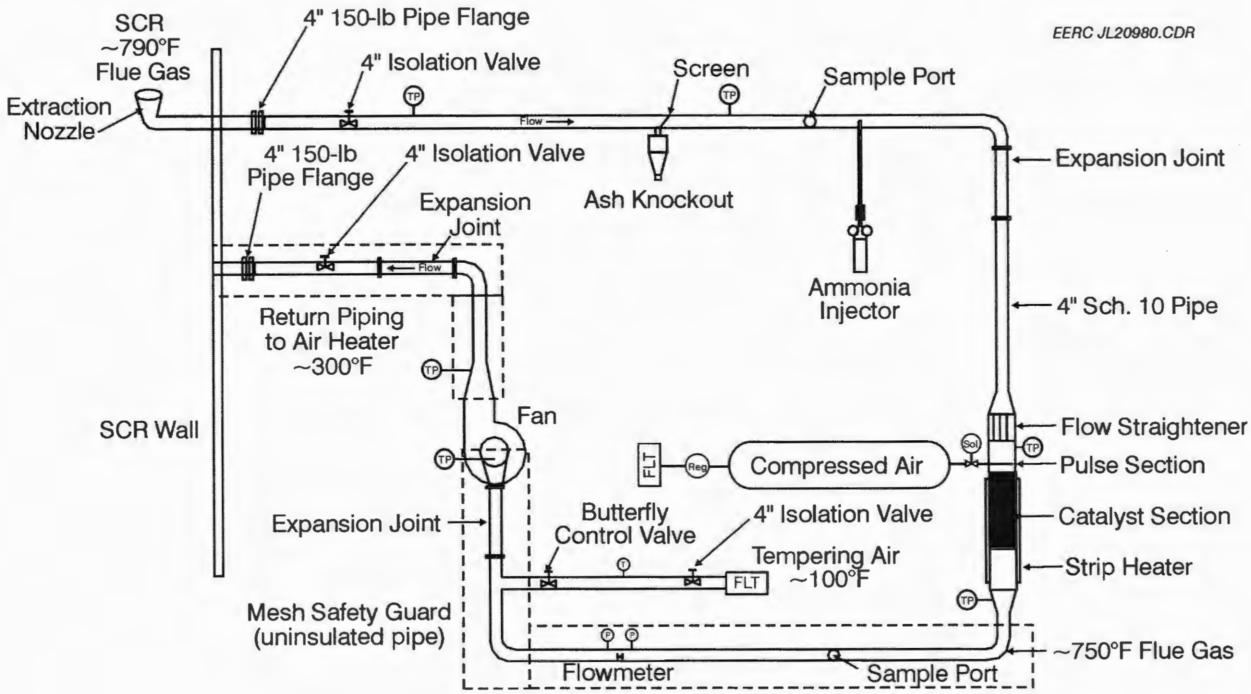

Figure 17. Conceptual schematic of the SCR reactor slipstream field test unit.

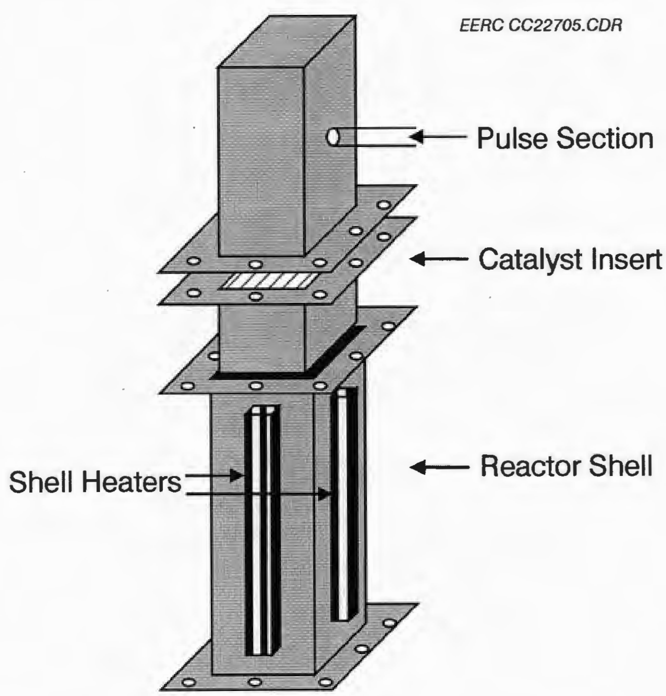

Figure 18. SCR catalyst section.

- NH_3 injection rate: 0.5:1 with NO_x level
- Tempering air for fan: ~1.4–5.7 scmm (50–200 scfm)
- Catalyst dP: 0.5–1.0 inches water column
- Fan sized for up to 30 inches water column

For catalyst inspection or replacement, the catalyst section can be unbolted and slid out from the reactor (support brackets hold the remaining reactor pieces in place). Once a catalyst reactor section is removed, the top catalyst holder can be removed, and the section(s) of interest removed by pushing it up from the bottom and out the top. A new section is then inserted from the top to replace the piece removed.

Task 4 – SCR Test Chamber Installation and Data Collection at Utility Host Sites

The catalyst installed at the Baldwin and Coyote Stations was the Haldor Topsoe catalyst. Topsoe's DNX-series of catalysts comprises SCR DENOX catalysts tailored to suit a comprehensive range of process requirements. DNX-series catalysts are based on a corrugated, fiber-reinforced TiO_2 carrier impregnated with the active components V_2O_5 and tungsten trioxide (WO_3). The catalyst is shaped to a monolithic structure with a large number of parallel channels. The unique catalyst design provides a highly porous structure with a large surface area and an ensuing large number of active sites. Figure 19 is an image of the Haldor Topsoe SCR catalyst. The pitch of the catalyst was approximately 6 mm.

Figure 19. Haldor Topsoe SCR catalyst showing the gas flow passages.

The catalyst installed at the Columbia Station was a Babcock Hitachi plate-type catalyst. This catalyst is a TiO_2-based plate catalyst, developed and manufactured by Hitachi. Figure 20 shows the design of the catalyst. The pitch of the catalyst was approximately 10 mm.

Upon installation at each utility boiler unit, flue gas temperature, composition, and velocity measurements were obtained using portable equipment. Shakedown testing of the unit was conducted to ensure that all components were operating properly and that data were being logged and could be retrieved. After installation and shakedown were completed, the reactor was operated in a computer-controlled, automated mode and monitored on a daily basis to ensure proper operation and data quality. During operation of the SCR slipstream system, catalyst temperature, sootblowing frequency, and pressure drop across the catalyst were monitored and logged. Samples of the exposed SCR catalyst and associated deposits were obtained after exposure to flue gas and particulate for 2, 4, and 6 months. The samples of the catalyst were analyzed to determine the components that were bonding and filling pores, resulting in decreased reactivity.

The characteristics of ash that accumulated on the catalyst were examined using SEM–x-ray microanalysis and XRD (18). Correlations between the physical and chemical characteristics of any ash deposits on the SCR test section and entrained-ash sample collected at the chamber inlet and the coal inorganic composition were made to discern mechanisms of SCR blinding. Entrained ash was collected at Columbia Station only and characterized as to composition and size.

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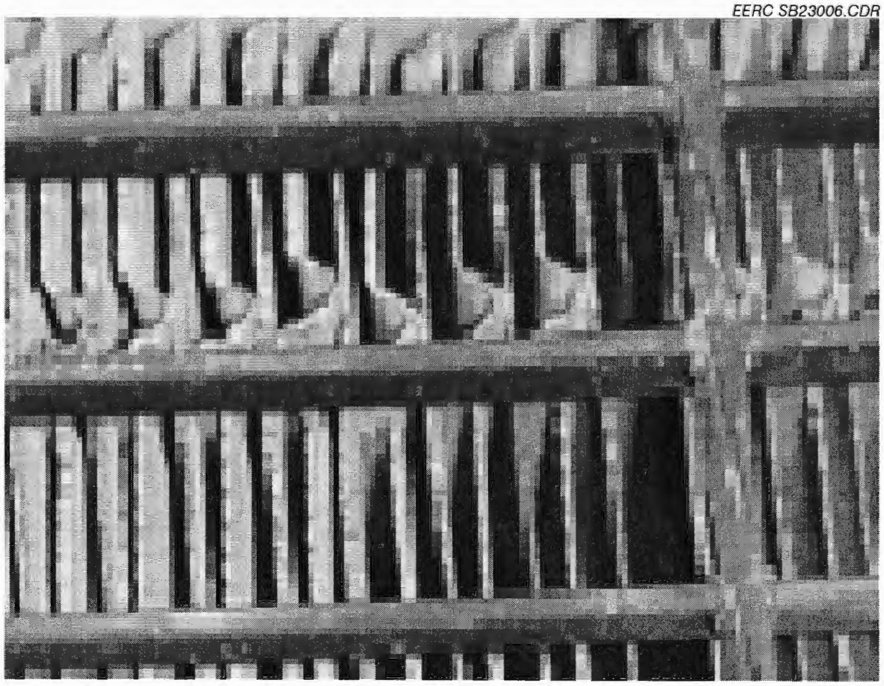

Figure 20. Babcock Hitachi SCR catalyst showing the gas flow passages.

Baldwin Station Data

The data presented in the following section represent a small portion of the operational data collected. The remainder of the data is available upon request. The reactor was installed at the Baldwin Station and operated for a 6-month time period on the Haldor Topsoe catalyst. The information obtained from testing included pressure drop, sootblowing cycles, and reactor temperatures. Table 11 summarizes the operating conditions of the reactors during the testing periods at all plants. Figures 21–23 show the pressure drop across the catalyst test periods from 0 to 2 months, 2 to 4 months, and 4 to 6 months, respectively. During the first 2 months of operation, the pressure shown in Figure 21 was about 0.5 inches of water; at the end of 2 months, the pressure drop was about 0.8 inches of water, indicating plugging had occurred. The air was pulsed a minimum of every 8 hours in an attempt to maintain cleanliness. The reactor was monitored on a daily basis, and adjustments in pulsing cycles were made in order to minimize deposit accumulation. However, for the first 2 months, the pressure drop steadily increased. During several periods when the unit was taken off-line, the temperature of the catalyst was maintained. At 2-month intervals, a section of catalyst was removed and replaced with a new one.

For Months 2 through 4, the pressure drop was highly variable initially but was about 0.8 inches of water. From Months 4 through 6, the pressure drop was maintained between 0.6 and 0.8 inches of water. This is due to the installation of a fresh catalyst section and leaving two-thirds of the catalysts in place that were partially plugged. The gas velocity in the single section of new, clean catalyst was high because of channeling, and the result of the high gas flow was less deposition and accumulation. Gas velocity has a significant impact on the potential for deposits to form. However, at high gas velocity, low NO_x conversion is likely.

Columbia Station Data

The reactor was installed at the Columbia Station and operated for a 6-month period of time for the Babcock Hitachi catalyst. The information obtained from the testing included pressure drop information, sootblowing cycles, and reactor temperature. Table 11 shows the reactor temperature, air-pulsing cycles, and airflow rates. Figures 24–26 show the test periods from 0 to 2 months, 2 to 4 months, and 4 to 6 months, respectively. The pressure drop across the SCR upon installation was about 0.4 inches of water and increased to an average of about 0.5 inches of water, but ranged from less than 0.4 to greater than 0.8 inches of water. Figure 25

Table 11. Selected Operating Conditions of the SCR Catalysts

Plant Name	Average SCR Inlet Temp., °F	Average SCR Outlet Temp., °F	Air Pulse Frequency	Flue Gas Flow Rate, acfm
Baldwin	645	549	Once a day and on demand	393
Columbia	672	662	Once a day and on demand	385
Coyote	675	667	Once a day and on demand	385

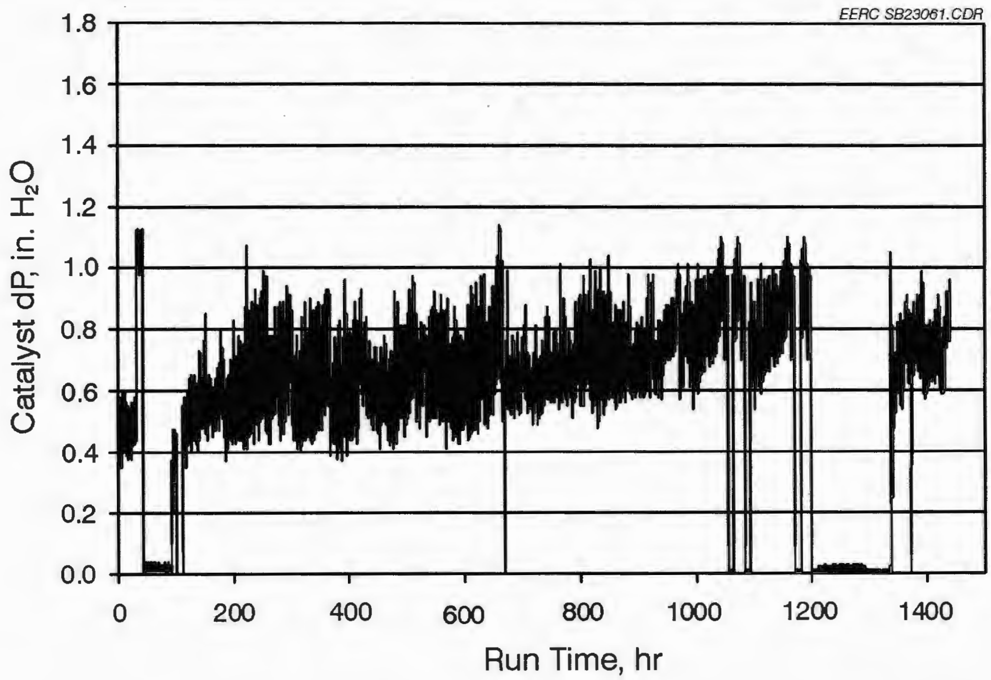

Figure 21. Catalyst pressure drop at Baldwin Station at 0 to 2 months of operation.

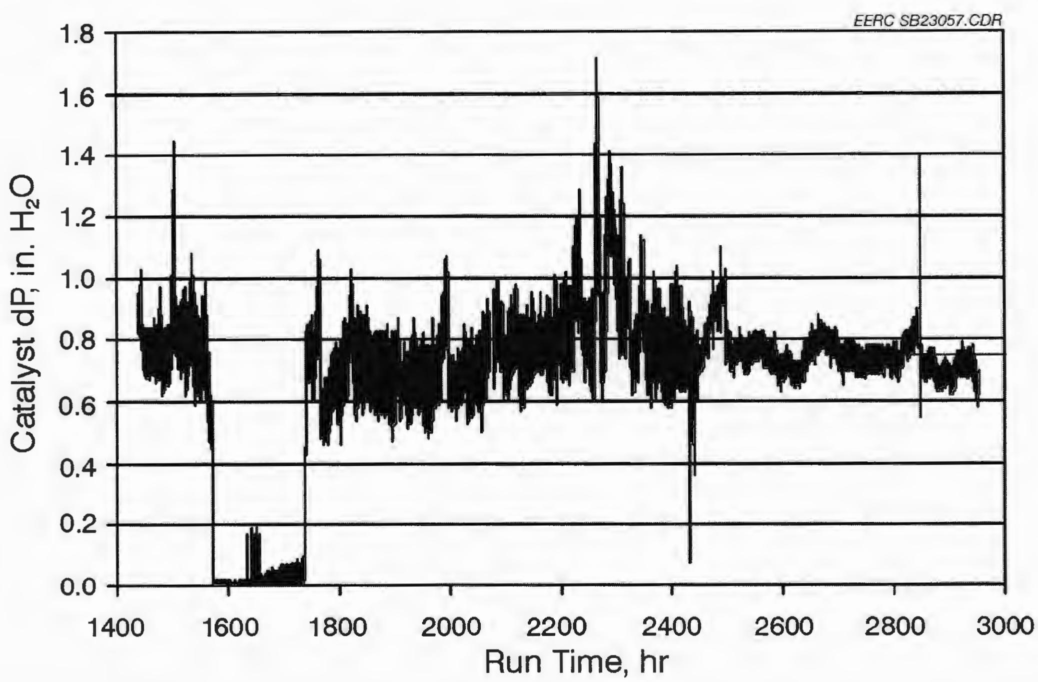

Figure 22. Catalyst pressure drop at Baldwin Station at 2 to 4 months of operation.

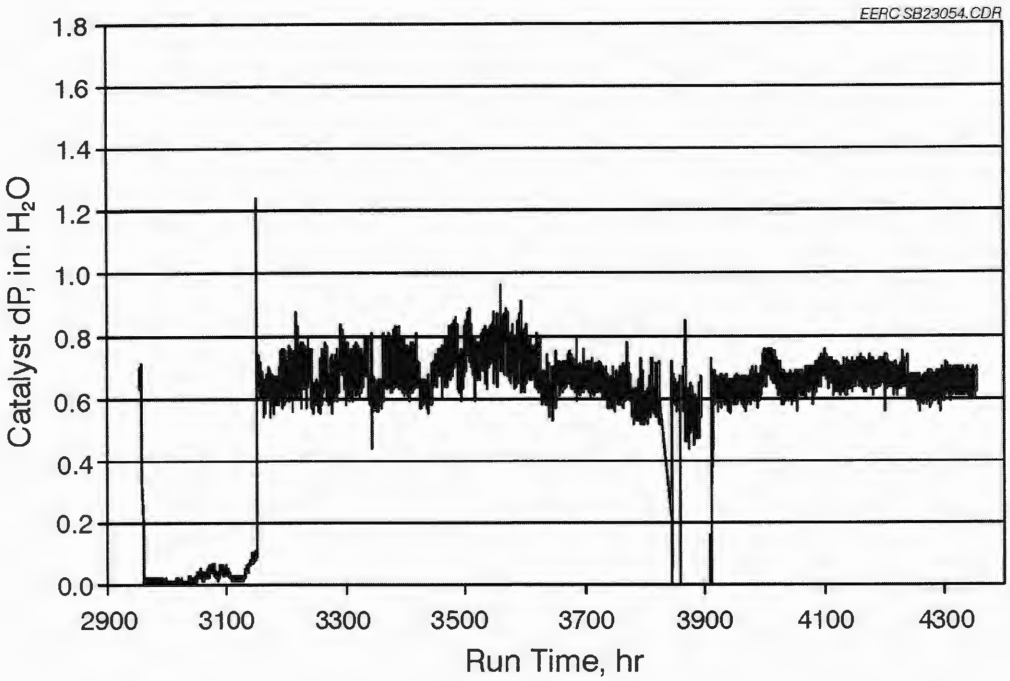

Figure 23. Catalyst pressure drop at Baldwin Station at 4 to 6 months of operation.

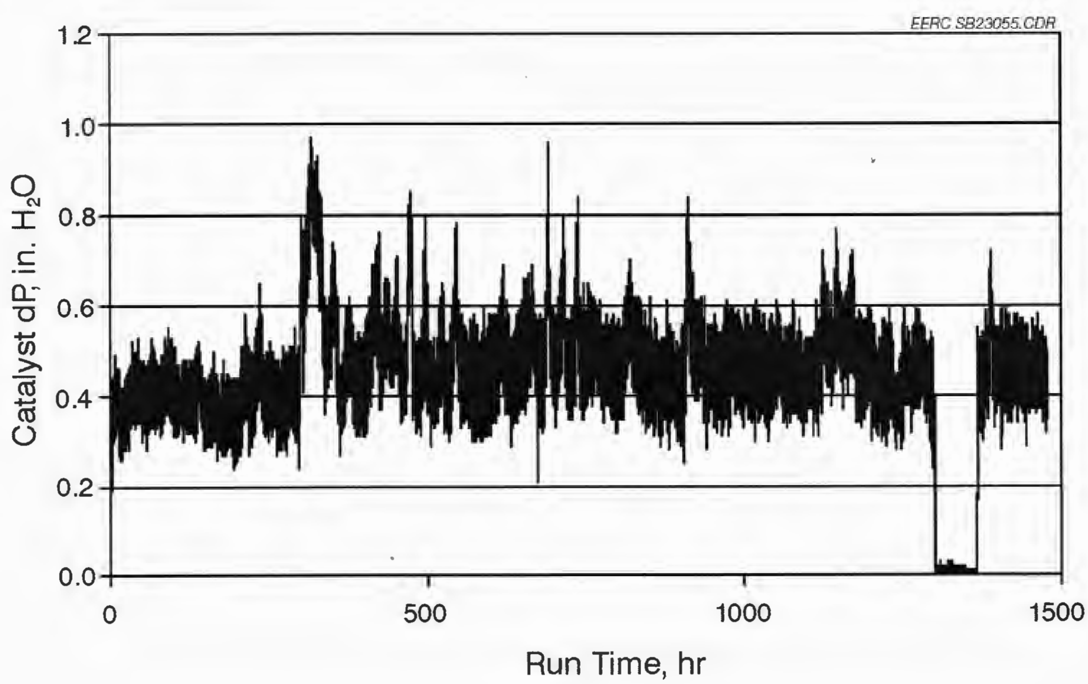

Figure 24. Catalyst pressure drop at Columbia Station at 0 to 2 months of operation.

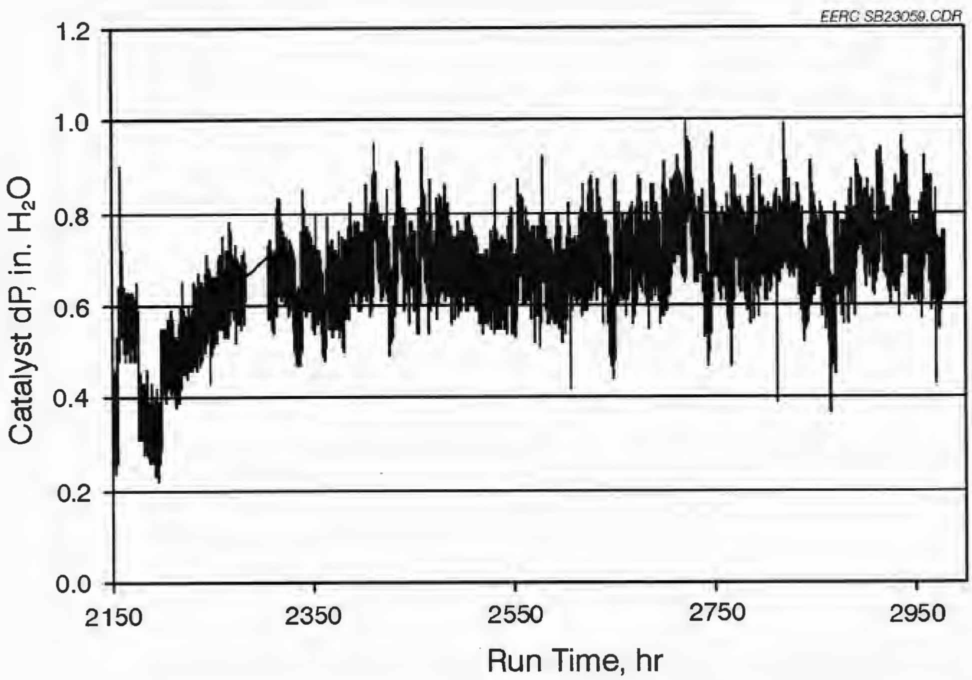

Figure 25. Catalyst pressure drop at Columbia Station at 2 to 4 months of operation.

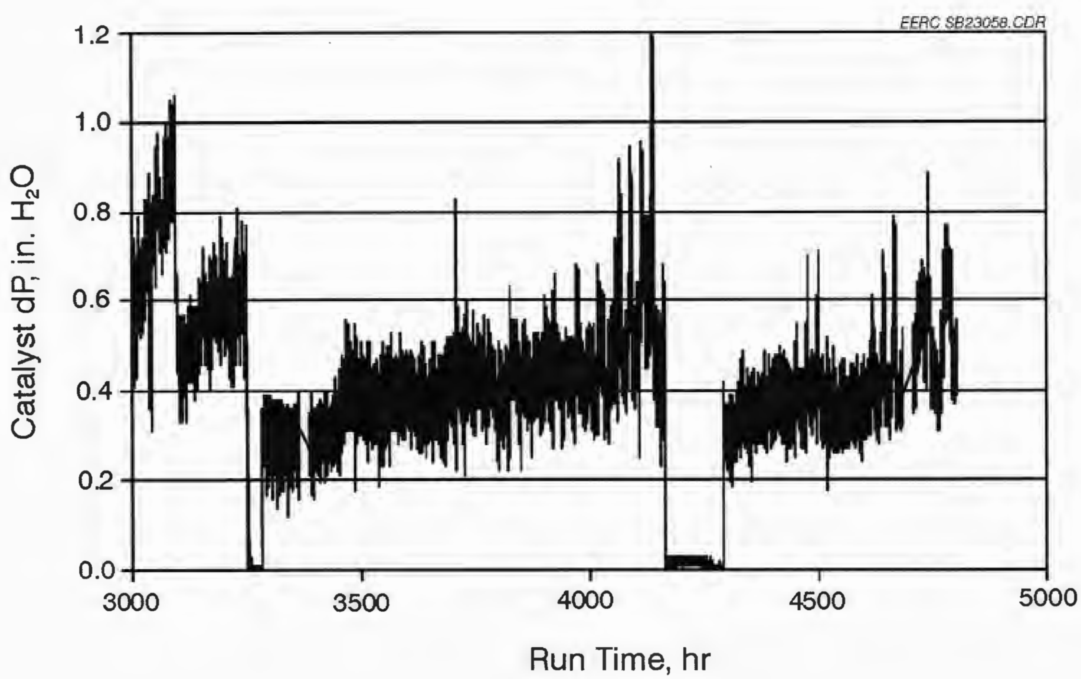

Figure 26. Catalyst pressure drop at Columbia Station at 4 to 6 months of operation.

shows the pressure drop for Months 2–4. The pressure drop increased from about 0.5–0.7 inches of water because of accumulation of ash. Figure 26 shows a rapid increase in pressure drop across the catalyst at about 3000 hours of operation, and aggressive pulsing brought it down to 0.4 inches of water until the catalyst section was changed out at about 3200 hours. After the reactor was cleaned and one catalyst section was replaced, the pressure drop was about 0.3 but increased to over 0.6 inches of water up to about 4100 hours. There was an outage at the plant, and aggressive pulsing of the reactor was conducted; the pressure drop was brought back down to 0.3 but rapidly increased to over 0.5 inches of water within 500 hours.

Coyote Station Data

The same reactor that was installed at the Baldwin Station was moved and installed at the Coyote Station. In addition, the same Haldor Topsoe catalyst formulation was used in the reactor. The cleaning cycles, temperatures, and gas flow rates are listed in Table 11. The reactor was operated for 6 months. Figures 27–29 show the test periods from 0 to 2 months, 2 to 4 months, and 4 to 6 months, respectively. The pressure drop across the catalyst upon installation was about 0.4 inches of water. After only 750 hours, the pressure drop was 1.5 inches of water, indicating significant plugging and blinding. Aggressive air pulsing was conducted, with little success in removing the deposits. The pressure drop for the catalyst was over two times greater than the pressure drop observed for the Baldwin Station utilizing the same reactor and the same catalyst. At about 1700 hours, the reactor was cleaned, and a section of catalyst was removed for characterization. The pressure drop after cleaning was 0.8–1.0 inches of water. The pressure drop did not increase as rapidly because of the higher velocities through the clean section of the catalyst. Figure 29 shows the pressure drop for 4–6 months of operation. The pressure drop

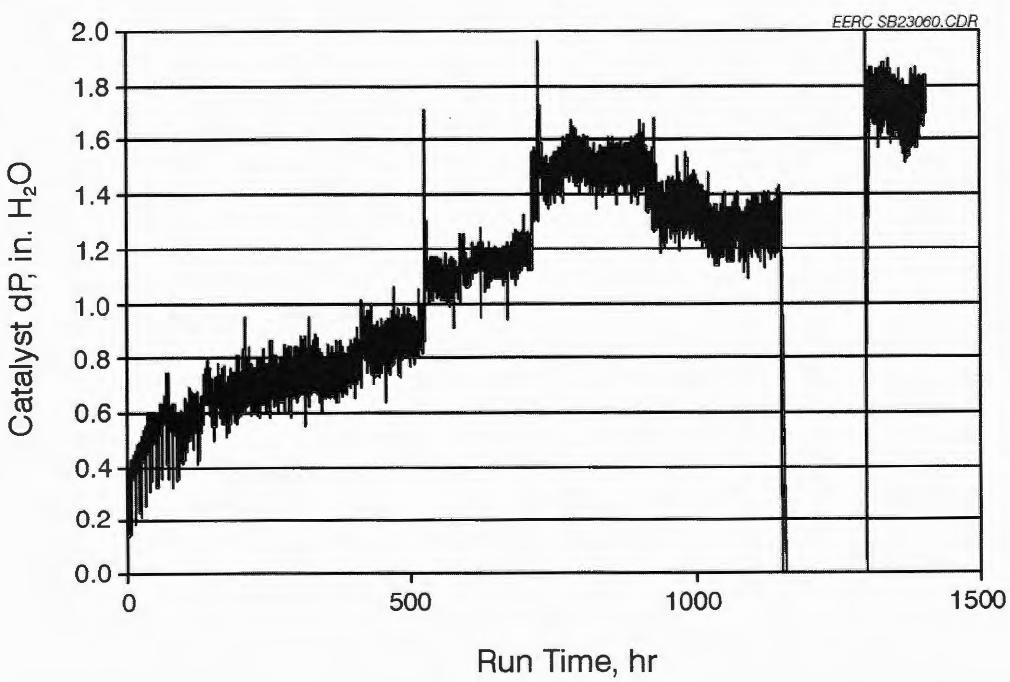

Figure 27. Catalyst pressure drop at Coyote Station at 0 to 2 months of operation.

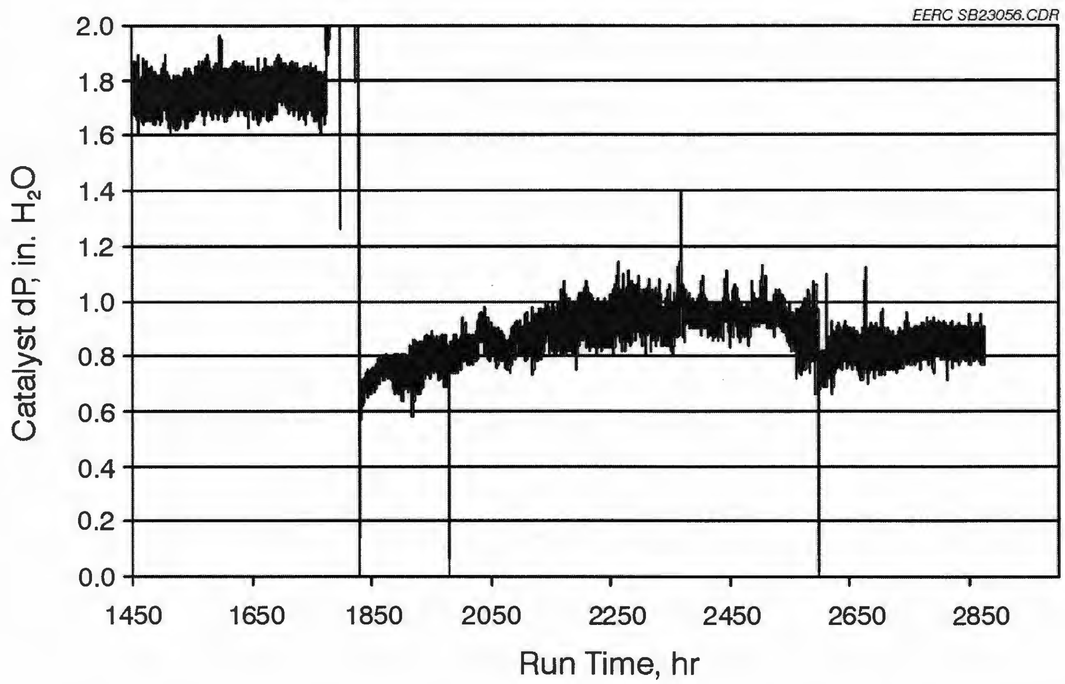

Figure 28. Catalyst pressure drop at Coyote Station at 2 to 4 months of operation.

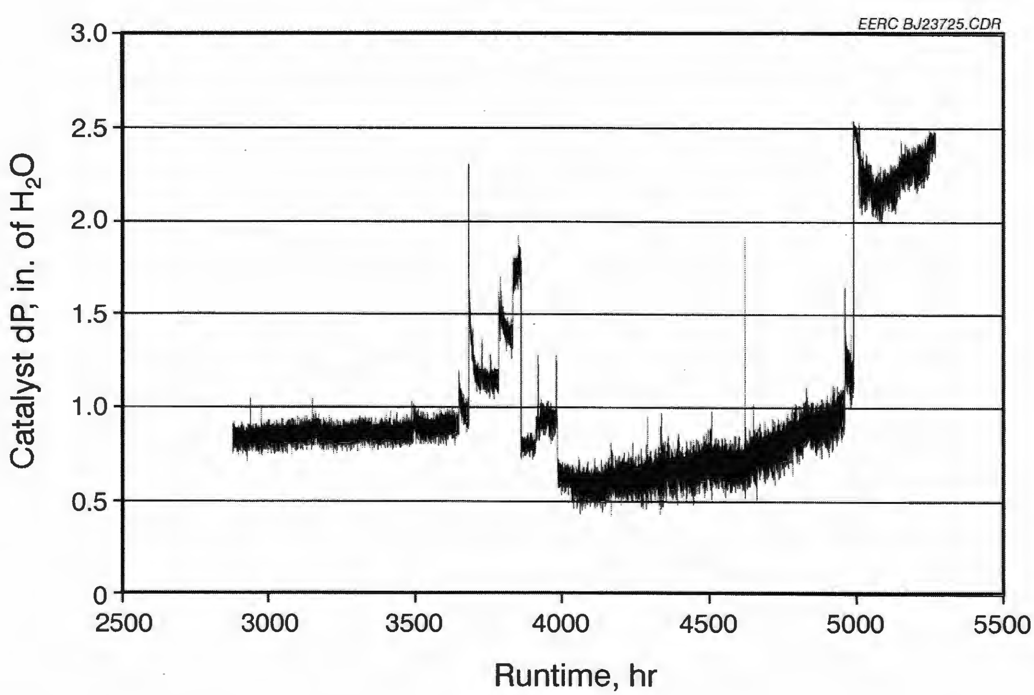

Figure 29. Catalyst pressure drop at Coyote Station at 4 to 6 months of operation.

during the last 2 months of testing was highly variable and at times reached values over 2 inches of water.

Visual Observations and Chemical Analysis

The tops of the catalysts were photographed during inspection and sampling of the catalyst sections. Figure 30 shows the ash materials that accumulated on the catalyst inlet after 2 months of operation. The most significant accumulation was noted for the Coyote Station, followed by Columbia and Baldwin. The Coyote Station had some larger pieces of ash deposit material on the surface as well as plugging of the catalyst passages. The Baldwin Station showed some obvious deposition along the walls of the reactor and some accumulation on the inlet sections. The Columbia Station showed more significant accumulation and plugging than the Baldwin Station. After 4 months, the tops of the catalysts were photographed during inspection and sampling of the catalyst sections, as shown in Figure 31. The most significant accumulation was noted for the Coyote Station and some accumulation for the Baldwin Station.

The ash materials that collected on the catalyst surfaces and pores were characterized by SEM and x-ray microanalysis, and in selected cases, XRD was used to determine the crystalline phases present. The catalysts were sampled after 2, 4, and 6 months. The sections were sampled, and approximately 2.5-cm squares were mounted for SEM analysis on double-stick tape and in epoxy resin. The double-stick tape samples allowed for characterization of the external morphology of the particles and catalyst surface. The samples mounted in resin were cross-sectioned and polished, which allowed for more detailed and quantitative analysis of the bonding materials and materials that accumulated in the pores of the catalyst. The data presented in the following section represent a small portion of the data collected by SEM analysis. The remainder of the data is available upon request.

Baldwin Station Deposits

Samples of catalyst were removed from the Baldwin Station after exposure to flue gas and particulate after 2, 4, and 6 months. Figure 32 shows the characteristics of the ash deposit material on the SCR catalyst after 2 months of exposure. This is a polished cross section of a deposit on the surface of the catalyst. Figure 32a shows particles on the surface of the catalyst that range in size from <1 to 15 μm. The larger particles range from oxides of solely silicon and iron to complex mixtures rich in aluminum and calcium; aluminum, silicon, and calcium; aluminum, calcium, and iron; and sodium, calcium, aluminum, and silicon. Chemical analysis of selected particles is summarized in Table 12. The samples of ash mounted on double-stick tape allow for the characterization of the external surfaces of the particles. The surface of a typical particle that is accumulating on the surface of the catalyst is shown in Figure 32b. The blebs on the surface are composed of calcium and sulfur, with some iron and minor amounts of sodium and potassium. Figure 32c shows a cross section of the deposited particles showing calcium- and aluminum-rich particles bonded together with a calcium- and sulfur-rich phase. This phase is in the form of calcium sulfate based on XRD analysis conducted on the deposited ash samples.

The 4-month sample from the Baldwin Station showed more extensive sulfation of the alkaline-earth elements present in the deposits. Figure 33 shows the images of a polished cross

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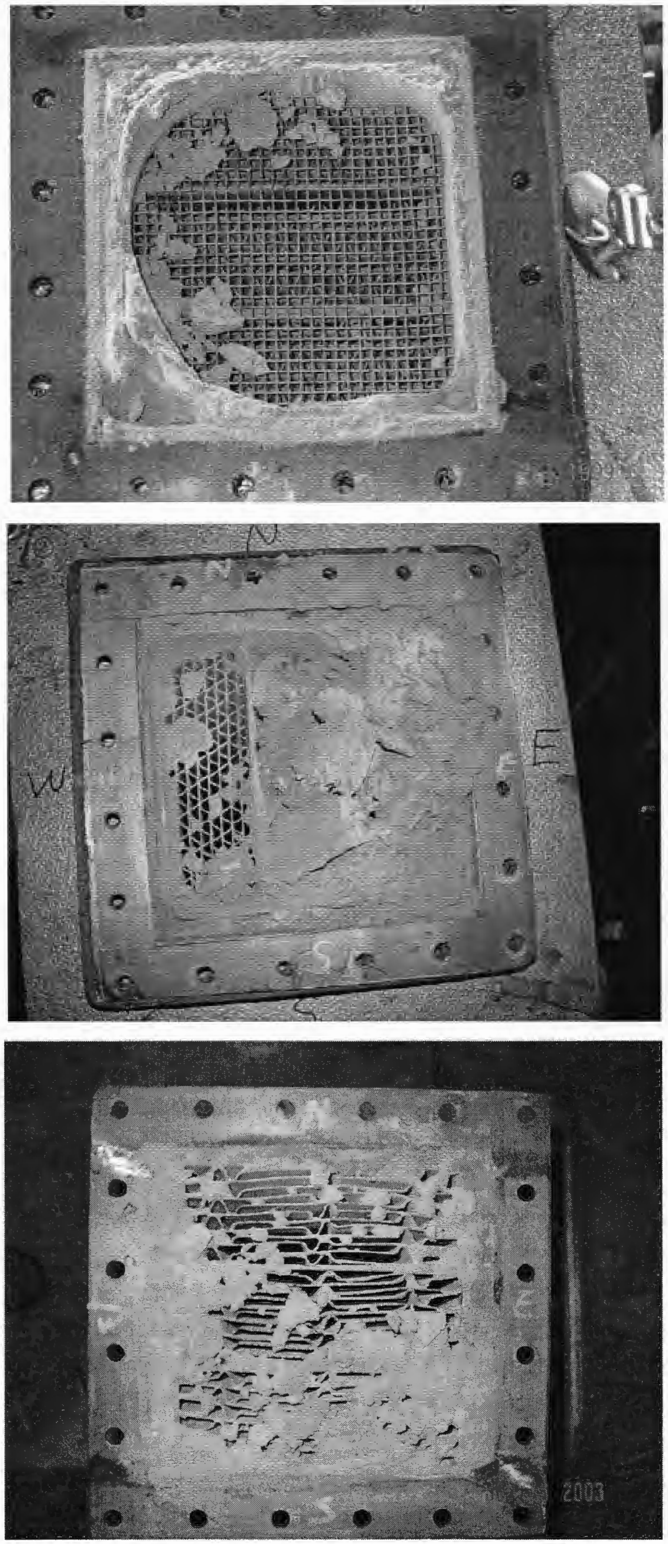
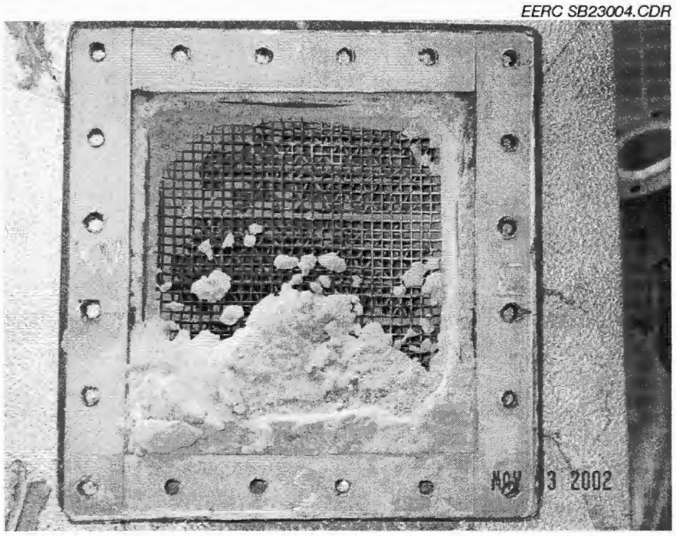


Baldwin Station after 2 months
PRB Coal

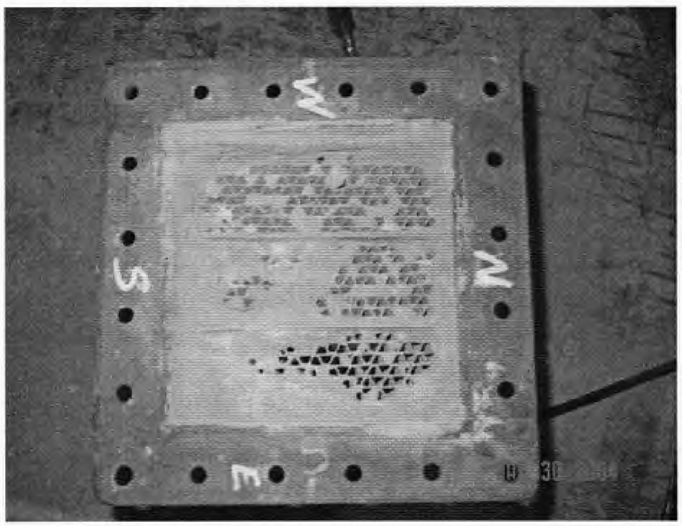
Coyote Station after 2 months
Lignite Coal

Columbia Station after 2 months
PRB Coal

Figure 30. Pictures of catalyst inlet after about 2 months of testing at each plant.



Baldwin Station after 4 months
PRB Coal

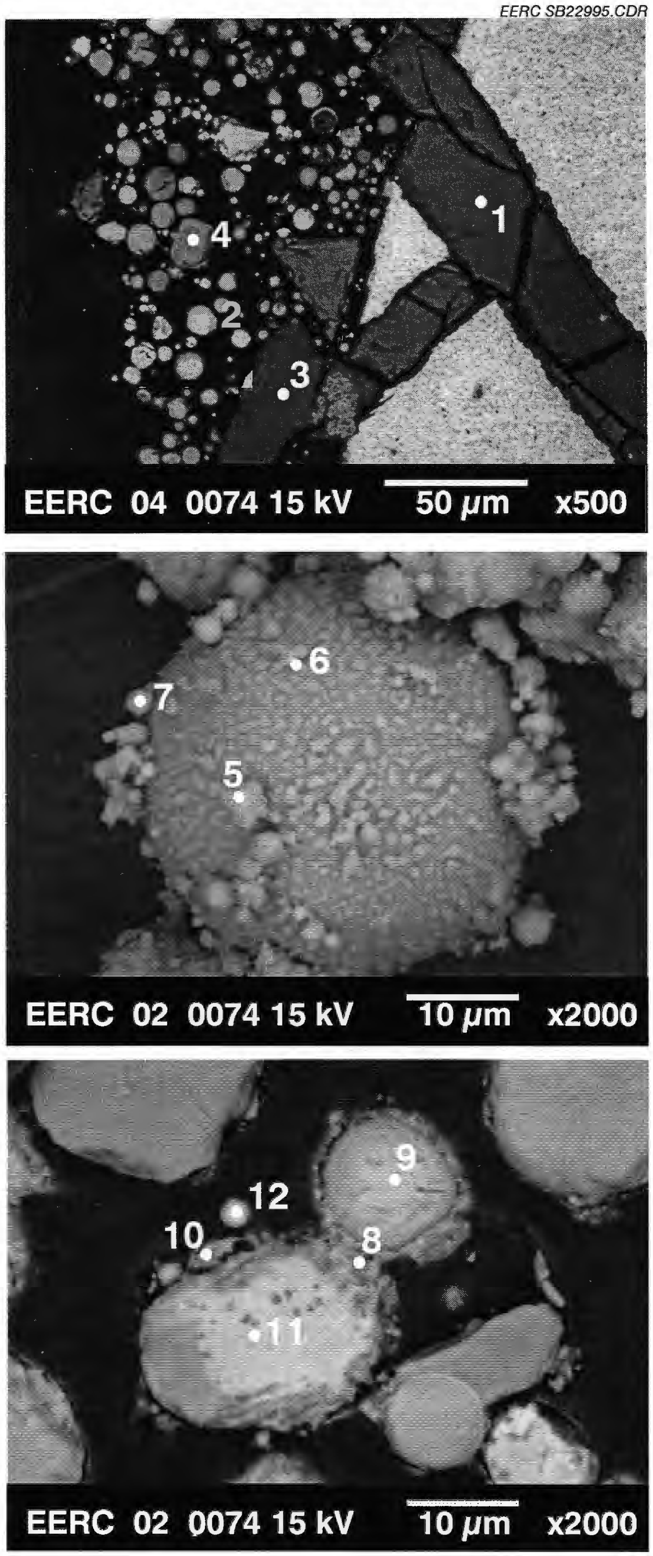


Coyote Station after 4 months
Lignite Coal

Figure 31. Pictures of catalyst inlet after about 4 months of exposure to flue gas and particulate.

section of an ash deposit on the surface of the catalyst. The deposit formed both on the surface of the catalyst and within the catalyst pores, as shown in Figure 33a. Figure 33b shows a higher-magnification view of the deposit on the catalyst surface. The deposit consists of particles of fly ash bonded together by a matrix of calcium- and sulfur-rich material, likely in the form of calcium sulfate. The chemical composition of selected points shown in Table 13 shows high levels of calcium and sulfur. There is much more extensive bonding of the materials with the sulfate matrix as compared to the 2-month sample.

The 6-month sample from the Baldwin Station showed extensive sulfation of the alkaline-earth elements present in the deposits. Figures 34a and 34b show regions of the catalyst where all the pores were blocked and a minimal amount of deposit on the surface of the catalyst. Figure 34c shows a higher-magnification view of the deposit that is filling the catalyst pore. The deposit consists of particles of fly ash bonded together by a matrix of calcium- and sulfur-rich material, likely in the form of calcium sulfate. The chemical compositions of selected points that



A

B

C

Figure 32. SEM images of ash collected on catalyst surface at the Baldwin Station after 2 months of exposure: A) low-magnification image of ash deposit on catalyst surface, B) high-magnification image of coated ash particle, and C) high-magnification image of polished cross section showing coatings on particles.

Table 12. Chemical Composition of Selected Points and Areas in Figure 32

	Element, wt%					
	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6
Oxide						
Na_2O	0.2	0.0	0.2	2.3	2.5	3.0
MgO	0.0	6.3	0.0	3.1	3.0	1.3
Al_2O_3	3.6	17.9	6.9	29.6	8.4	5.5
SiO_2	92.1	5.9	86.5	39.9	3.4	53.2
P_2O_5	0.1	0.4	0.0	0.0	1.8	0.0
SO_3	3.3	0.4	5.2	0.1	51.8	18.1
K_2O	0.0	0.0	0.0	0.6	0.4	0.5
CaO	0.0	49.4	0.1	18.6	16.4	14.6
TiO_2	0.7	4.5	0.4	1.0	0.0	0.0
Fe_2O_3	0.0	14.6	0.7	3.6	12.3	3.8
BaO	0.0	0.6	0.0	1.1	0.0	0.0
Total	100	100	100	100	100	100
	Point 7	Point 8	Point 9	Point 10	Point 11	Point 12
Oxide						
Na_2O	3.6	0.7	0.6	1.6	0.4	0.9
MgO	1.6	2.5	4.5	3.0	3.6	3.5
Al_2O_3	4.4	5.4	22.7	12.2	21.2	14.2
SiO_2	15.7	3.4	16.1	1.0	8.1	2.3
P_2O_5	1.5	0.3	0.5	2.3	0.0	4.6
SO_3	52.4	53.0	0.0	46.4	0.0	19.7
K_2O	0.7	0.2	0.0	0.1	0.0	0.0
CaO	13.0	28.8	41.5	27.1	51.1	39.2
TiO_2	0.0	0.0	0.0	0.0	0.0	0.0
Fe_2O_3	7.1	5.7	14.2	6.5	15.6	15.6
BaO	0.0	0.0	0.0	0.0	0.0	0.0
Total	100	100	100	100	100	100

indicate the presence of high levels of calcium and sulfur are listed in Table 14. There is much more extensive bonding of the materials with the sulfate matrix as compared to the 2-month sample. In addition, there are some regions of high levels of calcium, aluminum, and sulfur present. The calcium aluminum materials are likely derived from the calcium aluminum phosphate minerals found in the coal fired at this plant.

Columbia Station Deposits

The 2-month sample from the Columbia Station showed particles adhering to the surface and filling pores in the catalyst, as shown in Figure 35. Figure 35a shows the external morphology of the catalyst surface showing particles trapped in the pores of the catalysts. Chemical compositions of selected points are shown in Table 15. The 2-month sample shows significant evidence of sulfation after only 2 months of exposure. It appears to be more

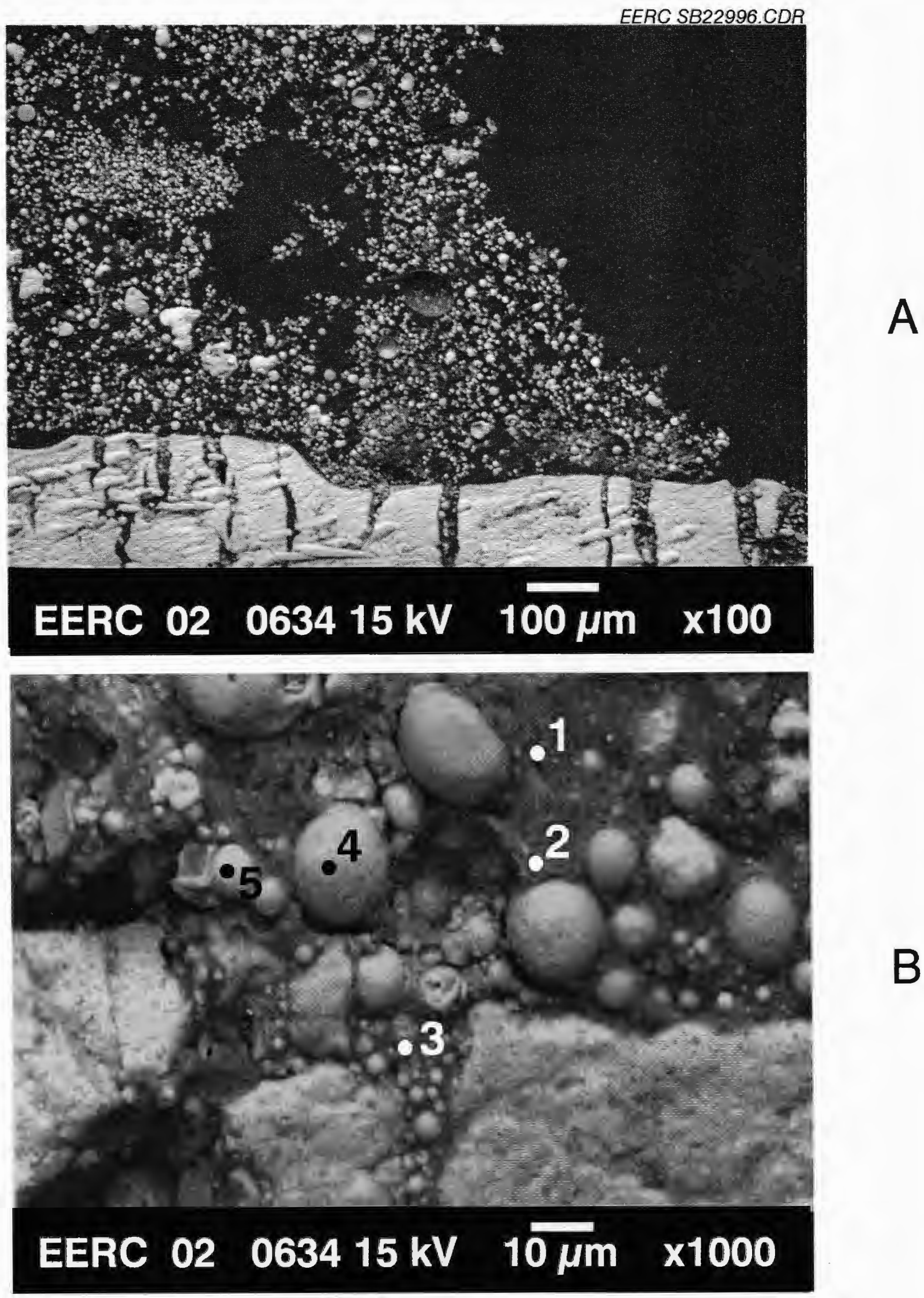


Figure 33. SEM images of ash collected on catalyst surface at the Baldwin Station after 4 months of exposure: A) low-magnification image of ash deposit on catalyst surface and B) high-magnification image of polished cross section showing particles in a matrix of calcium- and sulfur-rich materials.

Table 13. Chemical Composition of Selected Points and Areas in Figure 33

	Element, wt%				
	Point 1	Point 2	Point 3	Point 4	Point 5
Oxide					
Na_2O	1.7	2.3	0.0	0.3	1.0
MgO	5.9	3.0	1.2	1.8	3.8
Al_2O_3	3.7	2.5	3.3	5.7	6.3
SiO_2	9.7	31.5	13.3	70.0	18.5
P_2O_5	3.1	2.7	0.8	0.0	2.6
SO_3	48.1	31.0	35.8	0.0	32.1
K_2O	0.5	0.7	0.0	1.5	0.0
CaO	22.0	8.8	38.0	13.9	14.7
TiO_2	1.8	10.8	4.1	1.6	15.1
Fe_2O_3	2.1	6.6	3.4	4.2	5.9
BaO	1.4	0.0	0.0	0.9	0.0
Total	100	100	100	100	100

significant than that observed for the Baldwin 2-month sample. Figures 35b and 35c show a higher-magnification view of the deposit that is filling the catalyst pore. The deposit consists of particles of fly ash bonded together by a matrix of calcium- and sulfur-rich material, likely in the form of calcium sulfate.

The 4-month sample from the Columbia Station showed particles adhering to the surface and filling pores in the catalyst, as shown in Figure 36. Figure 36a shows the external morphology of the catalyst surface showing particles trapped in the pores of the catalysts. Chemical compositions of selected points are shown in Table 16. It appears to be more significant than that observed for the Baldwin 2-month sample. Figures 36b and 36c show a higher-magnification view of the deposit that is filling the catalyst pore. The deposit consists of particles of fly ash bonded together by a matrix of calcium- and sulfur-rich material, likely in the form of calcium sulfate.

The 6-month sample from the Columbia Station showed particles adhering to the surface and filling pores in the catalyst, as shown in Figure 37. Figure 37a shows the external morphology of the catalyst surface showing particles trapped in the pores of the catalysts. Chemical compositions of selected points are shown in Table 17. Figures 37b and 37c show a higher-magnification view of the deposit that is filling the catalyst pore. The deposit consists of particles of fly ash bonded together by a matrix of calcium- and sulfur-rich material, likely in the form of calcium sulfate. The 6-month samples show the most extensive degree of sulfation of the Columbia Station samples.

Coyote Station Deposits

The 2-month sample from the Coyote Station showed particles adhering to the surface and filling pores in the catalyst, as shown in Figure 38. Figure 38a shows the external morphology of the catalyst surface showing particles trapped in the pores of the catalysts. Chemical

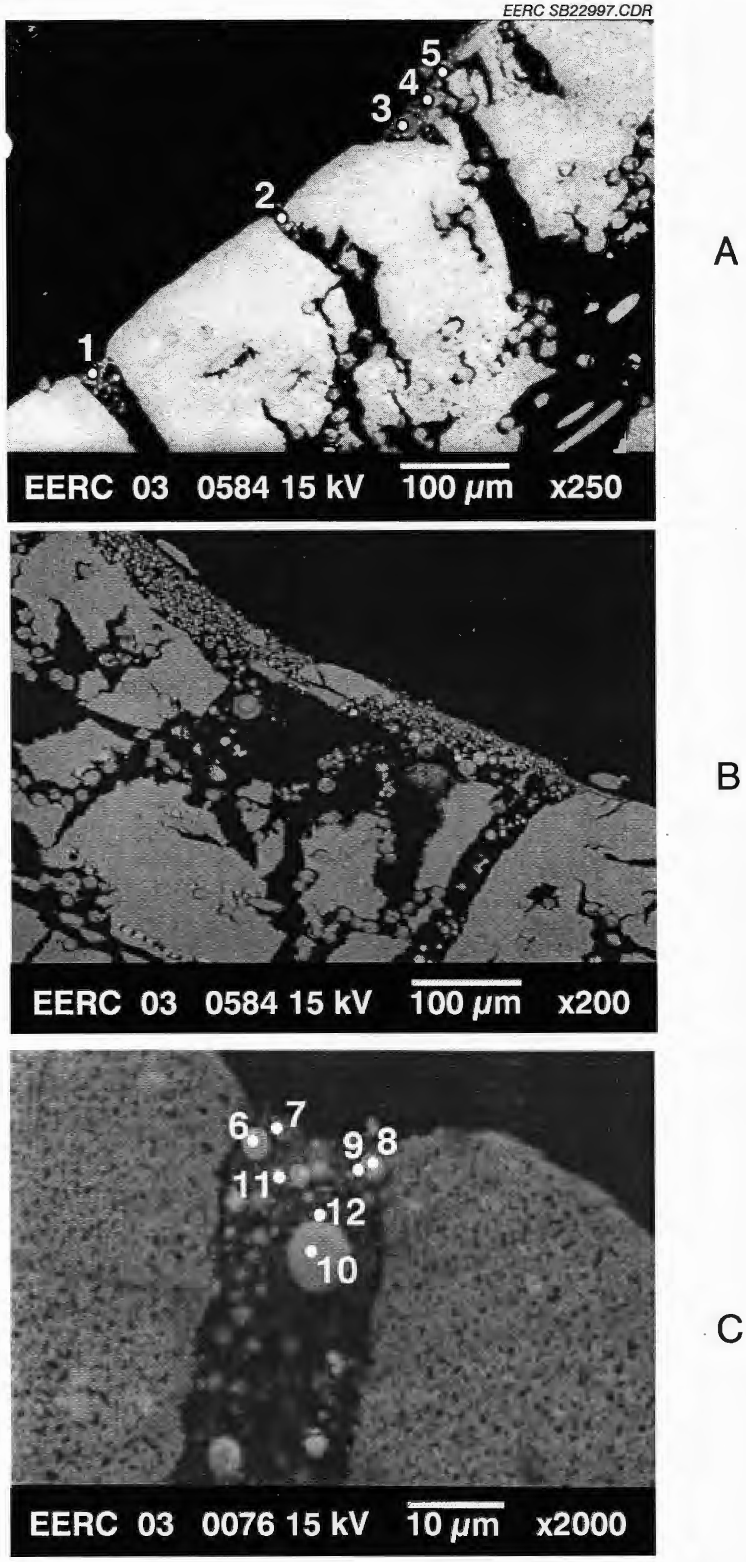


Figure 34. SEM images of ash collected on catalyst surface at the Baldwin Station after 6 months of exposure: A) low-magnification image of ash deposit on catalyst surface, and C) high-magnification image of polished cross section showing particles in a matrix of calcium- and sulfur-rich materials.

Table 14. Chemical Composition of Selected Points and Areas in Figure 34

	Element, wt%					
	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6
Oxide						
Na_2O	0.6	1.0	2.1	0.3	0.5	2.7
MgO	4.3	2.5	6.3	0.7	1.6	7.6
Al_2O_3	14.8	16.0	15.6	15.5	14.7	0.9
SiO_2	3.3	7.8	18.8	57.7	7.7	47.3
P_2O_5	2.3	2.1	0.5	0.6	1.8	0.0
SO_3	30.7	20.4	17.7	0.0	29.0	0.8
K_2O	0.7	0.0	1.0	0.4	0.9	0.9
CaO	28.8	28.7	28.1	22.5	34.9	28.4
TiO_2	2.0	7.2	2.2	0.3	1.3	1.1
Fe_2O_3	11.4	12.9	6.2	0.0	7.6	7.9
BaO	1.1	1.4	1.4	2.0	0.0	2.5
Total	100	100	100	100	100	100
	Point 7	Point 8	Point 9	Point 10	Point 11	Point 12
Oxide						
Na_2O	1.7	0.4	0.5	2.2	1.3	1.7
MgO	4.5	6.4	5.9	5.0	3.4	6.4
Al_2O_3	5.0	2.4	3.0	19.2	10.8	3.8
SiO_2	8.4	18.4	18.5	31.0	17.9	16.7
P_2O_5	1.8	0.9	1.0	0.0	1.7	1.2
SO_3	37.9	1.7	5.3	0.0	22.5	13.9
K_2O	0.4	0.0	0.0	0.9	0.8	0.0
CaO	31.4	52.6	49.0	28.9	30.6	45.4
TiO_2	1.9	6.9	7.4	2.4	2.0	1.1
Fe_2O_3	7.1	5.7	6.0	6.3	6.1	6.5
BaO	0.0	4.6	3.5	4.2	2.9	3.3
Total	100	100	100	100	100	100

compositions of selected points are shown in Table 18. The 2-month sample shows significant evidence of sulfation after only 2 months of exposure and was much more pronounced than the 2-month samples for the Baldwin and Columbia Stations that are fired on PRB coals. Figures 38b and 38c show a higher-magnification view of the deposit that is filling the catalyst pores. The deposit consists of particles of fly ash bonded together by a matrix of calcium- and sulfur-rich material, likely in the form of calcium sulfate. The presence of sodium enhances the bonding and sulfation of the particles to form a strongly bonded matrix.

The 4-month sample from the Coyote Station showed particles adhering to the surface and completely filling and masking the pores in the catalyst as shown in Figure 39. Figure 39a shows the external morphology of the catalyst surface showing the masking of the catalyst surface. Chemical compositions of selected points are shown in Table 19. The 4-month sample shows more sulfation than the 2 months of exposure samples. Figures 39b and 39c show a higher-magnification view of the deposit that is filling the catalyst pores. The deposit consists of

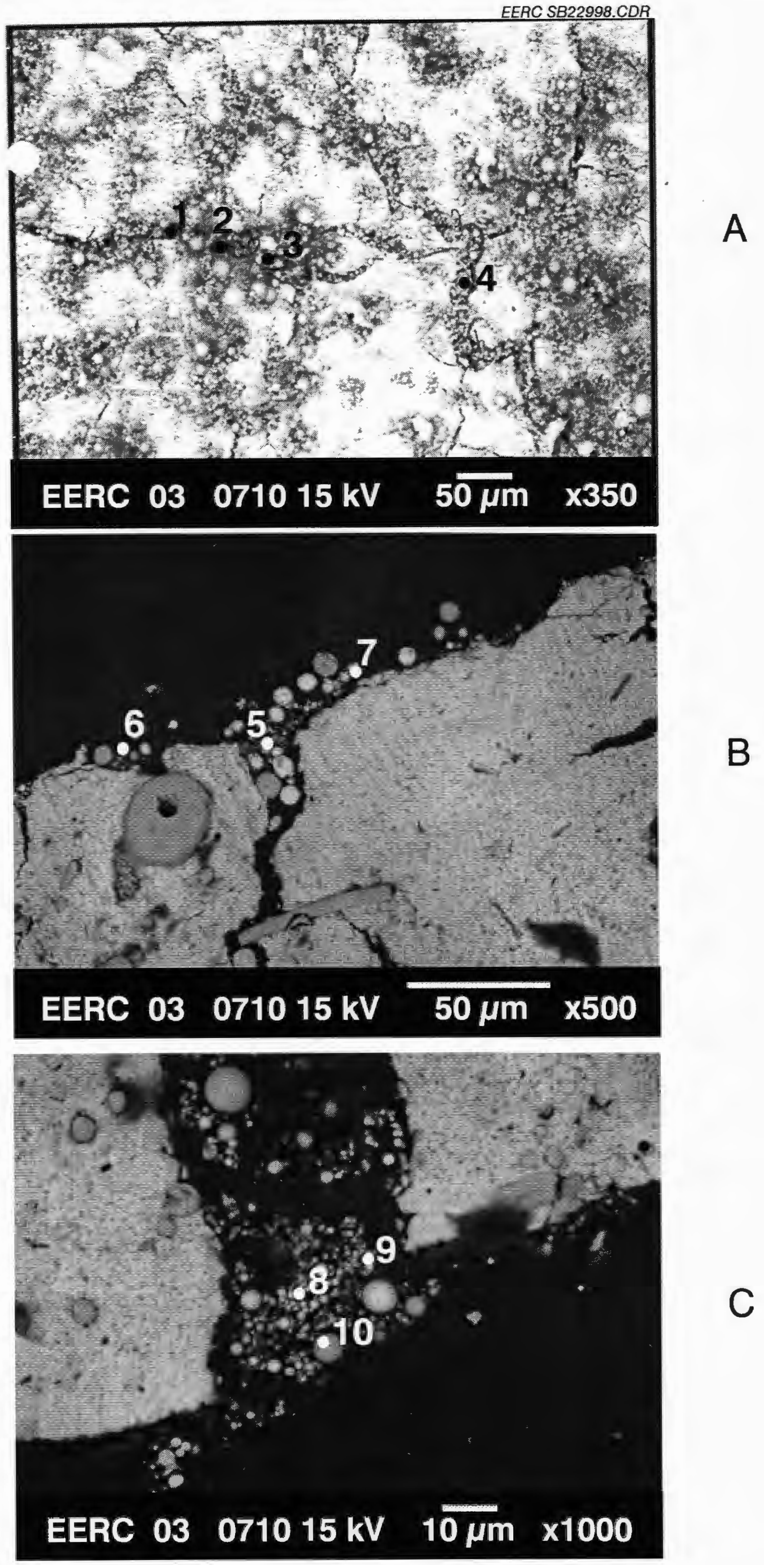


Figure 35. SEM images of ash collected on catalyst surface at the Columbia Station after 2 months of exposure: A) low-magnification image of ash deposit on catalyst surface, B) low-magnification image of polished cross section showing particles in a matrix of calcium- and sulfur-rich materials, and C) higher-magnification image of bonding.

Table 15. Chemical Composition of Selected Points and Areas in Figure 35

	Element, wt%				
	Point 1	Point 2	Point 3	Point 4	Point 5
Oxide					
Na_2O	0.0	0.9	1.3	0.1	0.3
MgO	0.7	1.5	3.2	3.9	0.9
Al_2O_3	12.2	17.6	20.9	12.2	5.9
SiO_2	10.8	4.1	23.3	7.3	6.3
P_2O_5	0.9	0.1	0.0	1.4	2.6
SO_3	15.2	17.6	16.8	17.1	32.3
K_2O	0.2	0.0	0.5	0.0	0.1
CaO	14.1	43.1	25.0	42.0	34.9
TiO_2	44.8	2.8	1.1	10.5	5.2
Fe_2O_3	1.1	12.3	3.9	5.5	11.5
BaO	0.0	0.0	4.2	0.0	0.0
Total	100	100	100	100	100
	Point 6	Point 7	Point 8	Point 9	Point 10
Oxide					
Na_2O	0.0	0.6	1.0	0.5	1.8
MgO	0.0	1.5	2.9	1.4	0.7
Al_2O_3	5.5	12.4	13.6	9.0	20.7
SiO_2	9.4	6.1	15.4	7.9	61.8
P_2O_5	1.2	0.6	1.7	3.1	0.2
SO_3	33.3	22.0	19.5	30.7	0.0
K_2O	0.0	0.0	0.1	0.2	2.5
CaO	44.1	48.5	34.1	38.3	4.4
TiO_2	0.5	4.4	2.4	2.6	2.2
Fe_2O_3	3.1	2.3	6.0	6.3	4.4
BaO	2.8	1.6	3.3	0.0	1.3
Total	100	100	100	100	100

particles of fly ash bonded together by a matrix of sodium-, calcium-, and sulfur-rich material, likely in the form of calcium sulfate. The presence of sodium and potassium enhances the bonding and sulfation of the particles to form a strongly bonded matrix. Significant sodium was found in the deposits, as shown in Table 19.

The 6-month sample from the Coyote Station showed particles adhering to the surface and filling pores in the catalyst, as shown in Figure 40. Figure 40a shows the external morphology of the catalyst surface showing particles trapped in the pores of the catalysts. Chemical compositions of selected points are shown in Table 20. Figures 40b and 40c show a higher-magnification view of the deposit that is filling the catalyst pore. The deposit consists of particles of fly ash bonded together by a matrix of sodium-, calcium- and sulfur-rich material, likely in the form of sulfate. The 6-month samples show the most extensive degree of sulfation of the Coyote Station samples.

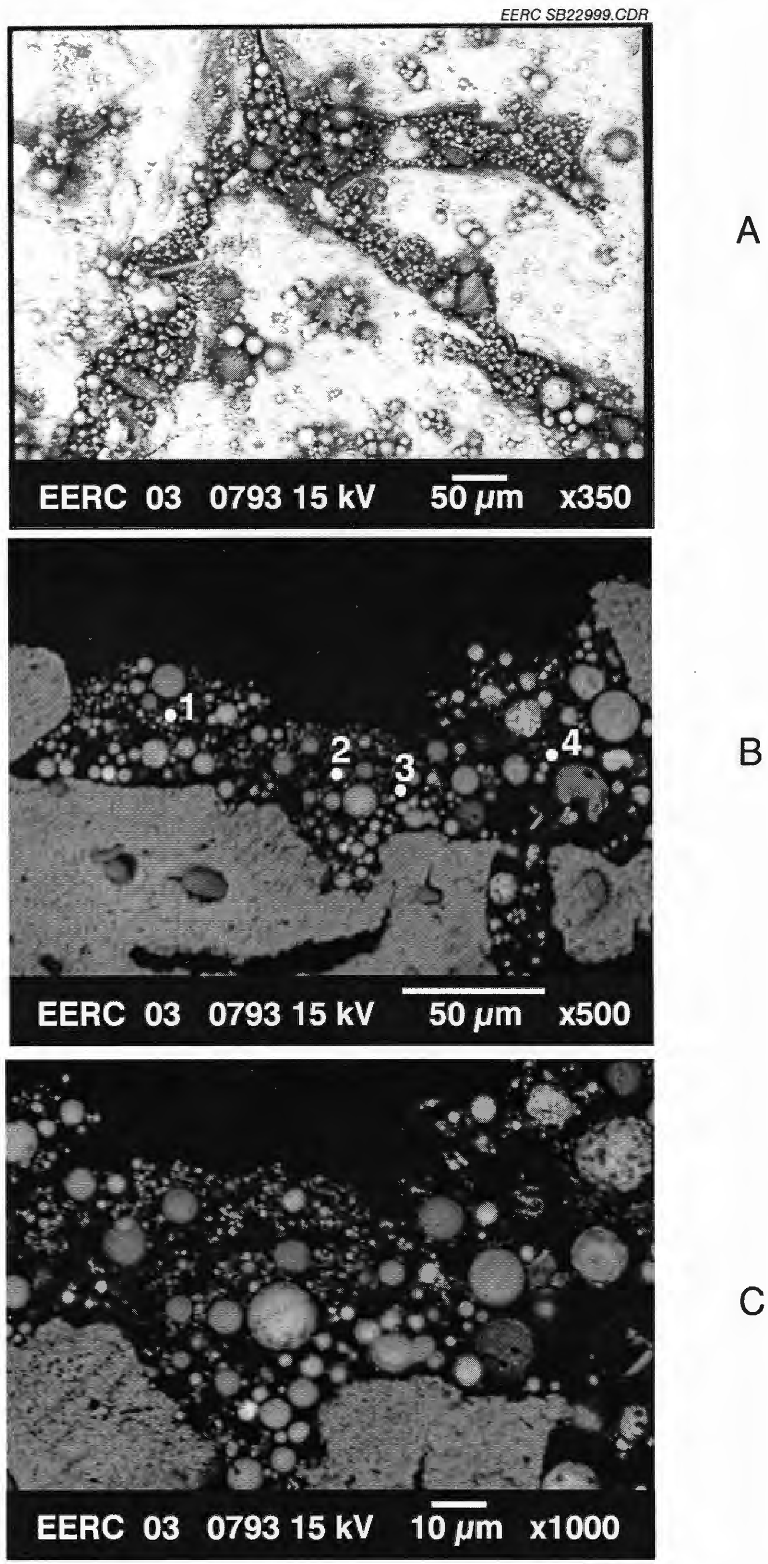


Figure 36. SEM images of ash collected on catalyst surface at the Columbia Station after 4 months of exposure: A) low-magnification image of ash deposit on catalyst surface, B) low-magnification image of polished cross section showing particles in a matrix of calcium- and sulfur-rich materials, and C) higher-magnification image of bonding.

Table 16. Chemical Composition of Selected Points and Areas in Figure 36

	Element, wt%			
	Point 1	Point 2	Point 3	Point 4
Oxide				
Na_2O	0.5	0.0	0.6	0.3
MgO	3.3	1.9	3.2	2.4
Al_2O_3	13.1	10.2	13.0	6.3
SiO_2	12.4	8.4	8.4	3.6
P_2O_5	1.3	0.5	2.1	0.6
SO_3	27.7	29.9	32.2	47.4
K_2O	0.2	0.6	0.1	0.8
CaO	32.1	38.1	28.9	33.2
TiO_2	1.0	2.7	1.3	0.0
Fe_2O_3	6.3	6.3	7.6	2.6
BaO	2.0	1.4	2.5	2.6
Total	100	100	100	100

Reactivity Testing

Samples of the catalyst from 2, 4, and 6 months of operations were submitted to the appropriate catalyst vendor for reactivity testing. The results of only the samples from the Baldwin installation are available at the time of this report. An addendum to this report will be sent when the results from Coyote and Columbia are made available to the EERC.

Table 21 contains the results of the reactivity analysis on the 2-, 4-, and 6-month samples from the Baldwin Station. After 2 months of operation, the catalyst had no noticeable loss of reactivity when compared to the reference catalyst. After 4 months, the reactivity was 96% of the reference, and after 6 months, the reactivity had dropped to 84% of the reference catalyst.

Task 5 – Determination of SCR Blinding Mechanisms

The mechanism for the formation of deposits that blind SCR catalysts involves the transport of very small particles rich in alkali and alkaline-earth elements, the surface of the catalyst, and reactions with SO_2/SO_3 to form sulfates. The formation of SO_3 from SO_2 is catalyzed by the SCR; this, in turn, increases the reaction rate of SO_3 to form sulfates. In some cases, the alkali and alkaline-earth elements will also react with CO_2 to form carbonates. XRD analysis shown in Figure 41 identified $CaSO_4$ as a major phase and $Ca_3Mg(SiO_4)_2$ and $CaCO_3$ as minor phases.

Lignite and subbituminous coals contain high levels of organically associated alkali and alkaline-earth elements, including sodium, magnesium, calcium, and potassium, in addition to mineral phases. The primary minerals present in these coals include quartz, clay minerals, carbonates, sulfates, sulfides, and phosphorus-containing minerals (18).

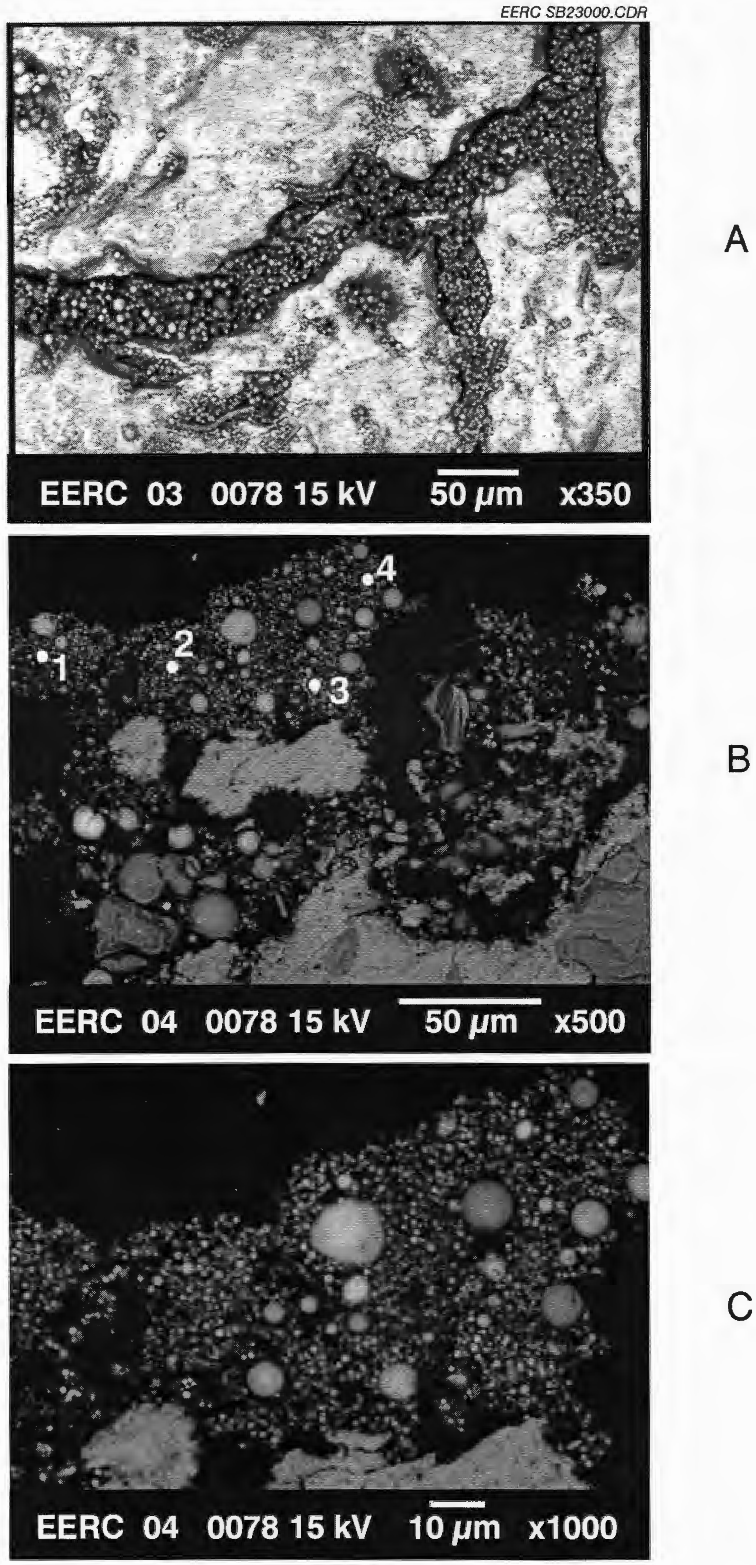


Figure 37. SEM images of ash collected on catalyst surface at the Columbia Station after 6 months of exposure: A) low-magnification image of ash deposit on catalyst surface, B) low-magnification image of polished cross section showing particles in a matrix of calcium- and sulfur-rich materials, and C) higher-magnification image of bonding.

Table 17. Chemical Composition of Selected Points and Areas in Figure 37

	Element, wt%			
	Point 1	Point 2	Point 3	Point 4
Oxide				
Na_2O	0.1	0.0	0.3	0.6
MgO	1.8	0.7	1.7	2.2
Al_2O_3	10.9	9.6	6.2	11.3
SiO_2	13.1	11.3	12.4	19.5
P_2O_5	3.9	4.8	0.2	2.1
SO_3	27.6	34.0	35.5	30.0
K_2O	0.5	0.3	0.1	1.2
CaO	33.0	25.9	39.8	25.8
TiO_2	0.8	2.5	1.6	3.3
Fe_2O_3	6.1	9.7	1.9	2.9
BaO	2.1	1.2	0.0	1.1
Total	100.00	100.00	100.00	100.00

During combustion, the inorganic components in the coal are partitioned into various size fractions based on the type of inorganic component, their association in the coal, and combustion system design and operating conditions. Significant research has been conducted on ash formation mechanisms and relationships and their resulting impacts on power plant performance (18–34). Typically, during combustion the inorganic components associated with western subbituminous and lignite coal are distributed into various size fractions of ash, as shown in Figure 42. The results shown in Figure 42 were obtained from isokinetic sampling, aerodynamically size-fractionating ash particles from a full-scale pc-fired boiler firing subbituminous coal, and analyzing each size fraction. The results show that the smaller-sized fractions of ash are dominated by partially sulfated alkali and alkaline-earth elements. These ash particles are largely derived from the organically associated cations in the coal. The larger-sized fraction has higher levels of aluminum and silicon derived from the mineral fraction of the ash-forming component of the coal.

Entrained ash was extracted from the Columbia Station at the point of the inlet to the SCR reactor and was aerodynamically classified and analyzed. The composition of the size fractions was compared to the chemical composition of the ash deposited on and in the catalyst, as shown in Figure 43. The comparison shows that the composition of the particle captured in the SCR catalyst is very similar to the $<5\text{-}\mu m$ size fraction. The deposited material shows significantly more sulfation than the entrained-ash size fraction, indicating that the sulfation process occurs after the particles are deposited in the catalyst.

The mechanism of SCR catalyst blinding when lignite or subbituminous coals are fired is shown in Figure 44 (35). The requirements for the formation of deposits that blind SCR catalyst include firing a coal that produces significant levels of $<5\text{-}\mu m$-sized particles. The particles are transported into the pores of the catalyst and subsequently react with SO_3 to form sulfates. The sulfate forms a matrix that bonds other ash particles. The SCR catalyzes the formation of SO_3 and thereby increases the rate of sulfation (9, 15). The sulfation of CaO increases the molar

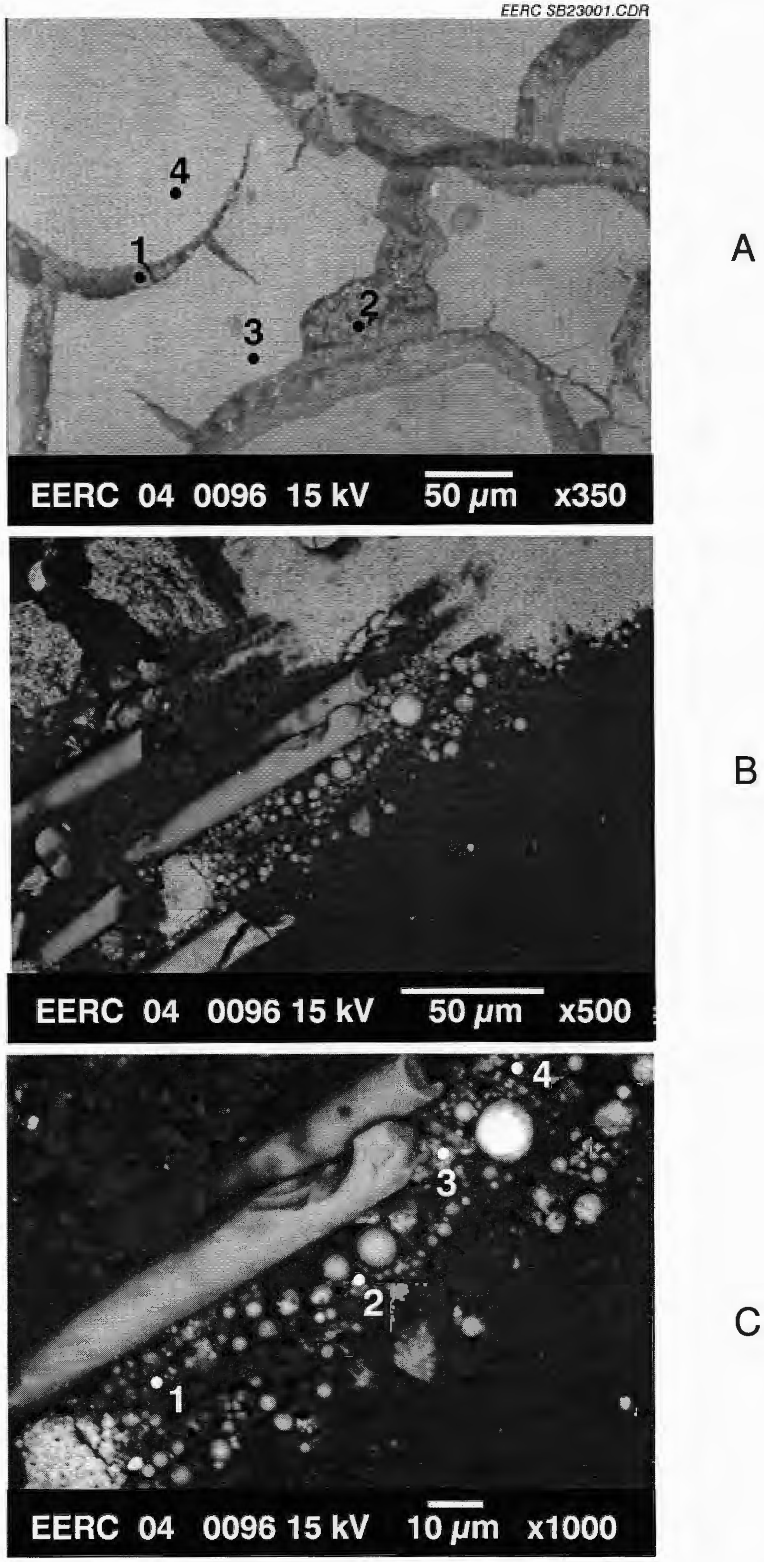


Figure 38. SEM images of ash collected on catalyst surface at the Coyote Station after 2 months of exposure: A) low-magnification image of ash deposit on catalyst surface, B) low-magnification image of polished cross section showing particles in a matrix of calcium- and sulfur-rich materials, and C) higher-magnification image of bonding.

Table 18. Chemical Composition of Selected Points and Areas in Figure 38c

	Point 1	Point 2	Point 3	Point 4
Oxide				
Na_2O	0.9	0.7	1.2	1.0
MgO	5.0	1.6	5.6	1.7
Al_2O_3	12.3	5.8	11.9	5.5
SiO_2	24.6	3.1	21.1	2.6
P_2O_5	0.7	0.0	0.5	0.0
SO_3	23.5	44.0	17.4	31.8
K_2O	0.5	0.3	0.8	0.4
CaO	14.9	36.4	19.6	46.9
TiO_2	7.2	1.9	8.0	2.1
Fe_2O_3	9.2	5.5	11.8	6.9
BaO	1.3	0.7	2.1	1.1
Total	100	100	100	100

volume, resulting in the filling of the pore. For coals that have high sodium contents, formation of low melting point phases such as pyrosulfates are possible (36). Pyrosulfate materials can melt at temperatures as low as 279°C (535°F) in coal-fired power systems.

Add-On Task – Characterization of Mercury Transformations Across SCR Catalysts for a Lignite Coal-Fired Boiler

The ability of mercury to be oxidized across the SCR catalyst was investigated at the Coyote Station. The Coyote Station is fired on North Dakota lignite, and the flue gas is dominated by elemental mercury. Measurement of mercury speciation was conducted using the OH method at the inlet and the outlet of the SCR catalyst. The measurements were made upon installation of the catalyst and after 2 and 4 months of operation. The results of the mercury speciation measurement at the inlet and outlet of the SCR catalyst conducted upon installation are shown in Figure 45. The inlet and outlet measurements were repeated three times and are shown in Figure 45. The level of elemental mercury at the inlet was approximately 76% to 92%, with the remaining in the oxidized form ranging from 8% to 24%. Very little was in the form of particulate mercury at the inlet. Measurement of mercury speciation was conducted with the NH_3 on and off. The results with the NH_3 off showed an increase in the oxidized mercury to 43% of the total mercury occurring across the SCR catalyst. However, when the NH_3 was introduced into the SCR catalyst, the amount of mercury oxidation decreased from 43% to 19%. There was an increase in the particulate mercury from 1.0% to 7.2%.

The mercury oxidation after the SCR catalyst was exposed to flue gas and particulate for 2 months is shown in Figure 46. The level of oxidized mercury at the inlet ranges from 7.5% to 11.1% of the total mercury. The level of oxidized mercury at the outlet ranged from 7.6% to 14% of the total mercury. The level of particulate mercury increased from a negligible level to 3% of the total mercury at the outlet.

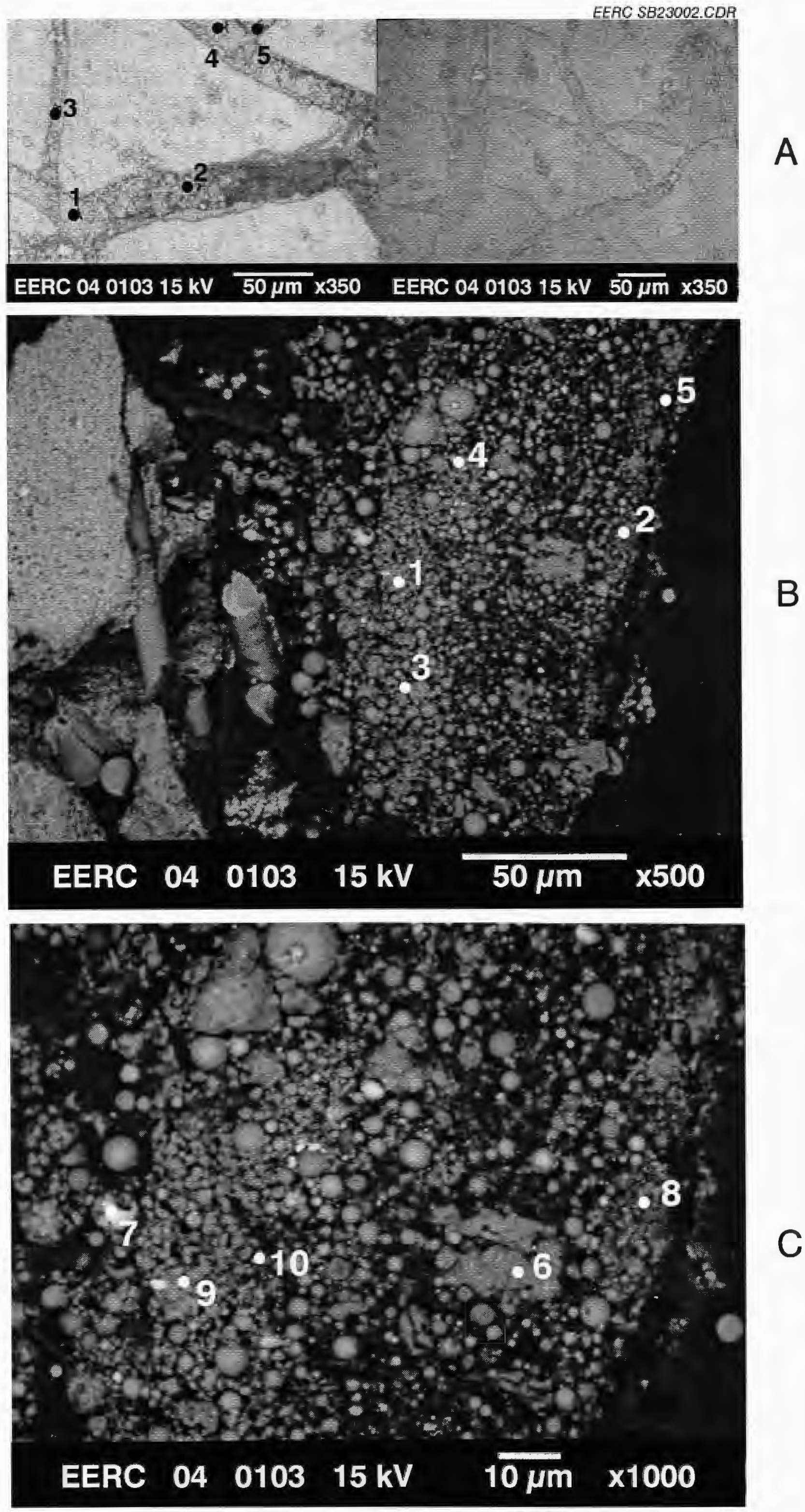


Figure 39. SEM images of ash collected on catalyst surface at the Coyote Station after 4 months of exposure: A) low-magnification image of ash deposit on catalyst surface, B) low-magnification image of polished cross section showing particles in a matrix of calcium- and sulfur-rich materials, and C) higher-magnification image of bonding.

Table 19. Chemical Composition of Selected Points and Areas in Figure 39b and 39c

	Element, wt%				
	Point 1	Point 2	Point 3	Point 4	Point 5
Oxide					
Na_2O	6.7	1.9	7.1	6.2	3.1
MgO	1.1	1.7	1.1	2.6	3.2
Al_2O_3	2.6	8.8	4.0	4.8	10.5
SiO_2	7.0	21.1	11.3	5.6	32.2
P_2O_5	0.2	2.4	0.0	0.2	0.9
SO_3	54.7	38.5	56.4	57.5	30.4
K_2O	2.0	2.8	0.7	2.8	2.4
CaO	18.0	3.4	15.8	9.3	2.3
TiO_2	0.6	0.8	1.1	1.3	1.5
Fe_2O_3	5.8	5.1	2.1	6.5	9.8
BaO	1.4	13.5	0.5	3.4	3.6
Total	100	100	100	100	100
	Point 6	Point 7	Point 8	Point 9	Point 10
Oxide					
Na_2O	9.5	2.6	10.4	8.9	4.4
MgO	1.2	1.9	1.3	3.0	3.7
Al_2O_3	2.6	8.6	4.2	4.9	10.6
SiO_2	6.3	18.2	10.5	5.0	28.9
P_2O_5	0.1	1.9	0.0	0.1	0.7
SO_3	41.8	28.4	44.9	44.5	23.4
K_2O	3.2	4.3	1.2	4.4	3.8
CaO	24.5	4.4	22.5	12.8	3.1
TiO_2	0.6	0.8	1.3	1.5	1.8
Fe_2O_3	7.7	6.6	2.9	8.9	13.2
BaO	2.4	22.3	0.9	5.9	6.3
Total	100	100	100	100	100

The results of mercury oxidation across the SCR catalyst after 4 months of exposure to flue gas and particulate are shown in Figure 47. The results show a higher level of oxidized mercury at the inlet as compared to testing conducted at installation and after 2 months. The level of oxidized mercury at the inlet ranges from 32% to 38% of the total, with about 5% of the total in the particulate form. The outlet levels of oxidized mercury decrease after passing through the catalyst to about 20% of the total. The level of particulate mercury remained about the same across the catalyst.

The results of mercury oxidation across the SCR catalyst after 6 months of exposure to flue gas are shown in Figure 48. The amount of oxidized mercury at the inlet ranges from 6.5% to 10.5% of the total with about 2.0% in the particulate form. The levels of oxidized mercury at the outlet increases slightly to 8.5% to 11.0% of the total mercury, while the particulate bound mercury also increases to as high as 12.0%.

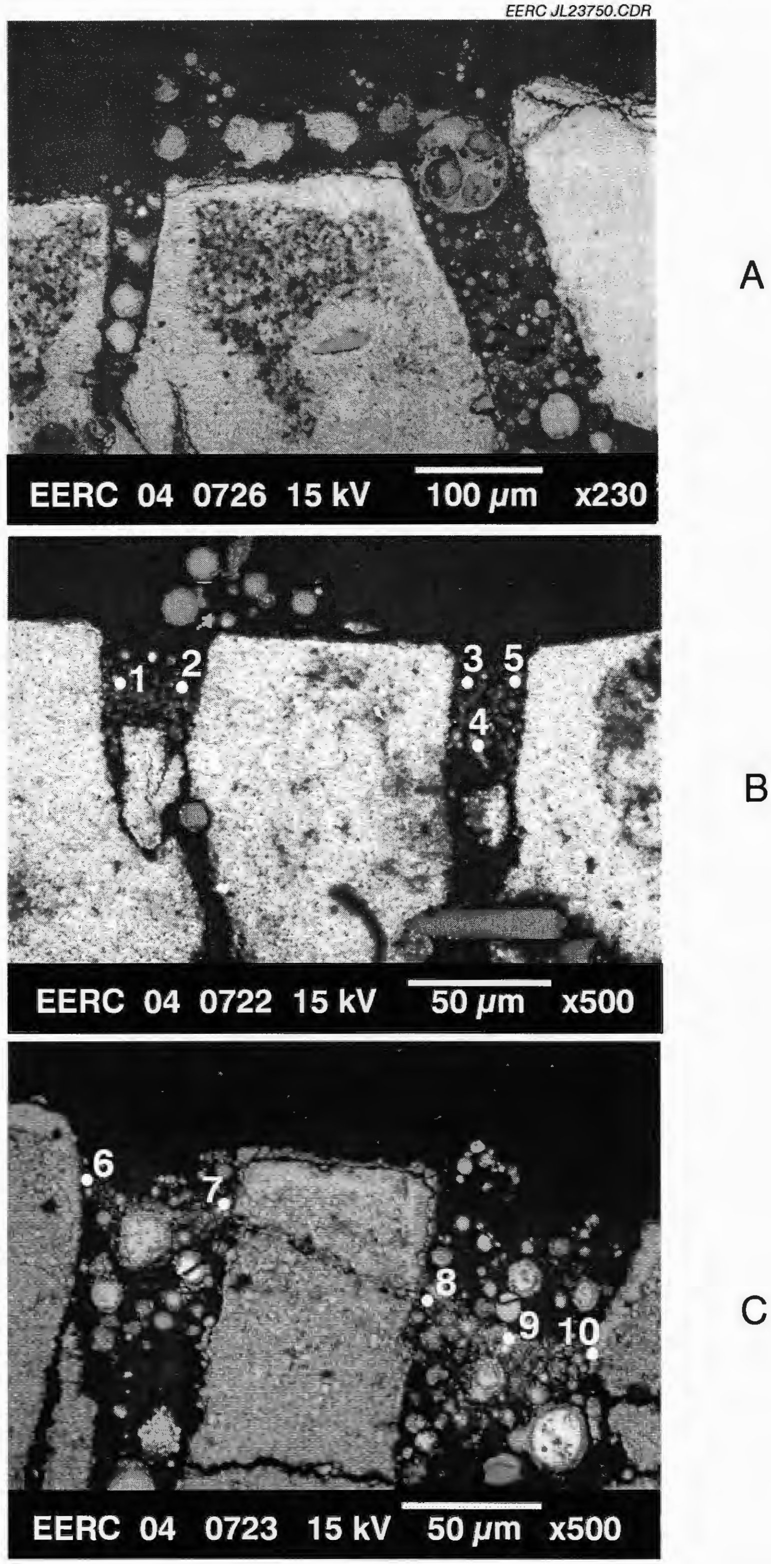


Figure 40. SEM images of ash collected on catalyst surface at the Coyote Station after 6 months of exposure: A) low-magnification image of ash deposit on catalyst surface, B) low-magnification image of polished cross section showing particles in a matrix of calcium- and sulfur-rich materials, and C) higher-magnification image of bonding.

Table 20. Chemical Composition of Selected Points and Areas in Figure 40

	Element, wt%				
	Point 1	Point 2	Point 3	Point 4	Point 5
Oxide					
Na_2O	5.0	3.2	6.6	5.8	4.1
MgO	1.6	0.0	0.0	7.6	1.4
Al_2O_3	2.1	3.3	0.6	0.8	1.7
SiO_2	10.7	12.8	3.6	2.6	14.4
P_2O_5	0.0	0.0	0.0	0.0	0.0
SO_3	57.9	40.7	67.0	71.0	52.7
K_2O	0.5	0.8	0.8	1.3	0.4
CaO	13.7	6.2	12.7	7.7	16.3
TiO_2	2.0	33.0	0.0	1.7	2.1
Fe_2O_3	6.5	0.0	8.8	1.4	7.0
BaO	0.0	0.0	0.0	0.0	0.0
Total	100	100	100	100	100
	Point 6	Point 7	Point 8	Point 9	Point 10
Oxide					
Na_2O	6.5	4.1	5.7	8.1	6.7
MgO	4.6	3.1	4.4	7.5	3.7
Al_2O_3	3.3	10.2	1.6	5.4	2.4
SiO_2	11.5	2.3	4.1	10.1	9.6
P_2O_5	2.2	0.5	0.0	0.9	7.2
SO_3	52.5	48.2	61.4	53.1	56.7
K_2O	1.9	1.0	10.0	3.0	0.9
CaO	13.6	23.9	2.6	8.6	10.5
TiO_2	2.7	3.7	0.7	0.0	0.0
Fe_2O_3	1.2	3.0	9.5	3.3	2.3
BaO	0.0	0.0	0.0	0.0	0.0
Total	100	100	100	100	100

Table 21. Results of Reactivity Tests for the Baldwin Station

Catalyst	$K–NO_x$ 350°C (662°F) (scfh/ft^3)	K/K_o 350°C (662°F)
Reference	22,808	—
2 month	23,400	1.03
4 month	21,361	0.96
6 month	19,510	0.84

Task 6 – Final Interpretation, Recommendations, and Reporting

Lignite and subbituminous coals contain high levels of organically bound alkali and alkaline-earth elements, including sodium, calcium, potassium, and magnesium. During combustion, partitioning of these elements occurs based on the size of particles, their association in the coal, and system configuration. This phenomenon, coupled with the fact that SCR catalyst

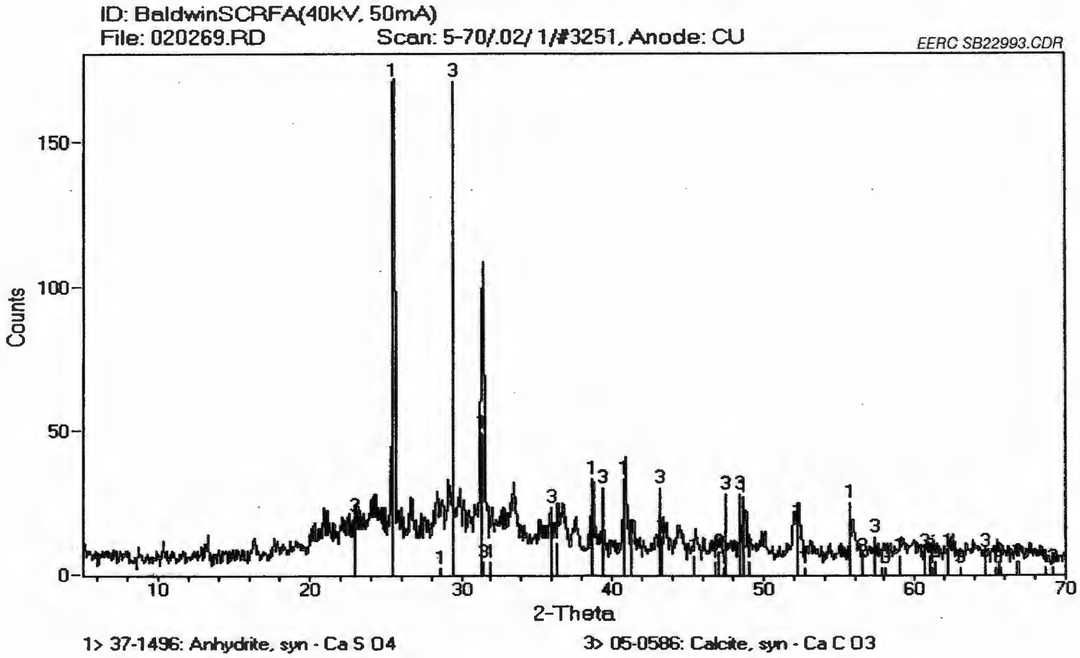


Figure 41. X-ray diffraction of ash collected on SCR catalyst (1 – $CaSO_4$, 2 – $Ca_3Mg(SiO_4)_2$, and 3 – $CaCO_3$).

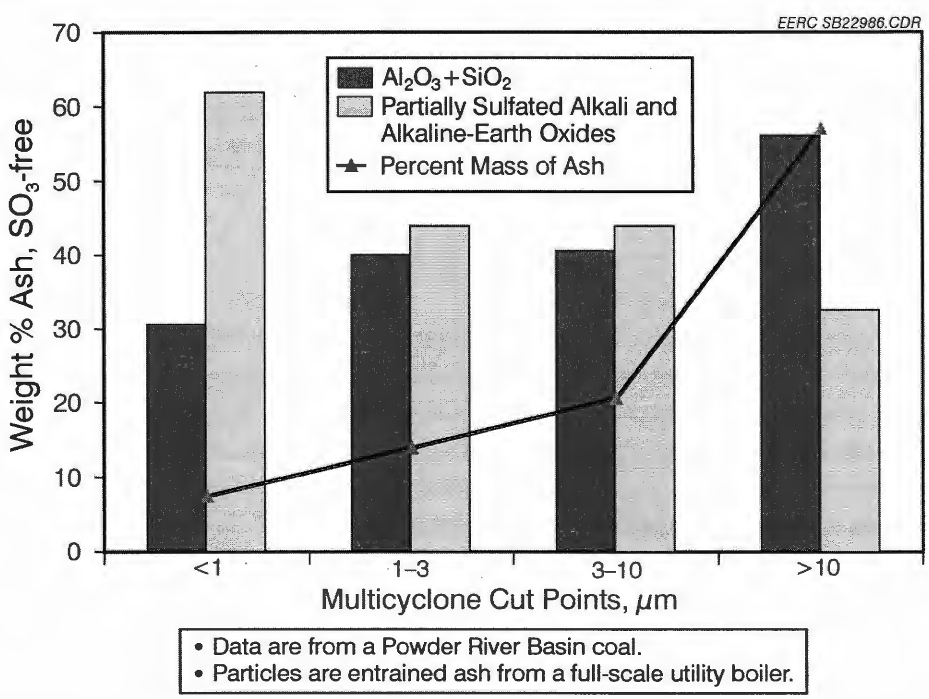


Figure 42. Simplified illustration of ash partitioning in combustion systems (18).

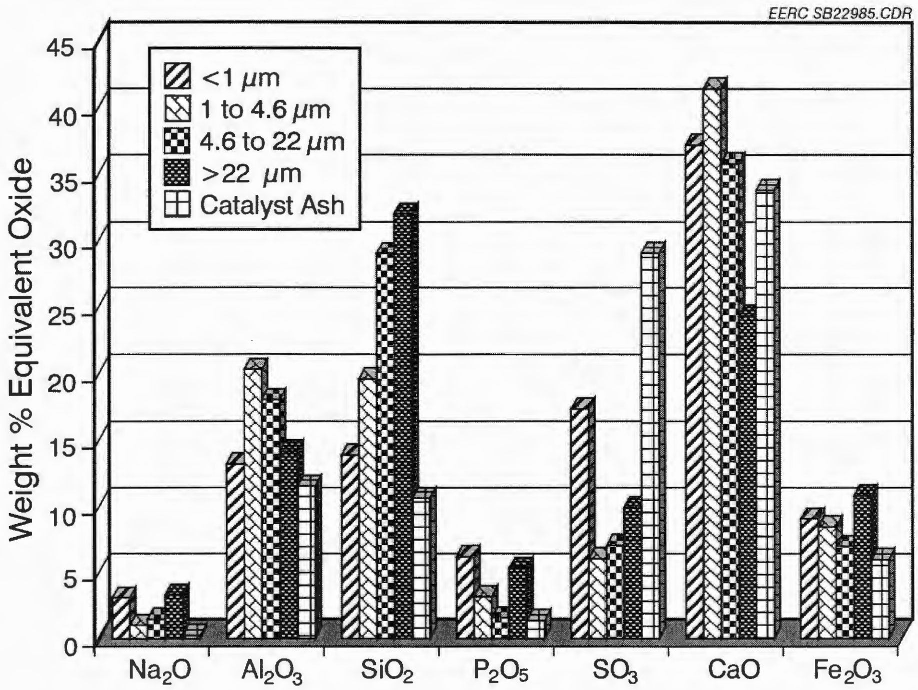


Figure 43. Comparison of entrained ash and deposited ash on catalyst for Columbia Station.

increases the oxidation of SO_2 to SO_3, will lead to extensive blinding of SCR catalyst by the formation of alkali or alkaline-earth sulfates. The results of this study lead the authors to suggest careful evaluation of each SCR installation on applications using subbituminous coals and suggest no installations of SCRs on plants firing lignite coal until further evaluations or improvements to the current technology can be carried out. Installations involving lignite fuels will need advanced cleaning techniques to handle the high-sodium and high-dust loads associated with burning most lignite fuels. The presence of SCR catalyst did not enhance mercury oxidation in the lignite-fired combustion system tested in this study.

CONCLUSIONS

The EERC evaluated the effects that ash from lignite- and PRB-fired combustion has on the performance of SCR catalyst. In order to conduct these tests, a slipstream reactor was designed to expose the SCR catalyst to coal combustion-derived flue gases and particulates. The system is computer-controlled and operates in an automated mode. The system can be operated and monitored remotely through a modem connection. SCR catalyst testing was conducted at two subbituminous-fired plants and one lignite-fired plant. The boiler configurations for the subbituminous-fired plants included a cyclone- and a tangentially fired boiler. The lignite plant was cyclone-fired.

The pressure drop across the catalyst was found to be the most significant for the lignite-fired plant as compared to the subbituminous-fired plants. Both coals had significant accumulations of ash on the catalyst, on both macroscopic and microscopic levels. On a

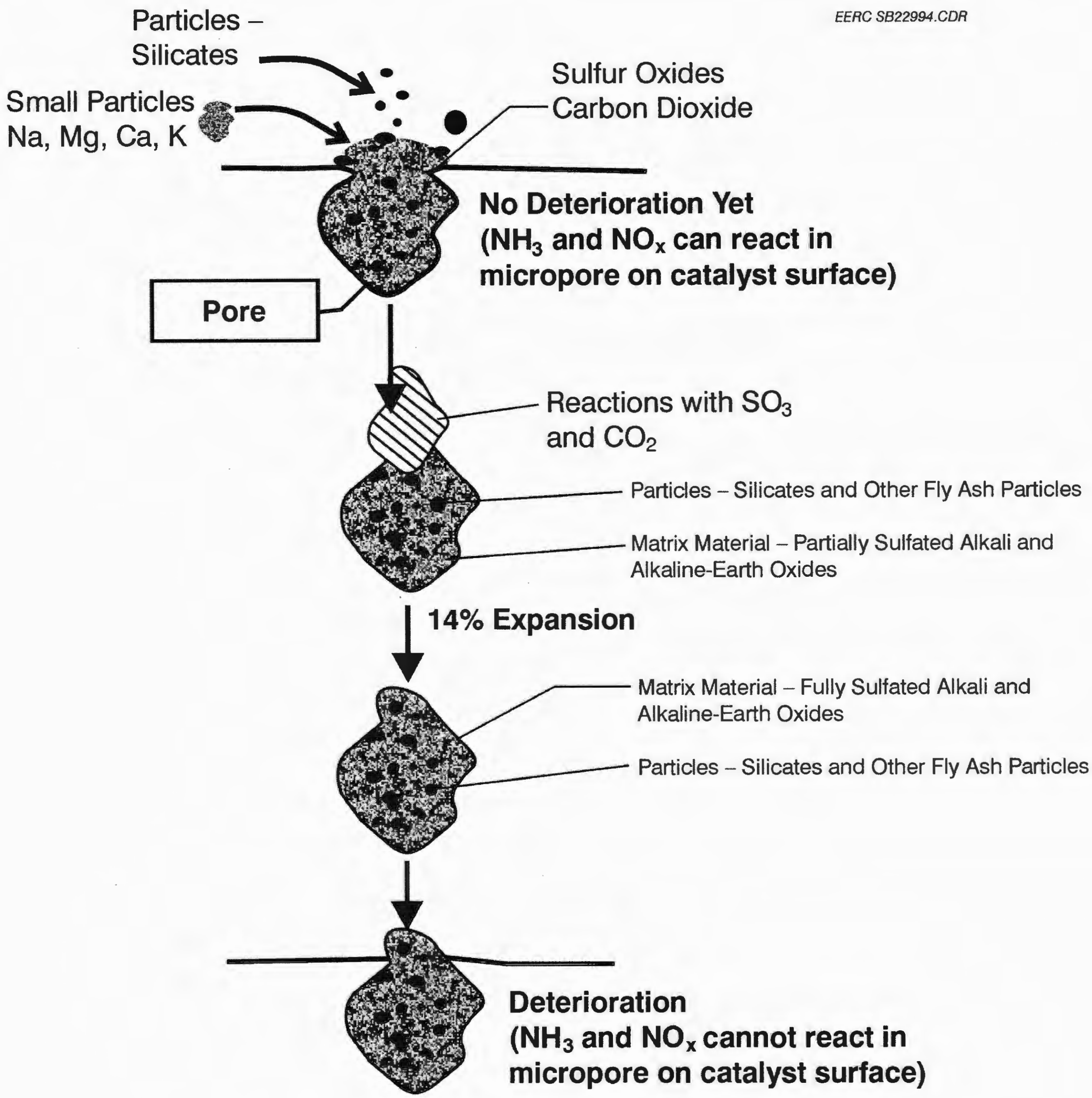


Figure 44. Mechanism of SCR catalyst blinding via the formation of sulfates and carbonates (modified after Pritchard and others [35]).

macroscopic level, there were significant observable accumulations that plugged the entrance as well as the exit of the catalyst sections. On a microscopic level, the ash materials filled pores in the catalyst and, in many cases, completely masked the pores within 4 months of operation. After 6 months of operation, the reactivity of the catalyst from the Baldwin Station was 84% of a comparable reference value.

The deposits on the surfaces and within the pores of the catalyst consisted mainly of sulfated alkali and alkaline-earth element-rich phases. The mechanism for the formation of the

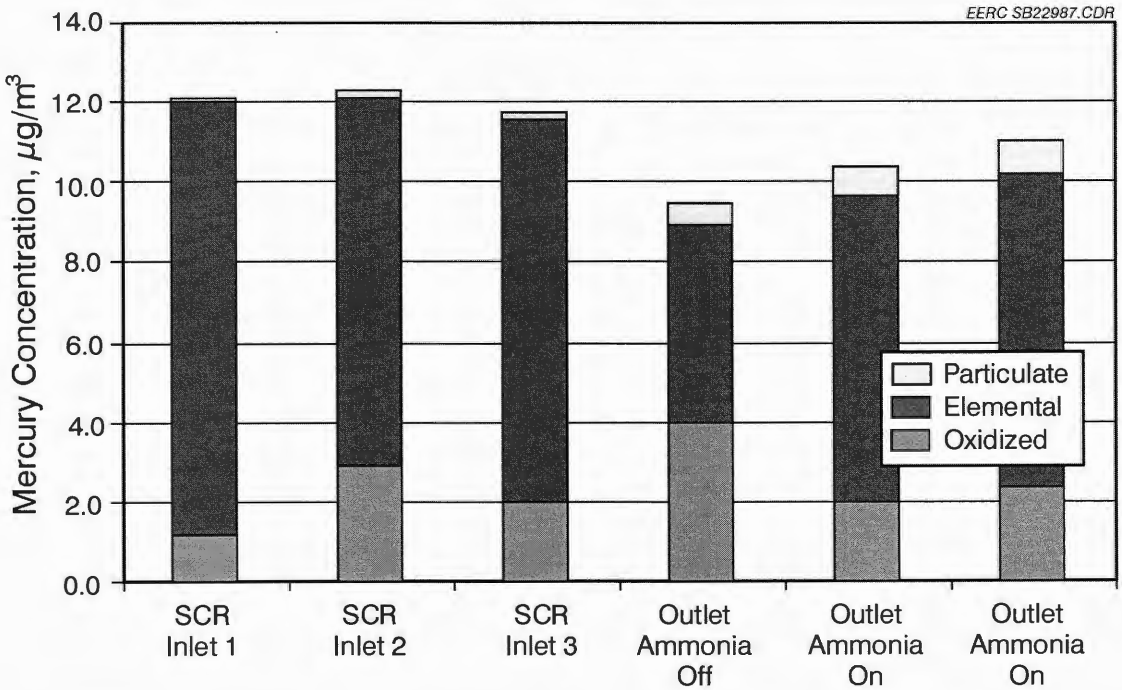


Figure 45. Mercury speciation measurement at the inlet and outlet of the SCR catalyst upon installation of the catalyst.

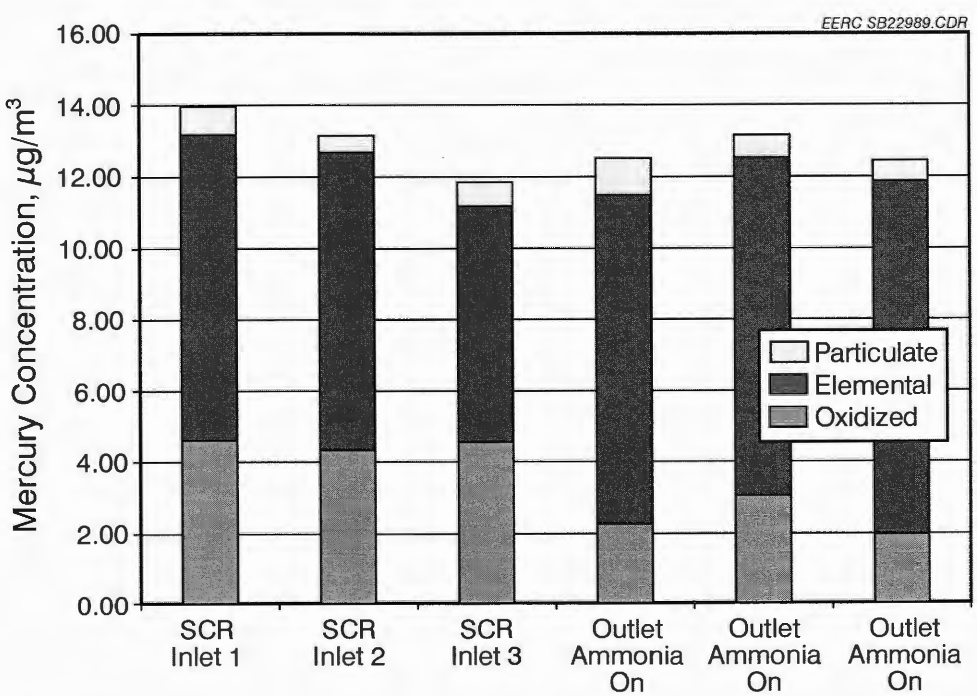


Figure 46. Mercury speciation measurement at the inlet and outlet of the SCR catalyst after exposure to flue gas and particulate for 4 months.

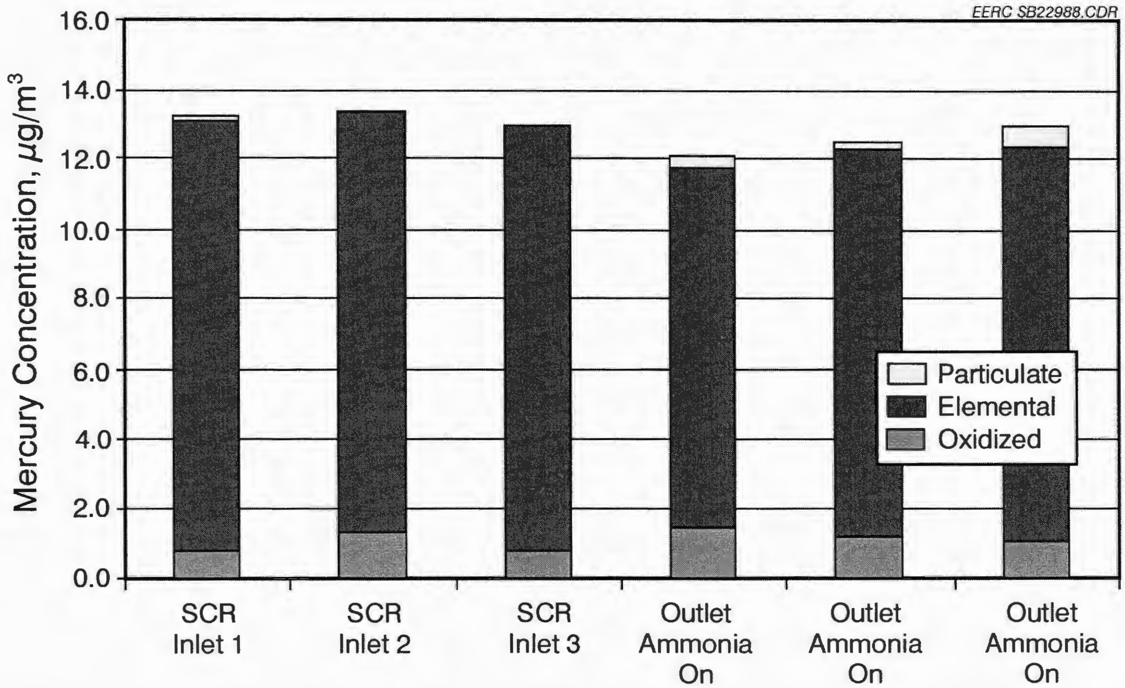


Figure 47. Mercury speciation measurement at the inlet and outlet of the SCR catalyst after exposure to flue gas and particulate for 2 months.

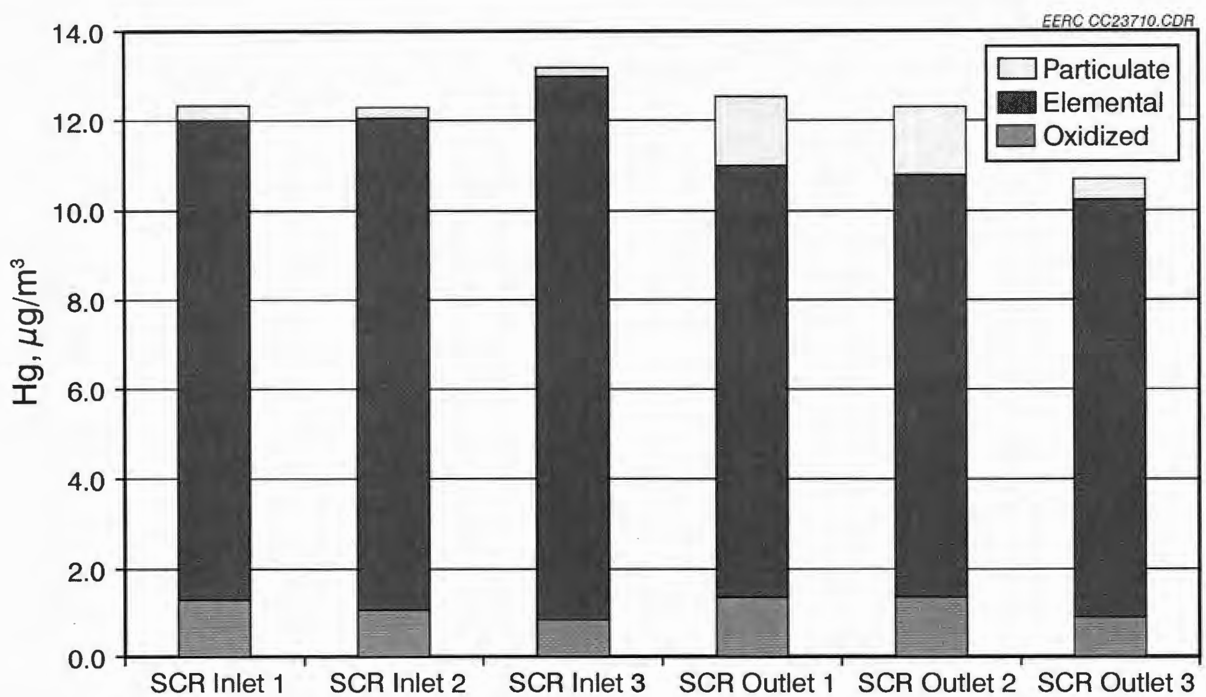


Figure 48. Mercury speciation measurement at the inlet and outlet of the SCR catalyst after exposure to flue gas and particulate for 6 months.

sulfate materials involves the formation of very small particles rich in alkali and alkaline-earth elements, transport of the particles to the surface of the catalyst, and reactions with SO_2–SO_3 to form sulfates. XRD analysis identified $CaSO_4$ as a major phase and $Ca_3Mg(SiO_4)_2$ and $CaCO_3$ as minor phases. These results are consistent with the bench-scale TGA and FACT modeling results. The only exception may be the absence of phosphate materials predicted in the FACT modeling; one possible explanation is that FACT considers each reaction independently and does not consider the selectivity of one reaction over another.

Lignite and subbituminous coals contain high levels of organically associated alkali and alkaline-earth elements, including sodium, magnesium, calcium, and potassium in addition to mineral phases. During combustion, the inorganic components in the coal are partitioned into various size fractions based on the type of inorganic component and their association in the coal and combustion system design and operating conditions. The results of this testing found that the smaller-sized fractions of ash are dominated by partially sulfated alkali and alkaline-earth elements. The composition of the size fractions was compared to the chemical composition of the ash deposited on and in the catalyst. The comparison shows that the composition of the particle captured in the SCR catalyst is very similar to the <5-μm size fraction.

This study suggests careful evaluation of each SCR installation in applications using subbituminous and lignite coals. Improvements are needed to ensure technical feasibility, especially with lignite-fired units. Installations involving lignite fuels will need advanced cleaning techniques to handle the high sodium and high dust loads associated with burning most lignite fuels.

The ability of mercury to be oxidized across the SCR catalyst was investigated at the Coyote Station. The Coyote Station is fired on North Dakota lignite, and the flue gas is dominated by elemental mercury. Measurement of mercury speciation was conducted using the OH method at the inlet and the outlet of the SCR catalyst. These results show limited oxidation of mercury across the SCR catalyst when lignite coals are fired. The reasons for the lack of mercury oxidation include the following: no chlorine present in the coal and flue gas to catalytically enhance the oxidation of Hg^0, higher levels of alkali and alkaline-earth elements acting as sorbents for any chlorine present in the flue gas, and lower levels of acid gases present in the flue gas.

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Energy & Environmental Research Center

JOINT VENTURE PROPOSAL PROJECT SUMMARY

PROJECT TITLE		DOE CONTRACT NUMBER
Assessment of Mercury Control Options and Ash Behavior in Fluidized-Bed Combustion Systems		DE-FC26-98FT40321
		CA TASK NUMBER NA
SUGGESTED PERFORMANCE MONITOR	EERC PROJECT MANAGER Steven Benson	CONTROL NUMBER BP7-19
PROJECT PERIOD Start: 1-1-05 End: 6-30-06	SUBMISSION DATE 12-2-04	EERC PROPOSAL NUMBER 2005-0131
PARTICIPANTS U.S. Department of Energy, North Dakota Industrial Commission (NDIC), ALSTOM, Babcock & Wilcox, Foster Wheeler, Montana-Dakota Utilities, and Sempra Energy		

WORK DESCRIPTION (SUMMARY)

The overall goal of this project is to evaluate mercury control options and their impact on performance for fluidized-bed combustion (FBC) power plants. Although FBC is used in a small percentage of current fossil fuel-fired power plants, the technology is being proposed for a number of new power plants. Mercury emission data from these systems are insufficient to make predictions as to the ultimate fate of mercury and the best options for mercury control.

This project aims to provide detailed information on the control of mercury emissions and their effects on ash behavior in the system. The system configurations to be examined include FBC systems equipped with baghouses and/or electrostatic precipitators (ESPs) for particulate control with and without a spray dryer absorber (SDA). The mercury control options include sorbent injection upstream, sorbent enhancements combined with sorbent injection, and mercury oxidation upstream of the SDA/baghouse or ESP. These mercury control strategies will be evaluated at the EERC using a pilot-scale circulating fluidized-bed combustor (CFBC) equipped with a baghouse, ESP, and SDA/baghouse or ESP.

A variety of fuel ranks will be considered for testing in this project, including but not limited to lignite and subbituminous coals. The final selection of specific fuels to be tested will be based on sponsor input. The specific objectives will be to 1) determine the speciation of mercury in flue gases produced in CFBC systems utilizing a limestone bed; 2) test mercury control options such as sorbent injection to capture mercury and additives to promote mercury oxidation; 3) determine the effect of additives on system performance because of corrosion, ash deposition, and agglomeration; and 4) provide a cost estimate for control technologies deemed most promising for FBC systems.

The project will be completed within 18 months of initiation for a total cost of $1,000,000. The Energy & Environmental Research Center (EERC) is requesting $350,000 or 35% of the cost from the U.S. Department of Energy (DOE) through the EERC-DOE Jointly Sponsored Research Program (JSRP). An industrial consortium will fund the remaining $650,000, which includes $200,000 from the North Dakota Industrial Commission (NDIC).

YEAR	Prior	BP7		
TOTAL FUNDING:	$	$		
NONFEDERAL FUNDING	$	$		
Contract Award–Cash				
Cash Equivalent/In-Kind Contribution				
DOE FUNDING:	$	$		
FUNDS REQUESTED THIS ACTION:		$		

1,00

-----Original Message-----
From: Crocker, Charlene R. [mailto:ccrocker@undeerc.org]
Sent: Tuesday, November 30, 2004 9:28 PM
To: Fine, Karlene K.
Cc: 'hness@lignite.com'; Benson, Steven A.; Wixo, Connie Y.
Subject: Selective Catalytic Reduction and Impact of SCR Catalyst on Mercury Oxidation Final Report

November 30, 2004

Ms. Karlene Fine
Executive Director
North Dakota Industrial Commission
State Capitol, 10th Floor
600 East Boulevard Avenue
Bismarck, ND 58505-0310

Dear Ms. Fine:

Subject: Evaluation of Potential SCR Catalyst Blinding During Coal Combustion
Contract No. FY-00-XXXVI-100
Impact of SCR Catalyst on Mercury Oxidation in Lignite-Fired Combustion
Systems Contract No. FY-03-XLIX-119

The combined final report for the subject research projects is available for downloading on our ftp site as it is too large to send via e-mail. To download the document, open your Web browser and go to the url: ftp://ftp.undeerc.org/SCR%20Final/. The document is called "SCR Catalyst Blinding.pdf". If you have any problems downloading the report or would prefer a hard copy, please contact Connie Wixo at (701) 777-5161.

Thank you for your support of this project. It has been a pleasure working with you. If you have any comments or questions regarding the report, feel free to contact me at (701) 777-5177 or at sbenson@undeerc.org.

Sincerely,

Steven A. Benson

EERC
Energy & Environmental Research Center
UNIVERSITY OF NORTH DAKOTA
15 North 23rd Street — PO Box 9018 / Grand Forks, ND 58202-9018 / Phone: (701) 777-5000 Fax: 777-5181
Web Site: www.undeerc.org

December 3, 2004

Ms. Karlene Fine
Executive Director
North Dakota Industrial Commission
State Capitol, 10th Floor
600 East Boulevard Avenue
Bismarck, ND 58505-0310

Dear Ms. Fine:

Subject: Evaluation of Potential SCR Catalyst Blinding During Coal Combustion
Contract No. FY-00-XXXVI-100

Enclosed is the combined final report for the subject research project with all suggested changes made. The report also contains the results of the Impact of SCR Catalyst on Mercury Oxidation in Lignite-Fired Combustion Systems project which was completed in conjunction with the subject project.

We certify that we have been awarded and expended cash funds from the following sponsors in the execution of this research.

Of $240,000 awarded ($40,000 each), $239,812.22 has been expended from the following sponsors:

Otter Tail Power Company
Ameren UE
Alliant Energy Corporation
Ontario Power Generation
Dynegy Midwest Generation
EPRI

Of $48,000 of EERC in-kind contribution, $48,494 has been expended.

Of $200,000 awarded from the North Dakota Industrial Commission, $199,950.5[illegible] been expended.

Of $335,333 awarded from the U.S. Department of Energy National Energy Techı Laboratory, $335,332.50 has been expended.

Note

Thank you for your support of this project. It has been a pleasure working with you. If you have any comments or questions regarding the report, feel free to contact me at (701) 777-5177 or at sbenson@undeerc.org.

Sincerely,

Steven A. Benson
Senior Research Manager

SAB/krg

Enclosure

c: Harvey Ness, Lignite Energy Council
Jason Laumb, EERC

INDUSTRIAL COMMISSION OF NORTH DAKOTA

LIGNITE RESEARCH, DEVELOPMENT AND MARKETING PROGRAM

http://www.state.nd.us/ndic

MEMORANDUM

December 8, 2004

TO: Karlene Fine, Executive Director and Secretary
North Dakota Industrial Commission

FROM: Harvey M. Ness, Director and Technical Advisor
Lignite Research, Development and Marketing Program

cc: John W. Dwyer, Chairman
Lignite Research Council

SUBJECT: FY00-XXXVI-100: "Evaluation of Potential SCR Catalyst Blinding During Coal Combustion"; Contractor: Energy & Environmental Research Center; Recommendation for Payment of $21,250 for the Final Report

---

I have reviewed the Final Report dated November, 2004 from the contractor (Energy & Environmental Research Center) regarding Contract No. FY00-XXXVI-100 for the project titled "Evaluation of Potential SCR Catalyst Blinding During Coal Combustion".

The Final Report is adequate to determine that the contractor has complied with the statement of work.

The contractor has met the terms of contract FY00-XXXVI-100 required for receiving the $21,250 payment for the Final Report. I recommend payment of the $21,250.

HMN/vg: 24.S.30.A

LIGNITE RESEARCH COUNCIL

John Dwyer
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jdwyer@lignite.com

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INDUSTRIAL COMMISSION OF NORTH DAKOTA

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November 29, 2004

Mr. Harvey Ness
Director
Lignite Energy Council
Lignite Research, Development and Marketing Program
1016 East Owens Avenue, Suite 200
PO Box 2277
Bismarck, ND 58502

Dear Mr. Ness:

Subject: Final Report for Evaluation of Potential SCR Catalyst Blinding During Coal Combustion and Add-On: Impact of SCR Catalyst on Mercury Oxidation in Lignite-Fired Combustion Systems; Contract No. FY-00-XXXVI-100

Enclosed is the final report for the subject task, with all suggested changes made. If you have any questions, please call me at (701) 777-5114, fax at (701) 777-5181, or e-mail at jlaumb@undeerc.org.

Sincerely,

Jason D. Laumb
Research Manager

JDL/drh

Enclosures

DOE DISCLAIMER

DOE ACKNOWLEDGMENT

This report was prepared with the support of the U.S. Department of Energy (DOE) National Energy Technology Laboratory Cooperative Agreement No. DE-FC26-98FT40321. However, any opinions, findings, conclusions, or recommendations expressed herein are those of the authors(s) and do not necessarily reflect the views of DOE.

EERC DISCLAIMER

NDIC DISCLAIMER

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(B) Assumes any liabilities with respect to the use of, or for damages resulting from the use of, any information, apparatus, method, or process disclosed in this report.

Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the North Dakota Industrial Commission. The views and opinions of authors expressed herein do not necessarily state or reflect those of the North Dakota Industrial Commission.

JV 31 – EVALUATION OF POTENTIAL SCR CATALYST BLINDING DURING COAL COMBUSTION AND ADD-ON: IMPACT OF SCR CATALYST ON MERCURY OXIDATION IN LIGNITE-FIRED COMBUSTION SYSTEMS

ABSTRACT

Lignite and subbituminous coals from the United States of America have characteristics that impact the performance of catalysts used in selective catalyst reduction (SCR) for nitrogen oxide removal and mercury oxidation. Typically, these coals contain ash-forming components that consist of inorganic elements (sodium, magnesium, calcium, and potassium) associated with the organic matrix and mineral grains (quartz, clays, carbonates, sulfates, and sulfides). Upon combustion, the inorganic components undergo chemical and physical transformations that produce intermediate inorganic species in the form of inorganic gases, liquids, and solids. The alkali and alkaline-earth elements are partitioned between reactions with minerals and reactions to form alkali and alkaline-earth-rich oxides during combustion. The particles resulting from the reaction with minerals produce low-melting-point phases that cause a wide range of fireside deposition problems. The alkali and alkaline-earth-rich oxides consist mainly of very small particles ($<5\ \mu m$) that are carried into the backpasses of the combustion system and react with flue gas to form sulfates and, possibly, carbonates. These particles cause low-temperature deposition, blinding, and plugging problems in SCR systems. These coals also lack sufficient levels of chlorine needed to oxidize mercury. Slipstream testing was conducted at two subbituminous-fired power plants and one lignite-fired power plant to determine the impacts of ash on SCR plugging, blinding, and mercury oxidation. The results indicated a high potential for blinding and plugging because of the formation of sulfate-bonded deposits but no evidence of mercury oxidation.

100

CHAPTER 47-25.1
TRADE SECRETS

47-25.1-01. Definitions. As used in this chapter, unless the context requires otherwise:

1. "Improper means" includes theft, bribery, misrepresentation, breach or inducement of a breach of a duty to maintain secrecy, or espionage through electronic or other means.

2. "Misappropriation" means:

   a. Acquisition of a trade secret of another by a person who knows or has reason to know that the trade secret was acquired by improper means; or

   b. Disclosure or use of a trade secret of another without express or implied consent by a person who:

      (1) Used improper means to acquire knowledge of the trade secret;

      (2) At the time of disclosure or use, knew or had reason to know that the person's knowledge of the trade secret was:

         (a) Derived from or through a person who had utilized improper means to acquire it;

         (b) Acquired under circumstances giving rise to a duty to maintain its secrecy or limit its use; or

         (c) Derived from or through a person who owed a duty to the person seeking relief to maintain its secrecy or limit its use; or

      (3) Before a material change of the person's position, knew or had reason to know that it was a trade secret and that knowledge of it had been acquired by accident or mistake.

3. "Person" means a natural person, corporation, limited liability company, business trust, estate, trust, partnership, association, joint venture, government, governmental subdivision or agency, or any other legal or commercial entity.

4. "Trade secret" means information, including a formula, pattern, compilation, program, device, method, technique, or process, that:

   a. Derives independent economic value, actual or potential, from not being generally known to, and not being readily ascertainable by proper means by, other persons who can obtain economic value from its disclosure or use; and

   b. Is the subject of efforts that are reasonable under the circumstances to maintain its secrecy.

47-25.1-02. Injunctive relief.

1. Actual or threatened misappropriation may be enjoined. Upon application to the court, an injunction must be terminated when the trade secret has ceased to exist, but the injunction may be continued for an additional reasonable period of time to eliminate commercial advantage that otherwise would be derived from the misappropriation.

Section 6. Unless otherwise provided by law, all records of public or governmental bodies, boards, bureaus, commissions, or agencies of the state or any political subdivision of the state, or organizations or agencies supported in whole or in part by public funds, or expending public funds, shall be public records, open and accessible for inspection during reasonable office hours.

Section 7. The legislative assembly, in order to ensure continuity of state and local governmental operations in periods of emergency resulting from disasters caused by enemy attack, shall have the power and immediate duty (1) to provide for prompt and temporary succession to the powers and duties of public offices, of whatever nature and whether filled by election or appointment, the incumbents of which may become unavailable for carrying on the powers and duties of such offices, and (2) to adopt such other measures as may be necessary and proper for ensuring the continuity of governmental operations including, but not limited to, waiver of constitutional restrictions upon the place of transaction of governmental business, upon the calling of sessions of the legislative assembly, length of sessions, quorum and voting requirements, subjects of legislation and appropriation bill requirements, upon eligibility of legislators to hold other offices, residence requirements for legislators, and upon expenditures, loans or donations of public moneys. In the exercise of the powers hereby conferred the legislative assembly shall in all respects conform to the requirements of this constitution except to the extent that in the judgment of the legislative assembly so to do would be impracticable or would admit of undue delay.

Section 8. The house of representatives shall have the sole power of impeachment. The concurrence of a majority of all members elected shall be necessary to an impeachment.

Section 9. All impeachments shall be tried by the senate. When sitting for that purpose the senators shall be upon oath or affirmation to do justice according to the law and evidence. No person shall be convicted without the concurrence of two-thirds of the members elected. When the governor or lieutenant governor is on trial, the presiding judge of the supreme court shall preside.

Section 10. The governor and other state and judicial officers, except county judges, justices of the peace and police magistrates, shall be liable to impeachment for habitual drunkenness, crimes, corrupt conduct, or malfeasance or misdemeanor in office, but judgment in such cases shall not extend further than removal from office and disqualification to hold any office of trust or profit under the state. The person accused, whether convicted or acquitted, shall nevertheless be liable to indictment, trial, judgment and punishment according to law.

Section 11. All officers not liable to impeachment shall be subject to removal for misconduct, malfeasance, crime or misdemeanor in office, or for habitual drunkenness or gross incompetency in such manner as may be provided by law.

Section 12. No officer shall exercise the duties of his office after he shall have been impeached and before his acquittal.

Section 13. On trial of impeachment against the governor, the lieutenant governor shall not act as a member of the court.

Section 14. No person shall be tried on impeachment before he shall have been served with a copy thereof, at least twenty days previous to the day set for trial.

Section 15. No person shall be liable to impeachment twice for the same offense.

Section 16. The militia of this state shall consist of all able-bodied male persons residing in the state, between the ages of eighteen and forty-five years, except such as may be exempted by the laws of the United States or of this state. Persons whose religious tenets or conscientious scruples forbid them to bear arms shall not be compelled to do so in times of peace, but shall pay an equivalent for a personal service.

1. Any record of a public employee's medical treatment or use of an employee assistance program is not to become part of that employee's personnel record and is confidential and may not be released without the written consent of the employee. As used in this section, the term "public employee" includes any person employed by a public entity.

2. Except as otherwise specifically provided by law, personal information regarding a public employee contained in an employee's personnel record or given to the state or a political subdivision by the employee in the course of employment is exempt. As used in this section, "personal information" means a person's home address; home telephone number; photograph; medical information; motor vehicle operator's identification number; social security number; payroll deduction information; the name, address, phone number, date of birth, and social security number of any dependent or emergency contact; any credit, debit, or electronic fund transfer card number; and any account number at a bank or other financial institution.

3. Nonconfidential information contained in a personnel record of an employee of a public entity as defined in subdivision c of subsection 12 of section 44-04-17.1 is exempt.

4. Except as otherwise specifically provided by law, personal information regarding a licensee maintained by an occupational or professional board, association, or commission created by law is exempt. As used in this section, "licensee" means an individual who has applied for, holds, or has held in the past an occupational or professional license, certificate, permit, or registration issued by a state occupational or professional board, association, or commission.

44-04-18.2. Certain economic development records exempt from disclosure. Repealed by S.L. 1997, ch. 381, § 23.

44-04-18.3. Records of law enforcement and correctional employees - Confidential informants.

1. Any telephone number and the home address of an employee of a law enforcement agency, employee of a state or local correctional facility, and an employee of the department of corrections and rehabilitation are confidential. A record containing information relating to an employee of the department of corrections and rehabilitation may be disclosed to an appropriate authority under policy established by the department of corrections and rehabilitation.

2. Records or other information that would reveal the identity, or endanger the life or physical well-being, of an undercover law enforcement officer is confidential. For purposes of this subsection, an "undercover law enforcement officer" means a full-time, salaried employee of a local or state law enforcement agency who acts surreptitiously or poses as someone other than a law enforcement officer while engaging in the investigation of a violation of law.

3. A law enforcement officer or prosecutor, within the scope of the employment of the officer or prosecutor, may provide assurances of confidentiality to a person providing information regarding violations of the law. Any information that would identify or provide a means of identifying a confidential informant, if the identity of the informant is not otherwise publicly known, is confidential and may be disclosed only as permitted by law.

44-04-18.4. Confidentiality of trade secret, proprietary, commercial, and financial information.

1. Trade secret, proprietary, commercial, and financial information is confidential if it is of a privileged nature and it has not been previously publicly disclosed.

2. "Trade secret includes:

   a. A computer software program and components of a computer software program which are subject to a copyright or a patent, and any formula, pattern, compilation, program, device, method, technique, or process supplied to any state agency, institution, department, or board which is the subject of efforts by the supplying person or organization to maintain its secrecy and that may derive independent economic value, actual or potential, from not being generally known to, and not being readily ascertainable by proper means by, other persons or organizations that might obtain economic value from its disclosure or use; and

   b. A discovery or innovation which is subject to a patent or a copyright, and any formula, pattern, compilation, program, device, method, technique, or process supplied to or prepared by any public entity which is the subject of efforts by the supplying or preparing entity, person, business, or industry to maintain its secrecy and that may derive independent economic value, actual or potential, from not being generally known to, and not being readily ascertainable by proper means by, any person who might obtain economic value from its disclosure or use.

3. "Proprietary information" includes information received from a sponsor of research conducted by a public entity, as well as any discovery or innovation generated by that research, technical, financial, and marketing information and other documents related to the commercialization, and any other discovery or innovation produced by the public entity which an employee or the entity intends to commercialize.

4. This section does not limit or otherwise affect a record pertaining to any rule of the state department of health or to any record pertaining to the application for a permit or license necessary to do business or to expand business operations within this state, except as otherwise provided by law.

5. Unless made confidential under subsection 1, the following economic development records and information are exempt:

   a. Records and information pertaining to a prospective location of a business or industry, including the identity, nature, and location of the business or industry, when no previous public disclosure has been made by the business or industry of the interest or intent of the business or industry to locate in, relocate within, or expand within this state. This exemption does not include records pertaining to the application for permits or licenses necessary to do business or to expand business operations within this state, except as otherwise provided by law.

   b. Trade secrets and commercial or financial information received from a person, business, or industry that is interested in or is applying for or receiving financing or technical assistance, or other forms of business assistance.

44-04-18.5. Computer software programs exempt. Any computer software program or component of a computer software program contracted, developed, or acquired by a public entity or state agency, institution, department, or board and for which the public entity or state agency, institution, department, or board acquires a license, copyright, or patent is exempt from section 44-04-18 and section 6 of article XI of the Constitution of North Dakota. After receiving written approval from the governor, a state agency, institution, department, or board may enter into agreements for the sale, licensing, and distribution of its contracted, licensed, patented, or copyrighted computer software programs. A state agency, institution, department, or board may take any needed action, including legal action, to protect the state's interest in the computer software against improper or unlawful use or infringement and may collect and enforce the collection of any sums due for the licensing or sale of the computer software. A public entity may enter into agreements foı ..ıe sale, licensing, and distribution of its licenised, patented, or copyrighted computer software programs.

44-04-18.6. Access to legislative records and information. The following records, regardless of form or characteristic, of or relating to the legislative council, the legislative assembly, the house of representatives, the senate, or a member of the legislative assembly are not subject to section 44-04-18 and section 6 of article XI of the Constitution of North Dakota: a record of a purely personal or private nature, a record that is attorney work product or is attorney-client communication, a record that reveals the content of private communications between a member of the legislative assembly and any person, and, except with respect to a governmental entity determining the proper use of telephone service, a record of telephone usage which identifies the parties or lists the telephone numbers of the parties involved. This section does not apply to any record distributed at a meeting subject to section 44-04-19 and section 5 of article XI of the Constitution of North Dakota.

44-04-18.7. Criminal intelligence information and criminal investigative information - Nondisclosure - Record of information maintained.

1. Active criminal intelligence information and active criminal investigative information are not subject to section 44-04-18 and section 6 of article XI of the Constitution of North Dakota. A criminal justice agency shall maintain a list of all files containing active criminal intelligence and investigative information which have been in existence for more than one year. With respect to each file, the list must contain the file's number or other identifying characteristic and the date the file was established. The list required under this subsection is subject to section 44-04-18. Criminal intelligence and investigative information that is not considered "active" is not subject to section 44-04-18 and section 6 of article XI of the Constitution of North Dakota to the extent that the information is personal information.

2. "Criminal intelligence information" means information with respect to an identifiable person or group of persons collected by a criminal justice agency in an effort to anticipate, prevent, or monitor possible criminal activity. Criminal intelligence information must be considered "active" as long as it is related to intelligence gathering conducted with a reasonable good faith belief that it will lead to detection of ongoing or reasonably anticipated criminal activities.

3. "Criminal investigative information" means information with respect to an identifiable person or group of persons compiled by a criminal justice agency in the course of conducting a criminal investigation of a specific act or omission, including information derived from laboratory tests, reports of investigators or informants, or any type of surveillance. Criminal investigative information must be considered "active" as long as it is related to an ongoing investigation that is continuing with a reasonable good faith anticipation of securing an arrest or prosecution in the foreseeable future.

4. "Criminal justice agency" means any law enforcement agency or prosecutor. The term also includes any other unit of government charged by law with criminal law enforcement duties or having custody of criminal intelligence or investigative information for the purpose of assisting law enforcement agencies in the conduct of active criminal investigations or prosecutions.

5. "Criminal intelligence and investigative information" does not include:

   a. Arrestee description, including name, date of birth, address, race, sex, physical description, and occupation of arrestee.

   b. Facts concerning the arrest, including the cause of arrest and the name of the arresting officer.

* Best # to reach him at on 1-24-00

IMPORTANT MESSAGE

FOR Clifford DATE 1-21-00 TIME 2:18 A.M. (P.M.)

M TONY Licata

OF

PHONE ☐ FAX ☐ MOBILE * Cell: 914-672-3834

AREA CODE NUMBER EXTENSION

MESSAGE OR: 914-779-3451

Re: Tech[illegible] review —

Wants to discuss a possible

conflict of interest he has

SIGNED VR Re: LRC-XXXVI-A

OK

1/24/00

✓	PHONED
	RETURNED YOUR CALL
✓	PLEASE CALL
	WILL CALL AGAIN
	CAME TO SEE YOU
	WANTS TO SEE YOU

TOPS FORM 4006

Vicki Gilmore

From: Clifford Porter
Sent: Friday, January 14, 2000 3:37 PM
To: Vicki Gilmore
Subject: FW: Peer Review

-----Original Message-----
From: Licataener@aol.com [mailto:Licataener@aol.com]
Sent: Friday, January 14, 2000 2:14 PM
To: cporter@lignite.com
Subject: Re: Peer Review

Dear Mr. Porter:

I would be pleased to participate in your SCR peer review project.

Please send me your review package.

Tony Licata
KWH Technical Representative
c/o Licata Energy
2150 Central Park Ave., Suite 207
Yonkers, NY 10710
Phone: 914-779-3451
Fax: 914-779-4234

Combustion Resources LLC 1453 West 820 North
Provo, UT 84601
Consultants in Fuels, Combustion and the Environment

Dear Colleague,

Combustion Resources is pleased to announce the release of **CFD Workshop**, a new software product for performing Computational Fluid Dynamics (CFD) on personal computers (PC's). *CFD Workshop* is a low cost tool for the computational analysis of flow and combustion systems, and was designed specifically for use on PC's running Windows 95, 98 and NT. It is designed to be user-friendly and easy-to-use, even for those with a limited background in CFD.

The solver code used in *CFD Workshop* is based on PCGC-3, the comprehensive combustion code developed in the Advanced Combustion Engineering Research Center (ACERC) at Brigham Young University over the last two decades at a cost of millions of dollars. PCGC-3 has been applied and evaluated for a wide range of flow and combustion applications. *CFD Workshop* integrates PCGC-3 with a user-friendly interface to simplify problem setup and a wide range of graphics capabilities for visualizing the results of the simulation.

CFD Workshop can be used for the simulation of steady-state and transient, non-reacting and reacting, gaseous and particle-laden flows, including: pipe flow, combustors, gasifiers, ventilation systems, scrubbers, and much more. *CFD Workshop* models the applicable physical processes occurring in these systems, including: fluid and particle mechanics, heat transfer, chemical reactions, pollutant formation, particle deposition and slag formation.

CFD Workshop is an excellent tool for teaching and training of computational modeling of fluid flow and combustion processes. The intuitive graphical interface greatly simplifies problem setup, and the extensive visualization capabilities provide a powerful illustration of the physical processes being studied. Educational discounts and site licensing are available for *CFD Workshop*.

A brochure is enclosed which provides additional details about *CFD Workshop*. The brochure also provides information on how to contact Combustion Resources for any questions or to obtain additional information. A free demo version of *CFD Workshop* is available from Combustion Resources.

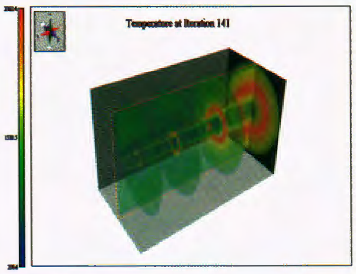
Sincerely,

Dr. Craig N. Eatough
Senior Manager

Dr. L. Douglas Smoot
Consultant

Dr. Scott C. Hill
Senior Developer

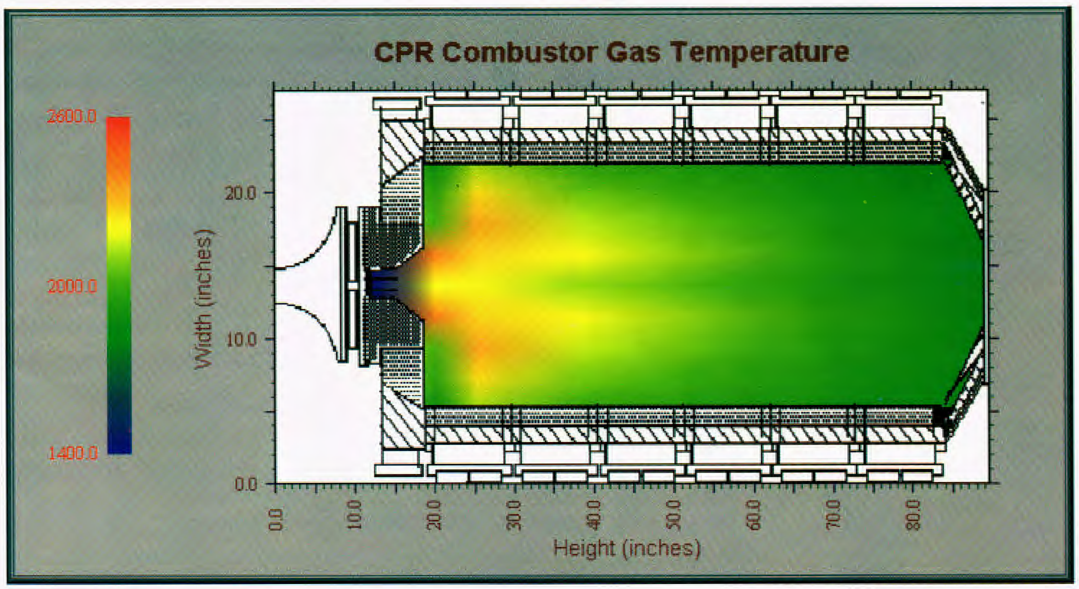
New Software



Have you been searching for a low cost tool to perform Computational Fluid Dynamics (CFD) and combustion modeling on your personal computer?

CFD Workshop

A New Software Tool for Computer Modeling of Fluid Mechanics and Combustion



CFD Workshop Raster Plot of Gas Temperature

Why You Need CFD Workshop

- Low Cost
- PC-Based Computing
- Easy to Use
- 3 Decades Development & Validation
- State-of-the-Art Combustion Models
- Integrated Grid Generation
- Interactive Graphics
- Windows 95/98/NT
- 90-Day Free Technical Support
- Solver Fortran Source Code Available
- Customize with User Routines
- Valuable Teaching Tool
- Simplify Collaboration with Co-Workers

COMBUSTION RESOURCES, LLC

CFD Workshop

HERE'S MORE ABOUT CFD WORKSHOP

Sample Applications

- Gas, Oil, Coal Utility Furnaces
- Wind Tunnel
- Swirling Flows
- Room Ventilation Flow
- Burner Design
- Pollution Control
- Heat Exchanger
- Entrained Gasification
- Etc., Etc,. Etc.

Smart initialization improves convergence and reduces runtimes.

CFD Workshop is a powerful, low cost tool for performing computational fluid dynamics (CFD) and combustion simulations on personal computers (PC's). **CFD Workshop** is designed to simplify the application of CFD (CFD for Dummies!). It provides an integrated environment for problem set-up, solution and visualization of the results. It has a user-friendly interface for quickly generating the computational grid and setting the input and boundary conditions. Run time monitoring shows progress of the solution, including convergence history, mass and energy balances, and plotting of intermediate results. Various plotting capabilities are available for analysis of the results of the simulation.

CFD Workshop runs on PC's with Windows 95/98/NT, making it more accessible to scientists, engineers and students everywhere. **CFD Workshop** is ideal for use in teaching and classroom environments, and simplifies collaboration between co-workers. **CFD Workshop** is easy to install, and includes numerous sample problems which simplify getting started with your own problems and applications. **CFD Workshop** allocates memory dynamically, so problem size is only limited by the amount of memory on your PC.

CFD Workshop uses Automatic Mesh Refinement (AMR) to improve convergence, assists in establishing grid independence of the solution, and optimizes resource utilization (computer memory and CPU). **CFD Workshop** consists of separate modules which can be used for analysis of multiphase flow dynamics and combustion, heat transfer, pollutant formation and fouling and slagging.

CFD Workshop is based on the comprehensive combustion code, PCGC-3, developed at Brigham Young University's *Advanced Combustion Engineering Research Center* (ACERC) over the last three decades. PCGC-3 has been thoroughly tested and evaluated by comparing predictions with measured results from a variety of facilities ranging from laboratory-scale to full-scale systems.

CFD Workshop is distributed by *Combustion Resources, LLC,* a general engineering company with an emphasis on combustion analysis, testing and simulations. Original developers of PCGC-3 participate in *Combustion Resources*, and provide support and continued development of **CFD Workshop**. Consulting services are available through *Combustion Resources* for modeling and testing of combustion systems.

We're on the Web – www.combustionresources.com

Typical Run Times (450 Mhz, Pentium II)

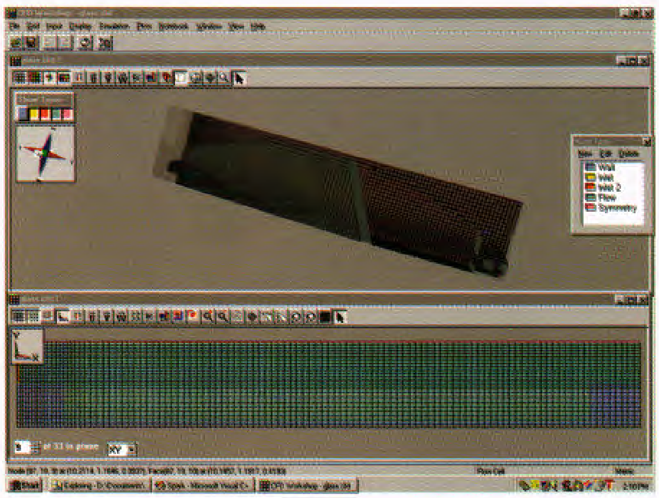
Non reacting flow (2000 cells) - 45 seconds
Reacting flow (2500 cells) - 1.5 minutes
Reacting flow (100,000 cells) - 3.6 hours
Particle-laden reacting flow (2000 cells) - 5.4 minutes
Particle-laden reacting flow (100,000 cells) 13.7 hours

CFD WORKSHOP FEATURES

The modular structure of **CFD Workshop** makes it easier to use by simplifying the user-interface to consist of only the capabilities you specify. The modular structure also makes the memory utilization more efficient. The general characteristics of the modules in **CFD Workshop** are :

Basic Module

- Gaseous Fluid Dynamics
- Grid Generation
- k-epsilon Turbulence Model
- Run-time Monitoring
- Graphical Output



CFD Workshop Screen Shot

Reacting Flow Module

- Equilibrium Reactions
- Gaseous Combustion
- Premixed Combustion (Magnussen/Hjertager)
- Diffusion Controlled Combustion (PDF)
- Turbulence/Chemistry Coupling
- Energy Equation

Particle Module

- Particle Flow/Combustion
- Stochastic Separated Flow (SSF) Model
- Deterministic Trajectory Model
- CPD Coal Devolatilization Model
- Char Oxidation
- Liquid Droplets Flow/Combustion
- Coal Slurries

Heat Transfer Module

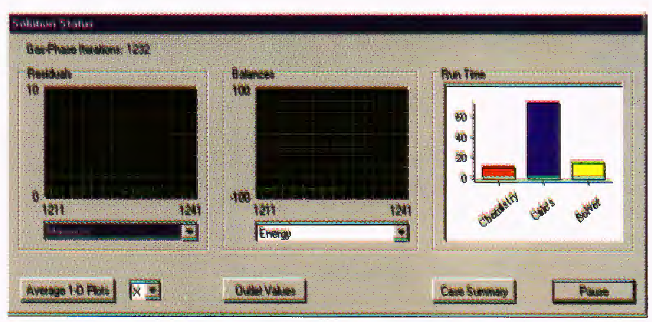
- Radiation (Discrete Ordinates)
- Wall Heat Transfer
  - Convection (Law of Wall)
  - Conduction
  - Outside Wall Temperature
  - Adiabatic
- Assigned Wall Temperatures
- Specified Heat Flux

Pollutants Module

- NO_x Model
  - Fuel NO
  - Thermal NO
  - Heterogeneous NO
  - Reburning
  - Advanced Reburning
- SO_x Sorbent Model
- Soot Formation/Transport

Fouling and Slagging Module (Available 1/1/00)

- Impaction
- Deposition
- Wall Properties



Educational Pricing and site licensing is also available for CFD Workshop

ADDITIONAL CFD WORKSHOP FEATURES

SuperPlot Graphics Package

- Run-time Visualization
- Integrated Graphics
  - X-Y plots
  - Raster
  - Scatter (3-dimensional)
  - Volumetric
  - Surface
  - Velocity
  - Particle Trajectories
- Open GL Based

Multiphase Flow Dynamics

- Gas
- Liquid
- Particles
- Slurries

Integrated Notebook Feature

- Data Comparisons
- Run-time History
- Notes
- Import Graphics

Grid Generation

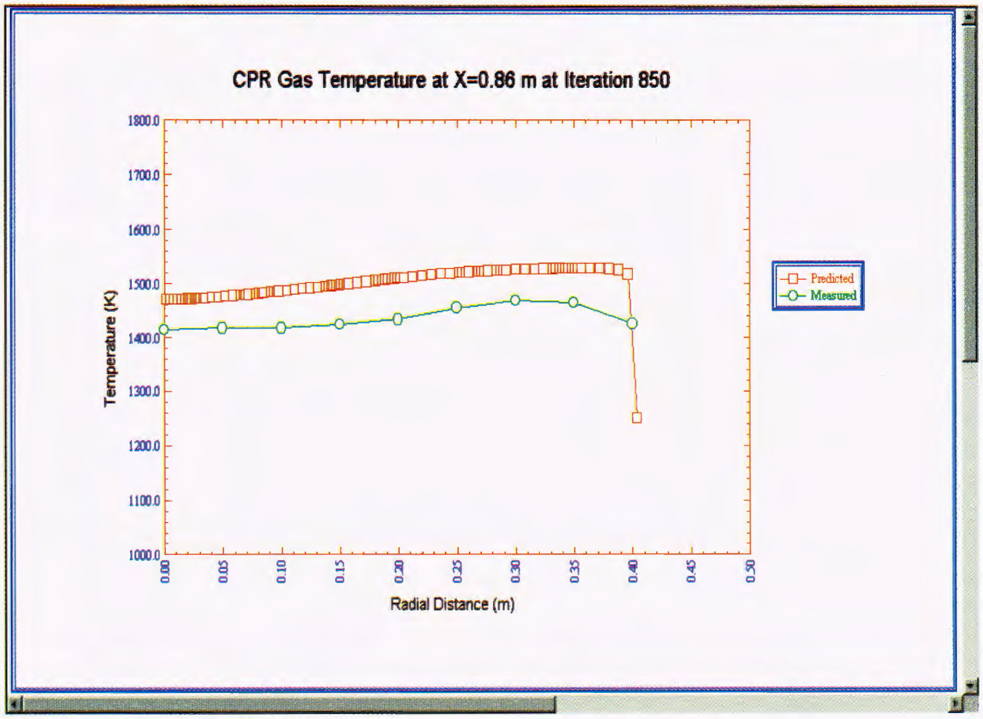
- Cartesian
- Cylindrical
- Automatic Mesh Refinement (AMR)
- Preset Geometries
- Grid Biasing
- 3 Dimensional Visualization
- 3 Dimensional Rotation

System Requirements
Windows 95/98/NT
>200 Mhz (Recommended)
64 MB Memory (>128 MB Recommended)
500 MB Hard Disk
Color Monitor

Code Use Workshop or Onsite Training Available

General

- Integrated Grid Generation and Graphics
- Dynamic Memory Allocation
- Problem Size Only Limited by Memory



CFD Workshop XY plot comparing measured and predicted results

Technical References

1. Hill, S.C. and Smoot, L.D., "A Comprehensive Three-Dimensional Model for Simulation of Combustion Systems: PCGC-3," *Energy & Fuels,* 7, 874 (1993)
2. Smoot, L.D. and Smith, P.J., Coal Combustion and Gasification, Plenum Press, New York (1985).
3. Eaton, A.M.., Smoot, L.D., Hill, S.C., Eatough, C.R, In Print, Prog. Energy Comb. Sci. (1999).
4. Brewster, B.S., Hill, S.C., Radulovic, P.T. and Smoot, L.D., "Chapter 8: Comprehensive Modeling," *Fundamentals of Coal Combustion,* L.D. Smoot, Editor. Elsevier, 567-703 (1993).

Contact us for a Free Demo, Pricing or Ordering Information,

COMBUSTION RESOURCES, LLC

1453 West 820 North
Provo, UT 84601

Phone: (801) 225-4356
Fax: (801) 226-6276
Email: info@combustionresources.com
Internet: www.combustionresources.com

CFD Workshop Order Form

PRODUCT	PRICE	INTRO OFFER	LITE VERSION
CFD Base Module	$2995	$1995 ____	$995____
Reacting Flow Module	$1995	$1495____	$750____
Particle Module	$1995	$1495____	$750____
Heat Transfer Module	$1995	$1495____	$750____
Pollutants Module	$1995	$1495____	$750____
Fouling/Slagging Module (available 4/1/2000)	$1995	$1495____	$750____

Shipping:		
UPS:	Ground	$10.00
	2nd Day	$15.00
	Next Day	$30.00
International:		$65.00

SUBTOTAL ________
SHIPPING ________
TOTAL ________

Please call for educational pricing

Please note: All prices are for an annual license and include eight hours of technical support for the CFD Application with an additional four hours of technical support for each module purchased. The Lite version is limited to 2-dimensional problems and includes one-half of the technical support by e-mail only.

SHIP TO:

Name ______________________________
Organization ______________________________
Address ______________________________
____
____
Telephone ______________________________

METHOD OF PAYMENT:

___Check (payable to Combustion Resources)
___Purchase Order (please attach)
___Visa ___Mastercard ___American Express
Card # ______________________________
Expiration Date ___________
Signature______________________________

Call: 800-827-4351
801-225-4356

Email: sales@supersoft.com
Fax: 801-226-6276

Mail: **Combustion Resources**
1453 West 920 North
Provo, UT 84601

CFD Workshop Free Demo

Fax this form to us at (801) 226-6276 and we will send you a demo or send us an email with the information below to info@combustionresources.com. The demo can also be downloaded from combustionresources.com.

Send the demo to:

Name__________________________________

Organization_____________________________

____

Address_________________________________

____

____

Telephone________________________________

Email____________________________________

Fine, Karlene K.

From: Fine, Karlene K.
Sent: Wednesday, May 03, 2000 8:01 AM
To: 'Zola, Jill'
Subject: RE: Lignite Research Contract No. FY00-XXXVI-100

Thanks, Jill, for letting me know the status of this project. After I receive the contract and the copies of the commitment letters will send the first payment. Thanks for your help. Karlene

-----Original Message-----
From: Zola, Jill [mailto:jzola@undeerc.org]
Sent: Tuesday, May 02, 2000 1:28 PM
To: 'Karlene Fine'
Subject: Lignite Research Contract No. FY00-XXXVI-100

Karlene,

The above agreement has been signed for the EERC and is on its way back to you. As the initial payment hinges on notification of the EERC's receipt of commitment letters from industrial participants and DOE's commitment to the project, I will forward copies of those documents to you upon their receipt.

We currently have three commitment letters totaling $120,000 in industry match. I will wait until we have two more before faxing them on to you. Please let me know if you have any questions or require further documentation.

Thanks,

Jill M. Zola
Contracts Officer
Business and Operations
Energy & Environmental Research Center
(701)777-4581 fax: (701)777-5181
jzola@undeerc.org

Fine, Karlene K.

From: Fine, Karlene K.
Sent: Wednesday, May 03, 2000 7:59 AM
To: 'Clifford Porter'
Subject: FW: Lignite Research Contract No. FY00-XXXVI-100

Clifford--for your information. K

-----Original Message-----
From: Zola, Jill [mailto:jzola@undeerc.org]
Sent: Tuesday, May 02, 2000 1:28 PM
To: 'Karlene Fine'
Subject: Lignite Research Contract No. FY00-XXXVI-100

Karlene,

The above agreement has been signed for the EERC and is on its way back to you. As the initial payment hinges on notification of the EERC's receipt of commitment letters from industrial participants and DOE's commitment to the project, I will forward copies of those documents to you upon their receipt.

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Thanks,

Jill M. Zola
Contracts Officer
Business and Operations
Energy & Environmental Research Center
(701)777-4581 fax: (701)777-5181
jzola@undeerc.org

Clifford Porter

From: Zygarlicke, Chris J. [czygarlicke@undeerc.org]
Sent: Friday, June 30, 2000 10:21 AM
To: Kenneth B. Stuckmeyer (E-mail); Edmundo Vasquez (E-mail); Terry Graumann (E-mail); Dave O'Connor (E-mail); Benson, Steven A.; Gunderson, Jay R.; Pavlish, John H.; Clifford R. Porter (E-mail); Rene Mangal (E-mail); Reda Iskandar (E-mail)
Subject: SCR Blinding Project Meeting

SCR_Blinding_Prospectus.doc

To all concerned:

This is a pre-meeting announcement for planning your schedule and you will receive a letter and email message next week with a finalized meeting date.

We are planning a kickoff meeting for the project entitled EVALUATION OF SCR CATALYST BLINDING DURING COAL COMBUSTION on either Wednesday August 2, 2000 or Thursday August 3, 2000. At this meeting we would refine, revise, and adjust the work scope and essentially get the project going. It would be in Grand Forks, ND and would only last a morning (i.e. 8:30 a.m.-noon). We are leaving space in the afternoon for those that would want to catch afternoon flights or get a tour of the EERC. I have attached an updated project overview/prospectus as a refresher.

We are excited about this project and want to get it going as soon as possible. We still have need for one additional commercial sponsor to completely meet our projected budget and we are confident that we will meet that goal in the next couple of weeks. Current sponsors include: Alliant Energy, Otter Tail Power Company, Ontario Power Technologies, AmerenUE, North Dakota Industrial Commission, EPRI, and the U.S. Department of Energy.

Please check your calendar and keep these dates open, if possible.

Best Regards,

Chris

Chris J. Zygarlicke
Energy & Environmental Research Center
University of North Dakota
Box 9018
Grand Forks, ND 58202-9018
phone 701-777-5123
fax 701-777-5181
czygarlicke@eerc.und.nodak.edu

<<SCR_Blinding_Prospectus.doc>>

EVALUATION OF SCR CATALYST BLINDING DURING COAL COMBUSTION

BACKGROUND

Nitrogen oxide emission limits will be reduced in the near future, requiring retrofits of existing units with low-NO_x burners and selective catalytic reduction (SCR) systems. Coals containing high alkali and alkaline-earth contents (sodium and calcium) in addition to moderate sulfur levels have the potential to impair the operation of SCR systems by the formation of sulfate-based deposits on catalyst surfaces, leading to higher NO_x emissions and potentially high ammonia slip. The Energy & Environmental Research Center (EERC) at the University of North Dakota is proposing a test program to determine the degree of catalyst blinding that may occur during operation of SCR catalyst in units firing low-rank coals. The project will assess blinding while firing Powder River Basin subbituminous coal and lignite at full scale.

TESTING

A skid-mounted test rig will be constructed to conduct full-scale evaluation of the SCR catalyst. The system consists of a catalyst section, an ammonia injection system, and sampling ports for NO_x at the inlet and exit. The portable system will be installed in the region ahead of the air heater at a full-scale utility and will isokinetically extract a slip stream from the flue gas duct using an induced-draft fan. Two units are expected to be constructed so that data may be collected simultaneously from two full-scale sites. Testing will be done on up to four boilers, including tests on a cyclone boiler firing Powder River Basin (PRB) coal, a lignite boiler, and a pulverized coal boiler burning PRB. NO_x emissions and total flue gas analysis will be obtained from each sampling port over a specified time period to study the blinding effect of fly ash and ash deposits on catalyst performance. A catalyst vendor will be involved in the project.

DELIVERABLES

This project aims to provide the sponsor with key information on the impacts of coal ash components on the performance of SCR catalysts under realistic conditions.

POTENTIAL SPONSORS

A potential sponsor is any utility facing NO_x emission limit reduction currently firing low-rank coal, alone, or as part of a blend. The project requires a minimum of six industrial sponsors to fully fund the work described above.

CURRENT SPONSORS

Alliant Energy, Otter Tail Power Company, Ontario Power Technologies, AmerenUE, North Dakota Industrial Commission, EPRI, and the U.S. Department of Energy.

INDUSTRIAL SPONSORSHIP

Industry support for the 2-year project requires an annual contribution of $20,000, for a total contribution of $40,000.

TIME FRAME

The project time frame is for 2 years. During the first year portable SCR test units will be built and installed. Testing will run into the second year on the units. Bench-scale testing will occur also in the first year to identify fuel specific impacts on SCR blinding. All work wil will be completed during Year 2, and the final project report will be delivered.

CONTACTS

Interested parties may obtain a detailed proposal or a more detailed description of the project by contacting any of the following individuals by telephone or e-mail:

John H. Pavlish, Senior Research Manager
701-777-5268
jpavlish@undeerc.org

Jay R. Gunderson, Research Engineer
701-777-5258
jgunderson@undeerc.org

Chris J. Zygarlicke, Research Manager
701-777-5123
czygarlicke@undeerc.org

Steve A. Benson, Associate Director
701-777-5177
sbenson@undeerc.org

DETAILED BUDGET

EVALUATION OF POTENTIAL SCR CATALYST MASKING DURING COAL COMBUSTION
MULTI CLIENT / DOE
PROPOSED START DATE: 01-Jul-00
EERC PROPOSAL #2000-0071

24-Jan-00

LABOR	LABOR CATEGORY	HOURLY RATE	TOTAL HOURS	TOTAL $ COST	NDIC SHARE HOURS	NDIC SHARE $ COST	OTHER COMMERCIAL SHARE HOURS	OTHER COMMERCIAL SHARE $ COST	EERC JSRP SHARE HOURS	EERC JSRP SHARE $ COST
C. ZYGARLICKE	PROJECT MANAGER	$32.35	680	$21,998	184	$5,952	216	$6,988	280	$9,058
J. GUNDERSON	PRINCIPAL INVESTIGATOR	$24.09	1200	$28,908	328	$7,902	372	$8,961	500	$12,045
D. MCCOLLOR	RESEARCH SCIENTIST/ENGINEE	$25.24	1314	$33,165	360	$9,086	440	$11,106	514	$12,973
D. TOMAN	RESEARCH SCIENTIST/ENGINEE	$24.23	1140	$27,622	312	$7,560	336	$8,141	492	$11,921
D. EVENSTAD	RES. TECHNICIAN	$20.65	1000	$20,650	272	$5,617	328	$6,773	400	$8,260
J. TIBBETTS	RES. TECHNICIAN	$20.56	840	$17,270	224	$4,605	276	$5,675	340	$6,990
S. BENSON	PRINCIPAL SCIENTIST	$41.35	680	$28,118	184	$7,608	216	$8,932	280	$11,578
---------------	SENIOR MANAGEMENT	$42.47	272	$11,552	72	$3,058	88	$3,737	112	$4,757
---------------	QUALITY CONTROL MANAGER	$22.29	78	$1,739	24	$535	24	$535	30	$669
---------------	RESEARCH SCIENTIST/ENGINEE	$28.96	62	$1,796	18	$521	22	$637	22	$638
---------------	RESEARCH TECHNICIAN	$14.91	532	$7,932	144	$2,147	156	$2,326	232	$3,459
---------------	TECHNICAL SUPPORT SERVICE!	$11.63	389	$4,524	80	$930	120	$1,396	189	$2,198
			8187	$205,274	2202	$55,521	2594	$65,207	3391	$84,546
ESCALATION ABOVE CURRENT BASE		7.5%		$15,396		$4,164		$4,891		$6,341
TOTAL DIRECT LABOR				$220,670		$59,685		$70,098		$90,887
FRINGE BENEFITS - % OF DIRECT LABOR		52%		$114,748		$31,036		$36,451		$47,261
TOTAL LABOR				$335,418		$90,721		$106,549		$138,148
OTHER DIRECT COSTS										
TRAVEL				$14,696		$4,000		$5,295		$5,401
SUPPLIES				$12,200		$3,320		$4,500		$4,380
EQUIPMENT > $750				$21,500		$0		$0		$21,500
COMMUNICATIONS - PHONES & POSTAGE				$2,200		$600		$800		$800
OFFICE (PROJECT SPECIFIC SUPPLIES)				$3,731		$950		$1,400		$1,381
GENERAL (FREIGHT, FOOD, MEMBERSHIPS, ETC.)				$300		$80		$100		$120
GRAPHICS				$24,080		$6,600		$8,700		$8,780
NATURAL MATERIALS ANALYTICAL RES. LAB.				$41,996		$12,100		$16,200		$13,696
FUELS & MATERIALS RESEARCH LAB				$3,651		$1,000		$1,300		$1,351
ANALYTICAL RESEARCH LAB.				$5,315		$1,500		$1,900		$1,915
COMBUSTION TEST SERVICE				$21,451		$7,000		$6,700		$7,751
PARTICULATE ANALYSIS				$6,863		$2,000		$2,400		$2,463
TOTAL OTHER DIRECT COST				$157,983		$39,150		$49,295		$69,538
TOTAL DIRECT COST				$493,401		$129,871		$155,844		$207,686
INDIRECT COST - % OF MTDC			VAR	$239,932	54%	$70,129	54%	$84,156	46%	$85,647
TOTAL ESTIMATED COST				$733,333		$200,000		$240,000		$293,333

SUMMARY BUDGET

EVALUATION OF POTENTIAL SCR CATALYST MASKING DURING COAL COMBUSTION
MULTI CLIENT / DOE
PROPOSED START DATE: 01-Jul-00
EERC PROPOSAL #2000-0071 24-Jan-00

CATEGORY	TOTAL HOURS	TOTAL $ COST	NDIC SHARE HOURS	NDIC SHARE $ COST	OTHER COMMERCIAL SHARE HOURS	OTHER COMMERCIAL SHARE $ COST	EERC JSRP SHARE HOURS	EERC JSRP SHARE $ COST
TOTAL DIRECT LABOR	$8,187	$220,670	$2,202	$59,685	$2,594	$70,098	$3,391	$90,887
FRINGE BENEFITS - % OF DIRECT LABOR 52%		$114,748		$31,036		$36,451		$47,261
TOTAL LABOR		$335,418		$90,721		$106,549		$138,148
OTHER DIRECT COSTS								
TRAVEL		$14,696		$4,000		$5,295		$5,401
SUPPLIES		$12,200		$3,320		$4,500		$4,380
EQUIPMENT > $750		$21,500		$0		$0		$21,500
COMMUNICATIONS - PHONES & POSTAGE		$2,200		$600		$800		$800
OFFICE (PROJECT SPECIFIC SUPPLIES)		$3,731		$950		$1,400		$1,381
GENERAL (FREIGHT, FOOD, MEMBERSHIPS, ETC.)		$300		$80		$100		$120
FEES		$103,356		$30,200		$37,200		$35,956
TOTAL OTHER DIRECT COST		$157,983		$39,150		$49,295		$69,538
TOTAL DIRECT COST		$493,401		$129,871		$155,844		$207,686
INDIRECT COST - % OF MTDC	VAR	$239,932	54%	$70,129	54%	$84,156	46%	$85,647
TOTAL ESTIMATED COST		$733,333		$200,000		$240,000		$293,333

NOTE: Due to limitations within the University's accounting system, the system does not provide for accumulating and reporting expenses at the Detailed Budget level. The Summary Budget is presented for the purpose of how we propose, account, and report expenses. The Detailed Budget is presented to assist in the evaluation of the proposal.

Energy & Environmental Research Center
UNIVERSITY OF NORTH DAKOTA
15 North 23rd Street — PO Box 9018 / Grand Forks, ND 58202-9018 / Phone: (701) 777-5000 Fax: 777-5181
World Wide Web Server Address: www.eerc.und.nodak.edu

July 7, 2000

Mr. Clifford R. Porter
North Dakota Industrial Commission
PO Box 2277
1016 East Owens Avenue, Suite 200
Bismarck, ND 58501

Dear Mr. Porter:

Subject: Kickoff Meeting for Selective Catalytic Reduction (SCR) Blinding Project

As a member of the consortium project entitled Evaluation of Potential SCR Catalyst Blinding During Coal Combustion, you are invited to attend a kickoff meeting on Thursday, August 3, 2000, at the Energy & Environmental Research Center (EERC). The project is valued at over $700,000, with funding being provided by the North Dakota Industrial Commission (NDIC), EPRI, five utilities, and the U.S. Department of Energy (DOE). By August, we will have acquired the necessary funding and will initiate the project with a kickoff meeting.

The purpose of the kickoff meeting is to 1) gather all parties involved (the EERC, utilities, NDIC, DOE) to foster communication, discussion, and teamwork; 2) establish a representative contact from each sponsoring organization; 3) familiarize all participants with the project and with the EERC; 4) receive input to refine the project work scope; 5) discuss design and operating conditions of the SCR field unit (test reactor); 6) make decisions on which power plants and coals/coal blends to test; and 7) discuss utility involvement and role in serving as a host site for field testing.

We hope that you will be able to attend this important meeting. If you, or another organization representative, are not able to attend, please provide your input before the meeting, and we will communicate with you regarding the meeting content (questions, discussions, and major decisions) and present your comments and suggestions at the meeting. Meeting minutes will be prepared and sent out promptly to all participants.

A tentative meeting agenda is as follows:

- We suggest that you fly in on Wednesday, August 2, 2000, and spend the night at a hotel.

- The meeting will begin promptly at 8:30 a.m. on Thursday, August 3, 2000. We will discuss some background on proposed mechanisms of SCR blinding, the design and experimental testing involving the test SCR reactor units, bench-scale testing, and the interpretation of SCR blinding mechanisms at the full scale. We will also cover project schedules, deliverables, and other project logistics.

- There will be a lunch either at the EERC or off-site.

- We will conclude with further discussion and a tour for those who are unfamiliar with EERC facilities by early afternoon so that participants can catch mid to late afternoon flights.

We sincerely look forward to working with you on this timely and important research project. Having firsthand knowledge of the effects of lignite and subbituminous Powder River Basin coal on SCR catalyst blinding will be invaluable as you develop and implement NO_x reduction strategies.

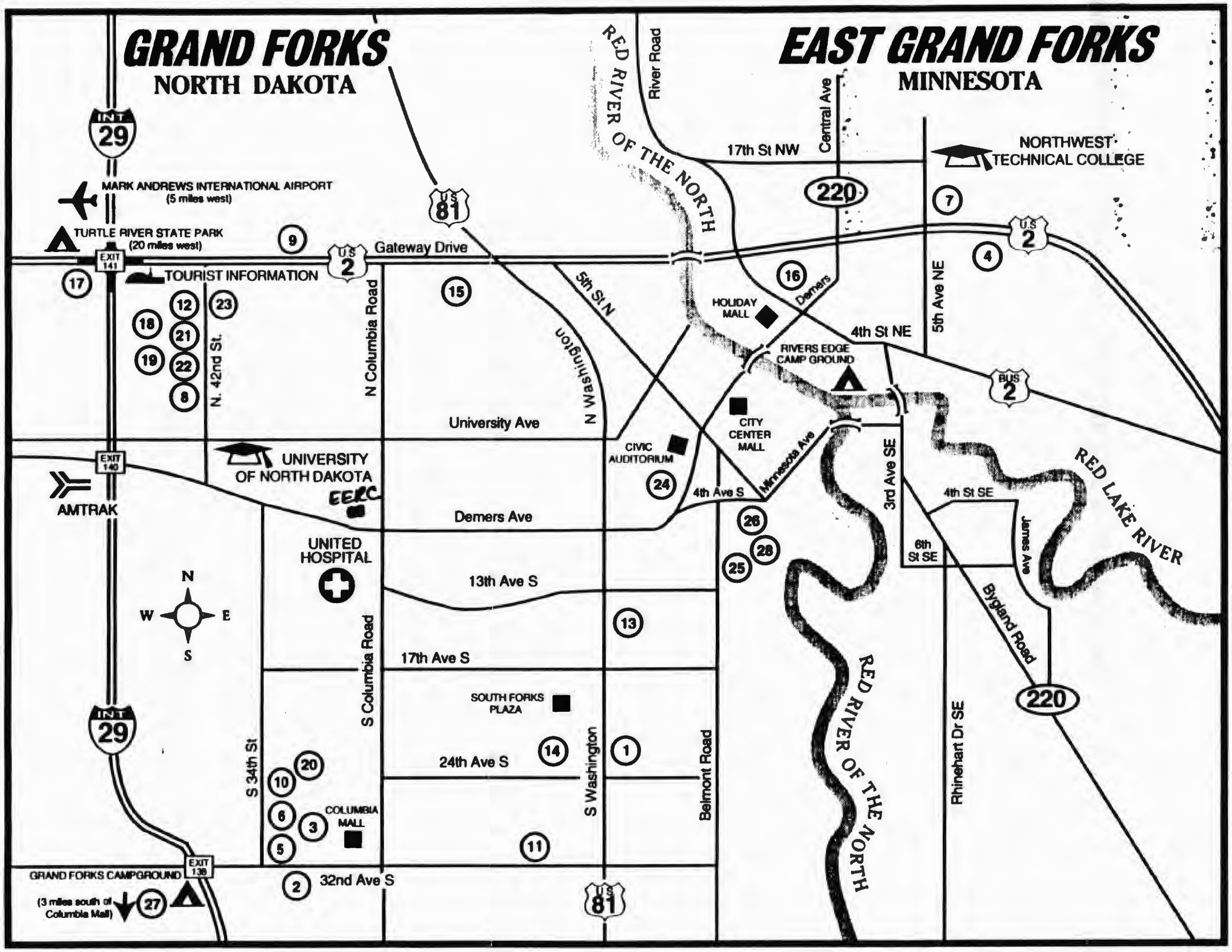
Please let me know whether you will be attending the meeting. I have enclosed some information on recommended hotels and a map on how to get to the EERC. We look forward to hearing from you. You may contact me at (701) 777-5123 or czygarlicke@undeerc.org.

Sincerely,

Christopher J. Zygarlicke
Research Manager

CJZ/jdk

Enclosure



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or (701)746-0444

1 - Ambassador Motel
2 - C'mon Inn
3 - Comfort Inn
4 - Comfort Inn & Suites East
5 - Country Hospitality Inn
6 - Days Inn
7 - East Gate Motel
8 - Econo Lodge
9 - Fabulous Westward Ho Best Western
10 - Fairfield Inn
11 - Happy Host Inn
12 - Holiday Inn
13 - Lucky Inn
14 - North Star Inn
15 - Plainsman Motel
16 - Plaza Motel
17 - Prairie Inn
18 - Ramada Inn
19 - Road King Inn
20 - Road King Inn-Columbia Mall
21 - Select Inn
22 - Super 8 Motel
23 - Super Highway Inn
24 - Town House Best Western

BED & BREAKFAST

25 - Big Red House
26 - Lord Byron's
27 - Merrifield House
28 - 511 Reeves

Come Join Us! Accommodations Guide

Greater Grand Forks

For more information:
Convention & Visitors Bureau
4251 Gateway Drive
Grand Forks, ND 58203
1-800-866-4566 or (701)746-0444

			# of Rooms	Child Discount	Rollaways	HBO	Radio	24 Hr. Desk	Restaurant	Lounge	Casino	Room Service	Off Sale	Valet Service	Laundry	Pool	Sauna	Whirlpool Suites	Whirlpool / Hot Tub	Vending	Video Games	Refrigerator	Microwave	Kitchenette	Pets	Handicap Rooms
	1	**Ambassador Motel** 1-800-833-5319 2021 S Washington St. (701)772-3[illegible]3	24	●	●	●		●							●					●		●	●	●	●	●
	2	**C'mon Inn** 3051 32nd Avenue S (701)775-3320 1-800-255-2323	80	●	●	●		●								●		●	●	●	●	●	●			●
	3	**Comfort Inn** 3251 30th Avenue S (701)775-7503 1-800-228-5150	67	●	●			●						●		●			●	●	●				●	●
	4	**Comfort Inn & Suites East** Hwy 2 East, EGF, MN (218)773-9545 1-800-452-5420	80	●	●			●		●				●	●	●	●	●	●	●	●	●	●	●	●	●
	5	**Country Hospitality Inn** 3350 32nd Avenue S (701)775-5000 1-800-456-4000	89	●	●		●	●						●	●	●	●		●	●	●	●	●			●
	6	**Days Inn** 3101 S 34th St. (701)775-0060 1-800-325-2525	52	●	●			●						●		●			●	●	●	●	●		●	●
	7	**East Gate Motel** Highway 2 East, EGF, MN (218)773-9822 1-800-639-6708	60		●			●												●					●	●
	8	**Econo Lodge** 900 N 43rd St. (701)746-6666 1-800-424-4777	44		●	●		●												●					●	●
	9	**Fabulous Westward Ho Best Western** Highway 2 West (701)775-5341 1-800-528-1234	108	●	●		●	●	●	●	●	●	●	●	●	●	●			●	●				●	
	10	**Fairfield Inn** 3051 S 34th St. (701)775-7910 1-800-228-2800	63	●	●	●	●	●								●			●	●	●	●	●		●	●
	11	**Happy Host Inn** 3101 S 17th St. (701)746-4411 1-800-489-4411	62	●	●	●		●												●						●
FAX: 701-780-9112	12	**Holiday Inn** 1210 N 43rd St. (701)772-7131 1-800-465-4329 *	150	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●					●
	13	**Lucky Inn** 1403 S Washington St. (701)772-3459	19	●	●	●		●												●		●		●		
	14	**North Star Inn** 2100 S Washington St. (701)772-8151	63	●	●	●	●	●	●			●				●	●		●	●	●			●		●
	15	**Plainsman Motel** 2201 Gateway Drive (701)775-8134 1-800-341-8000	50	●	●	●									●					●		●	●		●	●
	16	**Plaza Motel** 309 Demers Avenue, EGF, MN (218)773-1179	24	●		●		●												●		●	●	●		
	17	**Prairie Inn** 1211 N 47th St. (701)775-9901 1-800-571-1115	99	●	●			●								●				●	●				●	●
FAX: 701-775-9774	18	**Ramada Inn** 1205 N 43rd St. (701)775-3951 1-800-570-3951 *	100	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●	●	●	●				●
	19	**Road King Inn - North** I-29 & Highway 2 (701)775-0691 1-800-950-0691	101	●	●	●	●	●						●	●					●						
FAX: 701-746-8586	20	**Road King Inn - Columbia Mall** at Columbia Mall (701)746-1391 1-800-950-0691	85	●	●	●	●	●						●	●	●		●	●	●	●	●	●			●
	21	**Select Inn** 1000 N 42nd St. (701)775-0555 1-800-641-1000	120	●		●		●						●	●					●						●
	22	**Super 8 Motel** 1122 N 43rd St. (701)775-8138 1-800-800-8000	33	●	●	●		●												●						●
	23	**Super Highway Inn** 4001 Gateway Dr. (701)795-9960 1-800-795-4001	32	●	●	●		●												●		●	●			●
FAX: 701-746-1407	24	**Town House Best Western** 710 1st Avenue N (701)746-5411 1-800-867-9797 *	113	●	●	●	●	●	●	●	●	●	●	●		●	●		●	●	●	●	●	●	●	●

Numbers correspond with numbers on map. Dots indicate services available.
All properties have cribs, cable, outside outlets, credit card service, and non-smoking rooms available.

* FREE SHUTTLE SERVICE

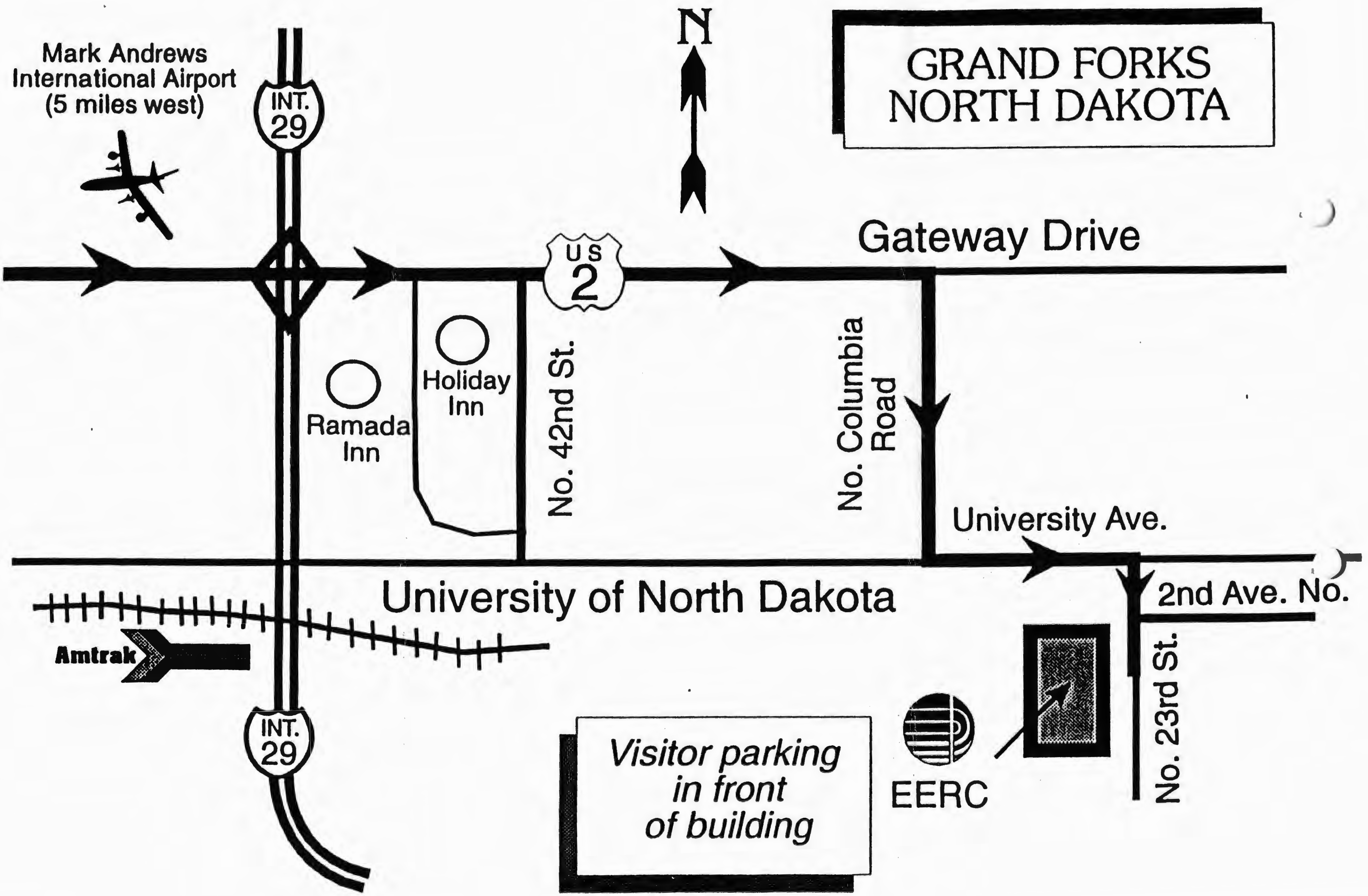
BED & BREAKFAST

(25) **Big Red House**
729 Belmont Road
Grand Forks, ND
(701)[illegible]332

(26) **Lord Byron's**
521 S 5th Street
Grand Forks, ND
(701)775-0194

(27) **Merrifield House**
Rt 1, Box 151
[illegible]nd Forks, ND
[illegible])775-4250

(28) **511 Reeves**
511 Reeves Drive
Grand Forks, ND
(701)772-9663


GRAND FORKS
NORTH DAKOTA
N
Mark Andrews
International Airport
(5 miles west)
INT.
29
US
2
Gateway Drive
Holiday
Inn
Ramada
Inn
No. 42nd St.
No. Columbia
Road
University Ave.
University of North Dakota
2nd Ave. No.
Amtrak
INT.
29
EERC
No. 23rd St.
Visitor parking
in front
of building

Clifford Porter

From: Foerster, LaRae [lfoerster@undeerc.org]
Sent: Thursday, November 16, 2000 1:43 PM
To: Bill Rogers (E-mail); Blair Seckington (E-mail); Brian Stage (E-mail); Charles Sedman (E-mail); Clifford Porter (E-mail); David T. Michaud (E-mail); Dennis Laudal (E-mail); Denny Smith (E-mail); Edmundo Vasquez (E-mail); James D. Kilgroe (E-mail); John Pavlish (E-mail); Kent Wanninger (E-mail); Kevin Galbreath (E-mail); Larry Monroe (E-mail); Manojit Sukul (E-mail); Mike Geers (E-mail); Paul Chu (E-mail); Reda Iskandar (E-mail); Rene Mangal (E-mail); Richard Read (E-mail); Scott Renninger (E-mail); Thomas A. Burnett (E-mail)
Subject: Evaluation of Mercury Speciation at Power Plants Using SCR and SNCR NOx Control Technologies

Prospectus - Full-Scale.doc

Prospectus - Full-Scale.wpd

Good Afternoon!

On behalf of John Pavlish and Dennis Laudal at the Energy & Environmental Research Center, we would like to thank you for your interest in the subject project. Details of the project are further discussed in the attached prospectus.

The pilot-scale SCR/mercury project is near completion. It appears for some coals, ammonia and/or the SCR catalyst may increase the particulatebound mercury concentration, thereby increasing mercury removal downstream of an ESP. The increased mercury removals as measured by the flue gas measurements were confirmed with mercury analyses of the corresponding fly ash. If the limited data is used in a linear regression analysis, the chlorine, sulfur, and calcium content of the coal appears to correlate with mercury speciation across the SCR. The chemistry of mercury on an SCR catalyst appears to be quite complex.

However, because ammonia slips were higher than expected in a fullscale SCR or selective noncatalytic reduction application and ammonia concentration may directly impact mercury speciation and removal, these results may or may not be consistent with fullscale applications. Therefore, the applicability of the conclusions from this pilotscale investigation must be evaluated by performing similar flue gas and fly ash measurements at utilityscale boilers equipped with SCR units.

Based on the recent discussions, we feel we are ready to move on to the field testing stage of the project, however, we are not exactly sure of what our next step should be. A meeting or conference call seems appropriate, but we thought that others may have some different ideas. We would like to begin to develop a final test plan that can be submitted as a proposal. To do this potential host sites need to be identified. Obviously, this will take a lot of planning and organization. Therefore, we would like some ideas on how to proceed (i.e., conference call, meeting).

Please understand that with the increasing number of participants, and the holidays, it may be difficult to find a time that is convenient for everyone, so please bear with us as we try to find a time and day that will provide the best results in the most timely manner.

Please express your interest in this project and forward any comments, suggestions, or ideas you may have to LaRae Foerster. You can reach me by phone at (701) 777-5246, by fax at (701) 777-5181, or by e-mail at lfoerster@undeerc.org <mailto:lfoerster@undeerc.org> . We will determine how to proceed based on the response that we receive.

Thank you,

LaRae Foerster
Energy & Environmental Research Center
University of North Dakota
PO Box 9018
Grand Forks, ND 58202-9018
Phone: (701) 777-5246
Fax: (701) 777-5181
E-mail: lfoerster@undeerc.org <mailto:lfoerster@undeerc.org>

<<Prospectus - Full-Scale.doc>> <<Prospectus - Full-Scale.wpd>>

EVALUATION OF MERCURY SPECIATION AT POWER PLANTS USING SCR AND SNCR NOX CONTROL TECHNOLOGIES

EERC Prospectus

Prepared for:
Alliant Energy
American Electric Power Company
Cinergy
Midwest Generation
NiSource
North Carolina Power & Light
Ontario Power Generation
Southern Company
Tennessee Valley Authority
Wisconsin Electric & Power Company

Electric Power Research Institute
Environmental Protection Agency
National Energy Technology Laboratory

Prepared by:

John H. Pavlish
Dennis L. Laudal

Energy & Environmental Research Center
University of North Dakota
PO Box 9018
Grand Forks, ND 58202-9018

EVALUATION OF MERCURY SPECIATION AT POWER PLANTS USING SCR AND SNCR NOX CONTROL TECHNOLOGIES

1.0 INTRODUCTION

Depending on the size and type of boiler, the 1990 Clean Air Act Amendments (CAAA) require specific reduction in NO_x emissions from coal-fired electric utilities. To meet CAAA Phase I requirements, the most common NO_x reduction strategy has been the installation of low-NO_x burners. These burners have the capability of reducing NO_x emissions by 40%–60%. However, as Phase 2 of the 1990 CAAA are implemented, and with the introduction of the more recent NOx SIP call regulation, and with possible establishment of new $PM_{2.5}$ and regional haze regulations, there are increased incentives to reduce NO_x emissions to a level below what can be achieved using low-NO_x burners. Selective catalytic reduction (SCR) technology, which can reduce NO_x emissions by >90%, and selective non-catalytic reduction (SNCR), which can reduce NO_x emissions by an additional 30% over low-NOx burners, are two NOx control strategies that are becoming more attractive and commercially available. Within the next 5 years, a number of U.S. utilities will be implementing one of these two approaches for overall NOx compliance.

SCR units have the potential to achieve the highest NO_x reductions by reducing NO_x to N_2 and H_2O in the presence of a catalyst. Generally, ammonia is the reducing gas and the system is operated a temperature of –350EC. The catalyst most commonly used to promote this reaction is vanadium/titanium metal oxide (V_2O_5/WO_3–TiO_2). Laboratory-scale testing at the Energy & Environmental Research Center (EERC) and elsewhere indicates that metal oxides, including V_2O_5 and TiO_2, promote the formation of oxidized mercury (Hg^{2+}) and/or particulate-bound mercury in relatively simple flue gas mixtures (1–5).

The SNCR process is similar to the SCR approach with respect to reducing NO_x to N_2 and H_2O. A reagent, most likely urea, is injected into the combustion products to react with the NO_x to form N_2 and H_2O. The reaction zone occurs in a rather narrow temperature zone, different for each application, and at higher temperatures than SCRs. Given that this reaction occurs at higher temperatures, farther upstream, increasing residence time, other combustion products may react which may ultimately affect mercury speciation. Consequently, mercury speciation impacts could be different for SCR and SNCR. Other low NOx options such as reburning, and overfire air, in combination with SNCR may also impact mercury speciation.

The proposed project addresses the question, What is the impact that SCR, SNCR, and other low NOx control technologies may have on total mercury emissions and on the speciation of mercury? Possible mechanisms that include:

- Changing the flue gas chemistry. The use of SCR, SNCR, or other low-NOx technologies result in reduced NO_x levels in the flue gas, and with SCR and SNCR the addition of small amounts of ammonia. It is well known that NO_x, particularly NO_2, has a substantial effect on mercury chemistry (6). The gas-phase effects of ammonia on mercury are unknown.

- Changing the fly ash chemistry. It is possible that the chemistry of the fly ash is changed such that its ability to adsorb or convert mercury species is changed.

- Catalytically oxidizing the mercury. It is possible that vanadium-based catalysts can promote the formation of Hg^{2+}. However, the extent to and the temperatures at which this can occur are unknown.

- Increasing wall deposition. SCR and SNCR systems generally result in the deposition of ammonium bisulfate and ammonium sulfate in the air preheater as well as the duct walls. It is not known whether this increased deposition could impact mercury emissions or mercury speciation.

Based on ICR results to date, it appears that there is a significant lack of good information on mercury speciation for systems that have low-NOx systems. This lack of information causes concern on how to estimate mercury emissions from these sources. And, as additional installations of low-NOx technologies are expected, how to predict emissions in the future. Regulatory agencies had hoped that SCR would enhance mercury conversion/capture, thus making it a technology that could be used for multi-pollutant control. As it is likely that mercury controls will be required, it is clear that a technology that promotes both NOx control as well as mercury control is desirable. Given the pilot- and full-scale data that exists, it is still unclear what impact NOx control may have on mercury control. Additionally, data gathered thus far is based on wet chemistry batch type sampling which may not reflect how the unit operates and therefore does not reflect actual mercury emissions.

In an attempt to begin evaluating the potential impact that low NOx control technologies may have on mercury speciation, pilot-scale tests were conducted at the EERC firing four different coals: a low- , medium- and high-sulfur bituminous coal and a Powder River Basin (PRB) subbituminous coal. For the medium to high-sulfur coals, the use of SCR appeared to result in oxidation of elemental mercury and increased mercury capture by the fly ash. This effect was not apparent with the low sulfur, low chlorine bituminous and the PRB coal. The low-sulfur bituminous coal showed no conversion across the SCR however there was a significant amount of the mercury captured in the fly ash. Given these results, it is apparent that coal type does play a major role in mercury speciation across an SCR.

To help determine the impact of low-NOx control technologies on mercury speciation, the EERC is proposing to test and sample flue gases from several power plants, possibly including TVA's Paradise Station where a SCR reactor was recently installed. The EERC is proposing to simultaneously sample upstream and downstream of SCR and other air pollution control systems at a predetermined number of power plants to evaluate the potential effects SCR, SNCR, and other low-NOx control technologies may have on mercury speciation and emission control. The primary research goal is verify previous pilot-scale results obtained at the EERC and to expand the understanding that SCR, SNCR, and other low-NOx control technologies may have on mercury speciation and emissions.

2.0 PROJECT OBJECTIVE

The primary research goal of this project is to verify previous pilot-scale results obtained at the EERC and to expand the understanding that SCR, SNCR, and other low-NOx control technologies may have on mercury speciation and emissions.

Specific hypotheses that will be investigated include the following:

- A V_2O_5-based SCR catalyst promotes the formation of Hg^{2+} and/or particulate-bound mercury through Hg^0–flue gas–metal oxide interactions.

- Operation of SCR and SNCR with specific coal types and appropriate ammonia injection will result in optimum conversion of Hg^0 to Hg^{2+} and/or particulate-bound mercury.

- Low-NOx control technologies such as low-NOx burners, in combination with reburn technologies and/or overfire air do promote the conversion of Hg^0 to Hg^{2+} and/or particulate-bound mercury.
- The promotion of Hg^{2+} and particulate-bound mercury formation improves the mercury removal efficiencies of conventional emission control devices.
- The ash collected under low-NOx conditions will not leach and is thermally stable.

3.0 STATEMENT OF WORK

3.1 Power Plant Testing

Power plants to be sampled will be selected and decided on by the project team under the following guidelines.

1. Test a unit with SCR NOx control using continuous mercury monitoring at inlet and outlet locations to assess and quantify mercury variability, forms, concentration, and emissions.

2. Test a unit with SNCR NOx control using continuous mercury monitoring at inlet and outlet locations to assess and quantify mercury variability, forms, concentration, and emissions.

3. Test a unit to evaluate the impact that SO3 and ammonia has on mercury variability, forms, concentration, and emissions. This could be combined with one of the above sites.

4. Using continuous mercury monitoring at various locations, test a unit to evaluate effects of fuel variability, sootblowing, air heater cleaning, load cycling, and other possible low-NOx combustion conditions.

Coal type is also a consideration that will be discussed and decided on by the project team.

3.1.1 Description of Sampling

Mercury speciation sampling is being proposed for up to four units, with Units 1 and 2 at the TVA Paradise Station being given initial consideration. An SCR reactor was recently installed and commissioned on Unit 2. With the exception of the installation of the SCR, these two units are very similar. In addition to firing the same coal, they both have the following characteristics:

- Nominal thermal input of 700 MW
- Cyclone boilers
- Wet venturi scrubbers for the removal of SO_2 and fly ash

Currently, both Units 1 and 2 have an ESP. However, to make room for the installation of the SCR, the ESP is being removed from Unit 2. The ESPs on these two units were installed in the 1960s and are very inefficient. The wet venturi scrubber is the primary particulate removal device for both units. Therefore, the ESPs are not expected to have much if any effect on mercury speciation.

At each unit, sampling would be conducted at four locations:

- Inlet to the SCR, or air preheater (for SNCR units)
- Outlet of SCR, or air preheater (for SNCR units)
- Inlet of ESP/baghouse
- Stack

It is envisioned that sampling would be done for a 12-14 day period using mercury continuous emissions monitors (CEMs) developed by the EERC, followed up by 4

Solid Ontario Hydro (SOH) methods and, optionally, up to 4 wet chemistry Ontario Hydro (OH) methods at each location throughout the sampling period to verify mercury CEM results. One of the mercury CEMs would be located at the stack for the entire sampling period, monitoring mercury in the flue gas on a 24-hour basis. The other mercury CEM would be rotated among the other 3 locations, sampling approximately 3 to 4 days at each location. Again, SOH and OH sampling would be taken coincident with sampling at these locations to verify mercury concentration/speciation and CEM performance.

In addition to the mercury speciation sampling, chloride samples using U.S. Environmental Protection Agency (EPA) Method 26A, SO_3 samples using the selective condensation method, and the ammonia slip measurements will also be taken.

3.1.2 Sampling Protocols

The proposed sampling strategy is based on providing continuous real time mercury data. The use of mercury CEMs is intended to provide 24-hour real-time data. Use of the SOH and OH mercury speciation methods are meant to serve as a quality control measure. During the sampling period, it is expected that the units will be operating at or near normal conditions. The mercury CEMs will operate 24 hours a day, thus providing data that can be related to changes in operating conditions. Operating conditions (i.e. load, excess O_2, NO_x, etc.) will be logged by plant personnel during the sampling period. SOHs and, optionally, OHs will be performed during the day shift, and may require some assistance from plant personnel. Triplicate sampling will be done at each location, coincident with mercury CEM sampling. From previous EERC experience, multiple samples are needed at each sampling location to ensure the quality of the data and to allow the precision of the data to be determined. It is expected that EPA Method 17 sampling procedures (in stack filtration) will be used at all locations except at the stack. At the stack, EPA Method 5 sampling procedures may be needed, because of the relatively low flue gas temperatures.

During each flue-gas sampling period, the coal, fly ash, scrubber sludge, etc. will also be sampled on a daily basis. In this way, a mercury balance across each air pollution control device can be obtained. In addition, to better understand mercury speciation impact, chemical characterization of the fly ash/scrubber sludge and coal will be completed.

It is assumed that a minimum of 3 EERC people will be necessary regardless of the test program selected. The role of these three people would be as follows:

- Overall Field Coordinator
- Hg CEM Operations
- Sampling Operations (Includes EPA Method 5 or OH method, Ammonia Slip, Chlorides, SOH, and SO_3)

Each power plant would supply personnel to take coal and ESP/Fabric Filter/FGD samples. Also, depending on the final test program, additional personnel will be needed to help with sampling activities. If the full test program is selected, 8 people would be needed. TVA has indicated they could supply 5 qualified people, all other plants are assumed to supply 3 people.

Presuming that the full test program is selected, the sampling and measurement team will consist of 8 people: the field coordinator/leader; a chemist to perform on-site analyses; a technician to build and recover sample trains; a person to collect coal, ash, and scrubber samples; one person to operate the CEM(s); and 2-4 people to do the sampling. The sampling team will be made of EERC and power plant personnel. Presuming OH methods are done, all the setup and breakdown of impinger trains and the analyses of the solutions will be done in a trailer which will be brought on-site. Two days will be necessary to set up at the plant and one day to tear down. Consequently, the sampling team will be onsite for 14 to 16 days.

3.1.3 Sampling Results

The results from each power plant for each test series will be compiled and presented in a final report. Data will be interpreted and presented in terms of mercury concentration and speciation at each location over the sampling period. Operating conditions will also be reviewed and presented along with mercury speciation data to infer possible relationships. Mercury collection efficiency will be calculated based on coal inlet concentrations as well as from inlet and outlet measurements. If possible, assuming adequate data is available, mercury mass balances will be performed and presented.

4.0 TEST FACILITIES

Up to four units will be tested. More detail on facilities will be provided after units have been selected.

5.0 MEASUREMENT AND SAMPLING PROCEDURES

5.1 Flue Gas Constituent Concentrations

To determine the O_2 levels at each sample location, a Teledyne portable O_2 analyzer using a paramagnetic cell will be used. This portable O_2 analyzer's linearity is verified prior to use using EPA Protocol 1 certified gas standards. Flue gas velocity, moisture, and flow rate determinations will be performed according to EPA Methods 2 and 4 in conjunction with the SOH and OH methods. The particulate matter at each location will be measured in either an EPA Method 17 or EPA Method 5 configuration as part of the Ontario Hydro train. Other flue gas constituents such as CO_2, NO_x, SO_2, and CO will be obtained either using the same portable analyzer used to measure O_2 and/or from the plant CEMs.

5.2 Ontario Hydro Mercury Speciation Method

As supporting measurement to verify mercury CEMs, speciated mercury analyses will be performed using a Solid Ontario Hydro (SOH) method developed by Frontier GeoSciences. Over that last year, this method has been tested at a couple of facilities and appears to compare quite well to the standard wet chemistry Ontario Hydro (OH) mercury speciation method, which was the method selected by EPA for its information collection request (ICR). The SOH method is much easier to use and is less costly. However, the SOH has not undergone a formal validation process, thus, the data provided by SOH must be used with this in mind. Optionally, standard wet chemistry OH methods will be made as determined appropriate by the project team.

5.3 Chlorine, SO_3, and Ammonia Slip

Chlorine, SO_3, and ammonia slip will be measured. To measure chloride/fluoride concentrations in the flue gas, EPA Method 26A will be used.

5.4 Coal, Fly Ash, and Scrubber Sludge

The EERC has an automated direct mercury analyzer (DMA-80, Milestone, Inc.) that was recently validated as EPA Method 7473, entitled "Mercury in Solids and Solutions by Thermal Decomposition

Amalgamation and Atomic Absorption Spectrophotometry."

The following analyses will be performed on the coal and fly ash collected from the baghouse or ESP hopper.

Fly Ash and/or Scrubber Sludge

- Mercury
- Loss on ignition (carbon content)
- X-ray fluorescence (XRF) (major elements and some trace elements)
- Toxicity characteristic leaching procedure/synthetic groundwater leaching procedure (TCLP/SGLP)
- Thermal desorption
- X-ray diffraction (XRD)
- Scanning electron microscopy (SEM)

Coal

- Mercury
- Chlorides
- Ultimate/proximate
- Btu
- XRF (major and some trace elements)

The leaching tests and the thermal desorption analyses will be done to determine the stability of mercury captured in the ash material.

5.5 Mercury CEMs

Two different mercury CEMs will be used for these tests: the Semtech Hg 2000 and the PS Analytical Sir Galahad. Both of these instruments, when used in conjunction with the EERC conversion system, are able to measure speciated mercury.

6.0 SCHEDULE

It is expected that the project will take about 14 months to complete. It will take approximately 2 months between each plant site for site visit, sampling preparation, travel to and from the site, setup, teardown, and the actual sampling. Within three months of completion of the tests, a draft report will be issued for review and comment from project sponsors. A preliminary project schedule is shown in Table 2.

7.0 PROJECT MANAGEMENT

Mr. John Pavlish, EERC Senior Research Manager, will serve as Project Co-Manager. Mr. Pavlish has over 15 years of experience working with various power plant systems. For the past six years, Mr. Pavlish has served as Associate Director of the Center for Air Toxic Metals (CATM) program at the EERC. CATM is a multi-year, multi-million dollar program aimed at researching critical issues involving trace metals, in particular, mercury. Mr. Dennis Laudal, EERC Research Manager, will serve as the Project Co-Manager. Mr. Laudal has a M.S. degree in Chemical Engineering and over 19 years of research experience. For the past 10 years, Mr. Laudal has been responsible for preparation of technical test plans, supervision of pilot-scale research projects, and interpretation and publication of research findings involving various aspects of emission control from coal-fired combustion systems. For the past 3 years, Mr. Laudal has been the Project Manager for a project funded by EPRI and DOE to evaluate and develop mercury speciation measurement methods, including the OH mercury speciation method.

Mr. Kevin Galbreath will be the Principal Investigator for the proposed project. His prime responsibilities will be to help develop test plans, help oversee pilot-scale tests, and write reports.

In addition, Mr. Galbreath will be

responsible for the analytical work involved in the project.

Mr. Richard Schulz will serve as the sampling leader and will be responsible for all sampling activities in the field.

Table 2. Project Schedule

Date	Milestones
December 1, 2001	Project start date
January 1, 2001	Final selection of power plants
March 15, 2001	Test at power plant 1
May 1, 2001	Progress report for plant 1
May 15, 2001	Test at power plant 2
July 1, 2001	Progress report for plant 2
July 15, 2001	Test at power plant 3
September 1, 2001	Progress report for plat 3
September 15, 2001	Test at power plant 4
November 1, 2001	Progress report for plant 4
December 31, 2001	Complete draft of final report
January 31, 2002	Complete final report

7.0 FUNDING

Assuming that four plants would be sampled, and that both SOH and OH methods would be done, the total estimated cost for this project is $879,270 The total funds requested from industrial sponsors (i.e. EPRI, utilities, etc.) is $407,562 the U.S. Environmental Protection Agency at $200,000, and DOE at $271,708 through the DOE–EERC Jointly Sponsored Research Program. Assuming that four plants would be sampled, but only SOH methods would be done, the total estimated cost for this project option is $709,470. Under this option, the total funds requested from industrial sponsors (i.e. EPRI, utilities, etc.) is $335,682 the U.S. Environmental Protection Agency at $150,000, and DOE at $223,788 through the DOE–EERC Jointly Sponsored Research Program. A more detailed budget is provided in the table below.

Travel for the 1st plant includes a site visit, sampling activities, and two project review meetings. For each additional plant only a site visit and the travel necessary for the sampling activities are included. It is assumed that a minimum of 3 EERC people will be necessary regardless of the test program selected. The role of these three people would be as follows:

- Overall Field Coordinator
- Hg CEM Operations
- Sampling Operations (Includes EPA Method 5 or OH method, Ammonia Slip, Chlorides, SOH, and SO_3)

ESTIMATED BUDGET FOR PROJECT

	1st Plant (TVA)	Each Additional Plant	1st Plant (TVA)	Each Additional Plant
	With OH and SOH Methods and Hg CEMs		**With Only SOH Method and Hg CEMs**	
Total Direct Labor	$51,690	$53,500	$49,100	$40,570
Fringe Benefits	$27,910	$28,900	$27,190	$21,900
Total Labor	$79,600	$80,700	$76,290	$62,470
Travel	$18,500	$18,300	$16,500	$11,440
Equipment	$77,300	$0	$72,000	0
Subcontract (Frontier Geosciences)	$12,500	$12,500	$12,500	$12,500
Other Direct Costs	$28,350	$23,900	$18,350	$13,900
Total Direct Costs	$216,250	$135,400	$195,640	$100,310
Indirect Cost	$69,500	$62,440	$62,450	$50,150
Total Estimated Cost	$285,750	$197,840	$258,090	$150,460
Total Cost for 4 plants	$879,270		$709,470	

SOH = Solid Ontario Hydro Method (Frontier Geosciences)
OH = Ontario Hydro Method

Each power plant would supply personnel to take coal and ESP/Fabric Filter/FGD samples. Also depending on the test program personnel to help with sampling activities. If the full test program is selected 8 people would be needed. TVA has indicated they could supply 5 qualified people all other plants are assumed to supply 3 people.

It should be noted that the mercury CEMs or the SOH method are designed to obtain particulate-bound mercury. Therefore, if OH method samples are not done then EPA Method 5/17 samples will be done in its place. These filter will then be analyzed for mercury. At the stack these samples can be combined with the ammonia slip/SO_3/chloride samples. It addition, at all locations a SOH slipstream will be taken from the EPA Method 5/17 train.

The EERC will submit a proposal to DOE requesting approval of its share of the funding under the DOE–EERC Jointly Sponsored Research Program upon commitment from all project participants.

Three items are required from industrial sponsors for inclusion in the proposal to DOE:

- A formal commitment to the project. This can be a letter of commitment, a purchase order, or a signed contract.
- A biographical sketch or resume for project manager and/or key technical contributor.
- A short overview of industrial sponsor.

8.0 REFERENCES

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7. Miller, S.J.; Olson, E.S.; Dunham, G.E.; Sharma, R.K. Preparation Methods and Test Protocol for Mercury Sorbents. In *Proceedings of the Air & Waste Management Association's 91st Annual Meeting & Exhibition*; San Diego, CA, June 14–18, 1998; Paper 98-RA79B.07.

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Cormetech, Inc.
Environmental Technologies
Treyburn Corporate Park
5000 International Drive
Durham, North Carolina 27712
919-620-3000
fax 919-620-3001

100

CORMETECH

VIA E-MAIL

November 17, 2000

Re: SCR Catalyst Blinding Test

Dear Mr. Porter:

Attached, please find the non-disclosure agreement Reda Iskandar spoke to you about. Please print two copies, obtain an officer's signature on both copies, and send both paper copies back to me. Once fully executed, I will forward a copy to you for your files.

Should questions arise, please contact me at 919-620-3058 or by email moorekr@cormetech.com.

Best regards,

Kathryn R. Moore

Kathryn R. Moore

NON-DISCLOSURE AGREEMENT

BETWEEN

NORTH DAKOTA INDUSTRIAL COMMISSION,
LIGNITE ENERGY COUNCIL

AND

CORMETECH, INC.

In view of contemplated discussions between personnel of Cormetech, Inc. ("Cormetech") and North Dakota Industrial Commission, Lignite Energy Council, and the fact that product samples, specifications, process techniques, composition data, equipment designs, or other types of information may be submitted to North Dakota Industrial Commission, Lignite Energy Council to enable the latter to conduct evaluations and tests on Cormetech SCR catalysts, which materials or samples, specifications, process techniques, composition data, equipment designs and other types of information, all of which, including without limitation the results of such evaluations and tests, shall be deemed to constitute proprietary information of Cormetech ("INFORMATION"). The purpose of this Agreement is to obtain acknowledgment by North Dakota Industrial Commission, Lignite Energy Council concerning the treatment that is to be accorded to such INFORMATION. INFORMATION shall be marked proprietary or, if provided orally or visually except for samples of Cormetech SCR catalysts, will be described in a writing or other tangible from within thirty (30) days of disclosure.

(1) It is understood and agreed that INFORMATION, which may, from time-to-time be made available to North Dakota Industrial Commission, Lignite Energy Council is to be treated as confidential from the date of each disclosure. INFORMATION is to be used solely in connection with the evaluation to be conducted by North Dakota Industrial Commission, Lignite Energy Council for this agreed upon purpose and is not to be disclosed to persons other than personnel having a clear and reasonable need for access in connection with said evaluation. North Dakota Industrial Commission, Lignite Energy Council shall treat INFORMATION received from Cormetech as confidential by taking reasonable precautions in accordance with procedure yfollows to prevent disclosure of its own confidential information of like importance; shall not disclose INFORMATION, directly of indirectly, to any third party without Cormetech's written permission; and shall not use any of the INFORMATION except for evaluation. All INFORMATION shall be returned to Cormetech upon its request or when the need therefore terminates; provided, however, that the above requirements shall not apply to any INFORMATION which:

   (a) is now, or which hereafter, through no act or failure to act on the part of North Dakota Industrial Commission, Lignite Energy Council, becomes within the knowledge of the general public;

   (b) is known by North Dakota Industrial Commission, Lignite Energy Council at the time of receiving such INFORMATION as can be supported by competent evidence;

   (c) is hereafter furnished to North Dakota Industrial Commission, Lignite Energy Council by a third party as a matter of right and without restriction on disclosure. Catalyst materials manufactured by Cormetech are restricted from any test or disclosure by North Dakota Industrial Commission, Lignite Energy Council except as expressly authorized by Cormetech.

(d) is independently developed by North Dakota Industrial Commission, Lignite Energy Council and can be proven by competent evidence.

(e) is required to be disclosed by North Dakota Industrial Commission, Lignite Energy Council pursuant to a court or government order provided North Dakota Industrial Commission, Lignite Energy Council first notifies Cormetech in time to seek an appropriate protective order or other confidential protection.

(2) North Dakota Industrial Commission, Lignite Energy Council also agrees that it will not make any commercial use, in whole or in part, of any INFORMATION received from Cormetech without the prior written consent of Cormetech.

(3) Title to the above-described materials or samples provided by Cormetech hereunder, including without limitation those for test and evaluation, shall remain in Cormetech and such portions of such samples as are not consumed to an unrecoverable state in the course of the above-described testing and evaluation shall be disposed of by North Dakota Industrial Commission, Lignite Energy Council safely and in accordance with all Federal and State laws, as agreed by Cormetech.

(4) North Dakota Industrial Commission, Lignite Energy Council will (i) disclose in writing to Cormetech the types of and results of its evaluations or tests (including any composition analyses) of Cormetech materials or samples (including without limitation catalysts or products); (ii) not disclose the results of such test or evaluations to the public or third parties or use such results for any purpose other than as described above, without Cormetech's written consent; and (iii) otherwise treat the results of such tests, evaluations, and analyses as INFORMATION hereunder.

(5) The period for disclosure of INFORMATION under this Agreement begins on the effective Date and ends two (2) years thereafter. All obligations of confidentiality, limited use and nondisclosure hereunder with respect to any item of INFORMATION expires ten (10) years from the Effective Date of this Agreement. The "Effective Date" means the date of signature below by the last party to sign this Agreement.

(6) This Agreement shall be construed and interpreted according to the laws of the State of New York, not including, however, rules relating to choice or conflict of laws.

This Agreement is being submitted in duplicate. Please return one (1) copy, after being executed by an authorized representative, as an acknowledgment of the treatment to be accorded INFORMATION.

ACCEPTED AND AGREED:

NORTH DAKOTA INDUSTRIAL COMMISSION, LIGNITE ENERGY COUNCIL

By____________________________

Name__________________________

Title___________________________

CORMETECH, INC.

By____________________________

Name__________________________

Title___________________________

Date__________________________

Date__________________________

Clifford Porter

From: Moore, Kathryn R. [MooreKR@Cormetech.com]
Sent: Tuesday, December 05, 2000 1:58 PM
To: 'tgraumann@otpco.com'; 'kenneth_b_stuckmeyer@ameren.com'; 'blair.seckington@ontariopowergeneration.com'; 'sbenson@eerc.und.nodak.edu'; 'cporter@lignite.com'; 'edmundovasquez@alliant-energy.com'; 'doconnor@epri.com'; 'ted_lindenbusch@dynegy.com'; 'feeley@netl.doe.gov'
Cc: Iskandar, Reda S.
Subject: Addendum to SCR Catalyst Non-Disclosure Agreement

Addendum to SCT Catalyst Blind...

On November 17th, 2000 we emailed you a Non-Disclosure Agreement pertaining to the SCR Catalyst Blinding Test. This document is meant to serve as clarification that only the members within the study may discuss findings, etc. among each other and that there is to be no discussions, etc. with regards to this test with anyone outside this group.

It has come to our attention that our Non-Disclosure Agreement was not developed to use in a "multi-faceted" fashion. Therefore, we have attached an addendum to our Non-Disclosure, so as to clarify that everyone would be aware of the other parties involved in the est and that discussions could take place between these members, but no discussions outside the group will be allowed.

Attached is an addendum to be added to the original email sent to you on November 17th. Please print 2 copies, attaching one to each of the 2 Non-Disclosure Agreements you previously received. Once you have signed, please return to Kathryn R. Moore.

Thank you for your understanding and patience.

Kathryn R. Moore
Executive Assistant to the President/CEO
CORMETECH, Inc.
5000 International Drive
Durham, NC 27712
(919)620-3058
<<Addendum to SCT Catalyst Blinding.doc>>

ADDENDUM TO
NON-DISCLOSURE AGREEMENT

BETWEEN

PARTICIPANTS OF SCR CATALYST BLINDING TEST

AND

CORMETECH, INC.

The names and companies listed below are participants in the SCR Catalyst Blinding Test and a part of contemplated discussions between personnel of ("Cormetech") Inc. and each other.

Ontario Power Generation	Blair Seckington
Ottertail Power Company	Terry Garumann
Ontario Power Technologies	Rene Mangal
EPRI	Dave O'Connor
AmerenUE	Ken Stuckmeyer
Alliant Energy	Ednumdo Vasquez
Cormetech, Inc.	Reda Iskandar
North Dakota Industrial Commission, Lignite Energy Council	Cliff Porter
US DOE NETL	Thomas Feeley
EERC	Chris Zygarlicke
EERC	Steve Benson
EERC	Jay Gunderson
EERC	Don Toman
EERC	Jason Laumb
Dyneg	Ted Lindenbusch

In view of contemplated discussions between personnel of Cormetech, Inc. ("Cormetech") and Participants Of SCR Catalyst Blinding Test, and the fact that product samples, specifications, process techniques, composition data, equipment designs, or other types of information may be submitted to Participants of SCR Catalyst Blinding Test to enable the latter to conduct evaluations and tests on Cormetech SCR catalysts, which materials or samples, specifications, process techniques, composition data, equipment designs and other types of information, all of which, including without limitation the results of such evaluations and tests, shall be deemed to constitute proprietary information of Cormetech ("INFORMATION"). The purpose of this Addendum is to acknowledge and recognize the actual parties involved in this Agreement.

AGREED AND ACCEPTED:

NAME OF COMPANY	**CORMETECH, INC.**
By ____________________	By ____________________
Name ____________________	Name ____________________
Title ____________________	Title ____________________

Clifford Porter

From:	Reimer, Patti J. [preimer@undeerc.org]
Sent:	Monday, December 11, 2000 3:17 PM
To:	'tgraumann@otpco.com'; 'cporter@lignite.com'; 'feeley@netl.doe.gov'; 'pritchardsg@cormetech.com'; 'DOCONNOR@epri.com'; 'edmundovasquez@alliant-energy.com'; 'kenneth_b_stuckmeyer@ameren.com'; 'Rene.Mangal@kinectrics.com'; 'blair.seckington@ontariopowergeneration.com'; 'ted_lindenbusch@dynegy.com'; 'mark_liefer@dynegy.com'
Cc:	Benson, Steven A.; Toman, Donald L.; Gunderson, Jay R.; Laumb, Jason; Zygarlicke, Chris J.
Subject:	RESCHEDULED SCR Blinding Project Conference Call

Due to scheduling conflicts, the conference call has to be rescheduled again. This time, we are aiming for Friday, January 12, at 1:00 CST. Please let me know if you are available at that time. If you are not available, let me know of a time that week that would be more convenient for you. You can e-mail Steve your plant questionnaires as soon as they are completed.

Sorry for the inconvenience,
Patti Reimer

Energy & Environmental Research Center
University of North Dakota
PO Box 9018
15 North 23rd Street
Grand Forks, ND 58202-9018
Phone: (701) 777-5070
Fax: (701) 777-5181
E-mail: preimer@undeerc.org

5 CR Blinding Project

Clifford Porter

From: Reimer, Patti J. [preimer@undeerc.org]
Sent: Tuesday, January 02, 2001 11:50 AM
To: 'tgraumann@optco.com'; 'cporter@lignite.com'; 'patton@netl.doe.gov'; 'pritchardsg@cormetech.com'; 'DOCONNOR@epri.com'; 'edmundovasquez@alliant-energy.com'; 'kenneth_b_stuckmeyer@ameren.com'; 'ted_lindenbusch@dynegy.com'; 'mark_liefer@dynegy.com'; 'Rene.Mangal@kinetrics.com'; 'blair.seckington@ontariopwoergeneration.com'
Subject: SCR Blinding Project Conference Call

PlantQuestionnaire.doc

The SCR Blinding Project conference call is scheduled for Friday, January 12, at 1:00 CST. Steve needs the plant questionnaires completed and e-mailed back to him a.s.a.p. so he can compile the information for the conference call. If you already sent the questionnaire back to Steve, please disregard this notice. I have attached the plant questionnaire below.

<<PlantQuestionnaire.doc>>

The instructions for the call are as follows:

As soon as you are available for the call, dial (701) 777-4456. You will be prompted to enter a passcode, which is 1445 (be certain to hit the # key after entering the passcode number). You will then hear a beep, which means that you are on the line and connected. Please stay on the line even though no one else is on yet. Steve will be on the line a couple of minutes early. If you have trouble connecting, please call Linda at (701) 777-3206 and ask for assistance. These numbers will be the numbers to use for the conference call from now on.

Thank you,
Patti Reimer

Energy & Environmental Research Center
University of North Dakota
PO Box 9018
15 North 23rd Street
Grand Forks, ND 58202-9018
Phone: (701) 777-5070
Fax: (701) 777-5181
E-mail: preimer@undeerc.org

Questionnaire/Checklist

Evaluation of Potential SCR Catalyst Blinding During Coal Combustion

Please return by December 12, 2000 to
sbenson@undeerc.org

Plant Name: ________________________

Boiler Vendor: ________________________

Firing Method: ________________________

Gross MW: ________________________

Coal/Fuel Information: Please list all fuels currently fired at this station.

1. Coal Rank: __________ Mine: _____________ Region*: ______________
2. Coal Rank: __________ Mine: _____________ Region: ______________
3. Coal Rank: __________ Mine: _____________ Region: ______________
4. Coal Rank: __________ Mine: _____________ Region: ______________
5. Coal Rank: __________ Mine: _____________ Region: ______________
6. Coal Rank: __________ Mine: _____________ Region: ______________
7. Other Fuels: ________________ (Petroleum coke, tires, ……)

* Region – PRB, Illinois, Green River, Fort Union, etc.

Are fuels blended? Yes or No

Blending method – Brief description

____

____

____

Blend ratios ____

Air Pollution Control System (ESP, Scrubber, Baghouse) __________________________

Operating Temperature at Economizer Outlet, deg. F: _______________

Please review the expected requirements for each station (located below) and provide comments regarding the availability at this station.

Items needed for installing SCR at utility.

1. 30 Amps of 480 voltage 3 phase (could be welding outlet)

2. 100 Amps of 240 voltage single phase (4 wire ground and neutral)

3. Electrician available to hook up power to our breaker panel(s).

4. NEMA or whatever codes for electrical/structural components.

5. Access to welder and band saw to field fit piping and flanges from boiler to SCR and back into boiler. We will need either plant personnel to help us or we will need access to welder and saw.

6. Scissor jack or platforms to set up SCR; install piping; access to heaters and ammonia injection. These will also be needed for sampling from the inlet piping which will be ~15 feet high and for removing of catalysts at specified intervals.

7. Maximum of 100 feet from air heater for piping to and from SCR.

8. Minimum of a 4" port to insert 3 ½" piping for extraction of flue gas at temperature between 600° and 800° F.

9. Minimum of a 4" port for dumping flue gas from SCR back into boiler (Temperature is not an issue for this port location. Close proximity is preferred)

10. Inside location of approximately 20'x 20' floor space and 20' head room to set up SCR and control panel. This location should be in an area not heavily ulitilized by plant personnel if possible to minimize interference with plant operations.

11. Crane or elevator access for getting equipment to SCR location. The largest piece of equipment will be the control panel for data acquisition. This panel will be approximately 4' x 4' x 5' high. The piping lengths will be less than 20' long.

12. We will need dry compressed air (instrument air) at ~80 psig for pulse system. Pulsing should only be required several times a day, so quantity should not be an issue for plant.

13. Available ammonia for injection into upstream SCR piping or place where portable bottles can be set up. (If portable bottles are used, plant personnel will need to monitor bottles and change when empty.)

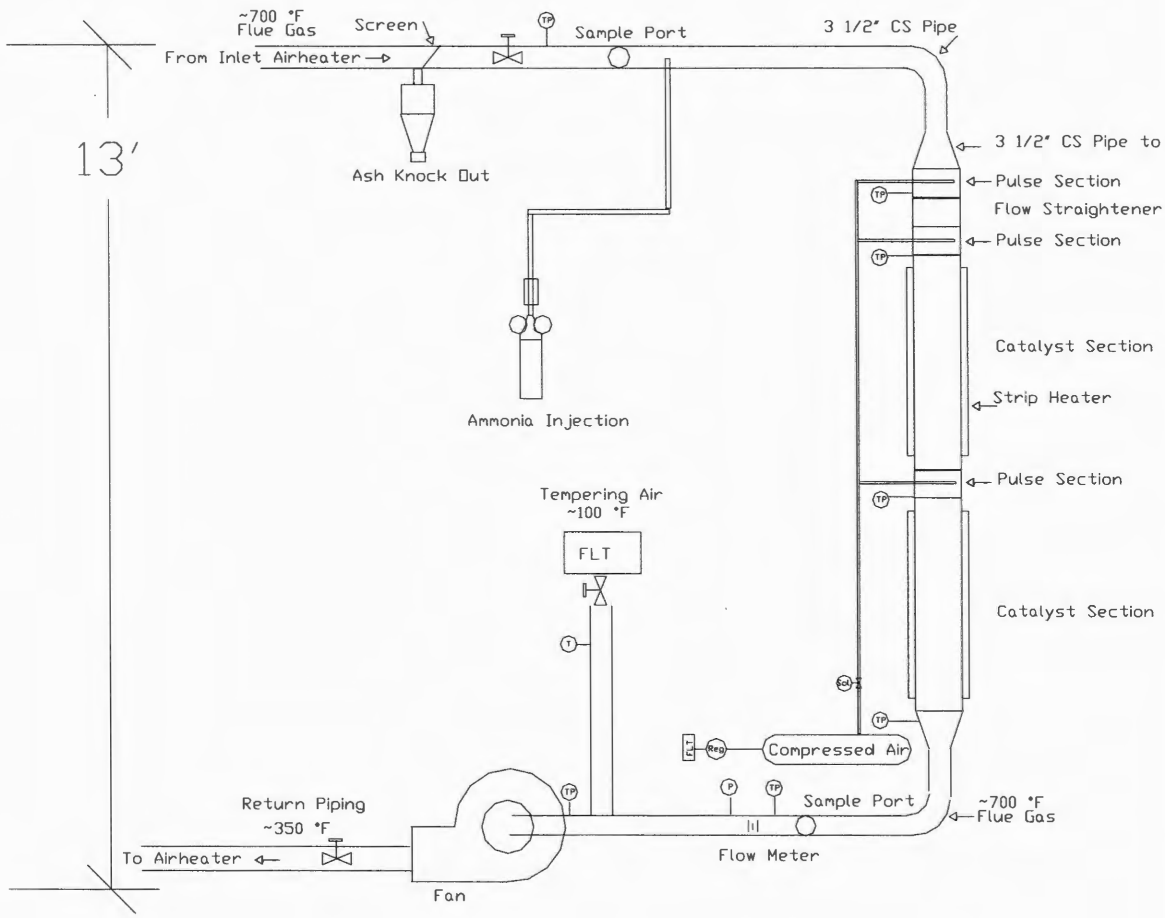
14. Prefer LAN/WAN DSL access for direct computer connection to data acquisition system from EERC to control and download data. Access to data acquisition can be achieved via a modem if necessary, but may encounter problems.

15. Personnel to check on unit and to record pressure readings once a day.

16. Personnel to close inlet and outlet valves to SCR if plant experiences an outage and to open when outage is over.

Questions: Please contact Jay Gunderson (701-777-5258 or jgunderson@undeerc.org) or Steve Benson (701-777-5177 or sbenson@undeerc.org).

SCR SCHEMATIC



Clifford Porter

From: Reimer, Patti J. [preimer@undeerc.org]
Sent: Thursday, January 18, 2001 4:18 PM
To: 'tgraumann@otpco.com'; 'cporter@lignite.com'; 'patton@netl.doe.gov'; 'pritchardsg@cormetech.com'; 'DOCONNOR@epri.com'; 'edmundovasquez@alliant-energy.com'; 'kenneth_b_stuckmeyer@ameren.com'; 'ted_lindenbusch@dynegy.com'; 'mark_liefer@dynegy.com'; 'Rene.Mangal@kinectrics.com'; 'blair.seckington@ontariopowergeneration.com'
Cc: Benson, Steven A.; Laumb, Jason; Zygarlicke, Chris J.; Toman, Donald L.; Gunderson, Jay R.
Subject: SCR Blinding Project

Plant Selection.xls

This message was sent on behalf of Steve Benson:

As we discussed on Friday we would identify the plants we would like to test. We have assembled a table that lists the plants considered and the plants we would like to test. The selection of the plants is based on coals being fired, boiler type, and location. The location of the plant effects the costs of testing. Please review and send me comments or call if you have questions or concerns. We will have a conference call on January 25, 2001 at 10:00am CST. Use the same call in instructions as last time. I will send you the minutes from the last meeting shortly.

Best Regards,

Steve Benson

Senior Research Advisor
Energy and Environmental Research Center
University of North Dakota
Grand Forks, ND 58202
Phone: 701-777-5177, Fax: 701-777-5181

<<Plant Selection.xls>>

SCR Blinding Project -- Selection Criteria for Plant Testing

Parameter	Nanticoke	Baldwin	Sioux Unit 2	Columbia	Edgewater	Coyote
Utility	Ontario Power	Dynegy	AmerenUE	Alliant	Alliant	Otter Tail
Boiler Type	Wall-fired	Cyclone/T-fired	Cyclone	T-Fired	Cyclone/Wall fired	Cyclone
Fuel type	PRB(many)/Bit	PRB -- Antelope	PRB/Bit	Caballo	Black Thunder/Bit	Lignite
Load	Lower load at night	Base	Base	Base	Base	Base
Location	Toronto	Baldwin, IL	West Alton, Mo	Portage, WI	Sheboygan, WI	Beulah, ND
Codes	No problem	No problem	No problem	No problem	No problem	No Problem
Ammonia (on site/available)	OK/yes	OK/no	OK/no	?	?	?
Available Plant Personnel/Support	Welding	Welding	Welding	Welding	Welding	Welding

Goals for testing -- determine the mechanisms of blinding considering firing conditions, fuel types, and blending.
Types of plants must include a pulverized coal fired boiler and a cyclone fired boiler. Fuel types to be included: PRB, Lignite, and PRB/Bit blend
Selection criteria -- plant type, coal type/blend, and location

Prioritized picks for test sites for the SCR Blinding project.

Field Test #1 -- Columbia

-- P.C.-fired which may be important for partitioning differences compared to cyclone
-- High potential blinding coal in Caballo, which can be burned nearly 100% for the entire test
-- Good fit operationally, we've tested their before an know the unit; NH4, hookups, electrical, plant personnel assistance, and codes should all be OK
-- Proximity; 1200 miles with only 16-20 hours travel time round trip (pulling a trailer).

Field Test #2 -- Sioux Plant

-- cyclone-fired which may be important for partitioning differences compared to a P.C. unit
-- High potential blinding coal in the Antelope, plus the higher relative S component of the Illinois Bituminous. Excellent to test whether the sulfur may enhance blinding. Data in literature thus far says that bituminous coals, even high sulfur ones have
-- Fairly consistent diet of fuels.
-- Good fit operationally in that it has had to deal with NH4 and other testing; hookups, plant personnel assistance, electrical, codes should all be OK
-- other research work at Sioux Plant with respect to SCR testing may add value for comparison.
-- Proximity: 2000 miles and 60-70 hours travel round trip (just west and south? of St. Louis)

Field Test #3 -- Coyote

-- cyclone fired
-- High potential blinding with high alkali (Ca-Na-Mg), plus fairly high S.
-- Excellent fit operationally with exact numbers on piping, etc.; all hookups, electrical, NH4, codes, plant personnel assistence, all no problem.
-- Experience working there before.
-- Very close proximity: 500 miles and 8-10 hours travel time round trip.
-- the cheapest to do, which means if we run into problems like cost overruns on the other field tests, we can no doubt still find a way to do this test because it is so close.

Other Field Tests
Baldwin - 4th choice (T-fired unit firing Antelope is a good alternate to the testing at Columbia)

-- cyclone or P.C.-fired
-- Good high potential blinding coal in Antelope, which should run moderately close to 100%
-- Good fit operationally with codes, hookups, Plant personnel assistance, NH4, etc.
-- Proximity: 2100 miles with 60-70 travel hours round trip (just southeast of St. Louis about 30 miles).

Nanticoke - 5th choice

-- Wall fired which may be good for having a comparison with another partitioning type.
-- PRB coals are not consistent with four types; blended 50-50 with low S bituminous. If sulfur is indeed playing a major role in blinding then it would be better to test at Sioux where we can compare one consistent type of coal with a higher S coal than
-- Mixed signals on operational fit; Rene says its a problems with respect to codes, hookups, and plant assistance and Blair says its OK
-- Proximity: 2800 miles and about 100 hours travel time round trip.

Edgewater - 6th choice

-- Coal utilized is primarily Black Thunder and this coal we feel will be as severe of a blinding coal as others

INDUSTRIAL COMMISSION OF NORTH DAKOTA

LIGNITE RESEARCH, DEVELOPMENT AND MARKETING PROGRAM

Governor,
John Hoeven
Attorney General,
Wayne Stenehjem
Commissioner of Agriculture,
Roger Johnson

MEMORANDUM

March 13, 2001

TO: Karlene Fine, Executive Director and Secretary
North Dakota Industrial Commission

FROM: Clifford R. Porter, Director CRP
Lignite Research, Development and Marketing Program

SUBJECT: FY00-XXXVI-100: "Evaluation of Potential SCR Catalyst Blinding During Coal Combustion"; Contractor: Energy & Environmental Research Center; Recommendation for Payment of $22,500 for First Quarterly Report (10/1/00 – 12/31/00).

I have reviewed the first quarterly report (October 1, 2000 – December 31, 2000) from the contractor (Energy & Environmental Research Center) regarding Contract No. FY00-XXXVI-100 for the project titled "Evaluation of Potential SCR Catalyst Blinding During Coal Combustion".

The first quarterly report is adequate to determine that the contractor has complied with the statement of work.

The contractor has met the terms of contract FY00-XXXVI-100 required for receiving the $22,500 payment for the first quarterly report. I recommend payment of the $22,500.

CRP/vg: 24.S.30.A

LIGNITE RESEARCH COUNCIL
John Dwyer, Chairman
Clifford Porter, Director & Technical Advisor
P.O. Box 2277
Bismarck, N.D. 58502
(701) 258-7117 (701) 258-2755 Fax

INDUSTRIAL COMMISSION OF NORTH DAKOTA
Karlene Fine
Executive Director
600 East Boulevard, State Capitol
Bismarck, N.D. 58505
(701) 328-3722 (701) 328-2820 Fax

John Dwyer

NORTH DAKOTA DEPARTMENT OF HEALTH
Environmental Health Section

Location:
1200 Missouri Avenue
Bismarck, ND 58504-5264

Fax #:
701-328-5200

Mailing Address:
P.O. Box 5520
Bismarck, ND 58506-5520

March 13, 2001

Richard R. Long, Director
Air and Radiation Program
USEPA Region 8
999 18th Street - Suite 300
Denver, CO 80202-2466

Dear Dick:

On behalf of the Department, I would like to thank you and your staff for coming to Bismarck on January 10th to meet with us in regard to EPA's proposed SIP call. We feel that the time was well spent, and we were pleased with your willingness to work with us in addressing the PSD sulfur dioxide increment issues.

As discussed in our meeting, we agreed that the Department would have additional time to update and refine the increment consumption analyses based upon 1999 and 2000 stationary source emissions data. The Department will develop an air quality modeling protocol by April 1, 2001 that addresses source emissions, modeling parameters and other appropriate matters. EPA will strive to complete its review of the protocol within 30 days. The Department will then complete its modeling analysis by January 2, 2002 or within nine months from the time EPA completes its review of the modeling protocol and provide EPA with a summary of our analysis by February 1, 2002. If the modeling analysis shows that the increment is exceeded, the Department will develop a work plan with a goal of completing a SIP revision by August 1, 2003 to resolve the increment issue.

We appreciate your Agency's willingness to work with the State of North Dakota so that we can continue to maintain clean air for our citizens and fulfill our responsibilities under the Clean Air Act. We also recognize EPA has responsibilities under the Clean Air Act and may proceed to issue a SIP call if the State cannot meet the above commitments. If you have any questions or comments on the above, please call me at 701-328-5150.

Sincerely,

Francis J. Schwindt, Chief
Environmental Health Section

FJS:cc

Clifford Porter

From: TGraumann@otpco.com
Sent: Wednesday, March 28, 2001 4:20 PM
To: DStockdill@GREnergy.com; cporter@lignite.com; StomberA@MDU.MDURES.com; bkrogh@mnpower.com; jkmiller@bepc.com; jgraves@minnkota.com; kganzer@bepc.com; mroth@GREnergy.com
Subject: RE: EERC particulate matter sampling and analysis

Chalk one up to Boundary Dam. I recall seeing some info within the last few years regarding their particulate emissions control equipment. Several of their units did not have ESP's at that time. Should the Health Department also be involved in the discussion?

Terry

Terry Graumann
Manager, Environmental Services
Otter Tail Power Company
P.O. Box 496
215 S. Cascade
Fergus Falls, MN 56538-0496
Telephone: 218-739-8407 Fax: 218-739-8629
E-Mail: tgraumann@otpco.com

-----Original Message-----
From: Stockdill, Diane GRE/CCS [mailto:DStockdill@GREnergy.com]
Sent: Wednesday, March 28, 2001 3:20 PM
To: Clifford Porter (E-mail) (E-mail); Andrea Stomberg (MDUGOMAIL) (E-mail); Brandon Krogh (E-mail); Jim K. Miller (E-mail); John Graves (E-mail); Keith Ganzer (E-mail); Mary Jo Roth GRE/ER; Graumann, Terry
Subject: FW: EERC particulate matter sampling and analysis

EERC is involved in a DOE project that is studying particulates. The
have a
sampling trailer and are doing initial testing prior to taking the
trailer
to other sites and states. To date they have sampled in Grand Forks, a
pristine site in Minnesota and near Kenmare. EERC was surprised by the
Kenmare samples. They found fly ash particles when the wind was from
the
North West. There were no fly ash particles when the wind was from the
southeast. Nothing exceeded the ambient air standards. Steve wanted to
make
us aware of the findings and see if we wanted to discuss the results
prior
to him writing the report.

-----Original Message-----

From: Benson, Steven A. [mailto:sbenson@undeerc.org]
Sent: Wednesday, March 28, 2001 2:56 PM
To: Stockdill, Diane GRE/CCS
Subject: EERC particulate matter sampling and analysis

Diane:

I have attached a PowerPoint presentation that provides an overview of
the
sampling trailer as well as some results from the ND sampling and
analysis.
All the images were from the ND site and collected with Burkhart or TEOM
samplers. Let me know if you have questions.

Regards,

Steve

<<EERCPMtesting.ppt>>

Steven A. Benson, Ph.D.
Senior Research Advisor
Energy and Environmental Research Center
University of North Dakota
Grand Forks, ND 58202
Phone: 701-777-5177, Fax: 701-777-5181

Clifford Porter

From: Fine, Karlene K. [kfine@state.nd.us]
Sent: Wednesday, March 28, 2001 4:07 PM
To: 'Clifford Porter'
Subject: DGC Investment Agreement

Under the Investment Agreement we have three provisions regarding the "Company" and access to information.

The Company shall deliver to the Investor (in addition to the financial statements to be prepared in accordance with generally accepted accounting principles) such other information relating to the financial condition, business, prospects or corporate affairs of the Company as the Investor may from time to time reasonably request; provided, however, that the Company shall not be obligated to provide information that it deems in good faith to be proprietary or confidential unless the Investor (that's us) provides reasonable assurances in writing that it will maintain the confidentiality of the information.

Upon receipt of prior written notice, the Company shall permit the Investor, or an officer, employee, or agent thereof, at such party's expense, to visit and inspect the Plant, to examine its books of accounts and records and to discuss the Company's affairs, finances, and accounts with its officers, all at such reasonable times as may be requested by the Investor; provided, however, that the Company shall not be obligated to provide access to any facilities or information that it reasonably considers to be a trade secret or similar confidential information unless the Investor provides reasonable assurances in writing that it will maintain the confidentiality of the information.

To the extent required to enable Investor to comply with the laws of the State of North Dakota and at Investor's cost, the Company shall furnish promptly, at Investor's request, such information as may be reasonably necessary to enable Investor to determine whether the Company is in compliance with the terms of this Agreement. The Company consents to reasonable disclosure by Investor of the Company's financial information in connection with the presentation of Investor's reports; provided, however, that prior to making any such disclosure, Investor shall give the Company thirty (30) days' written notice.

Clifford, that's all I could find in the Agreement. It is fairly broad, but as I already told you, hiring an auditor to audit a company's books would be a big step. We would have to be very suspicious before I would question an Arthur Anderson audit. What I don't know for sure is how they financed the CO2 pipeline and if Basin made a loan to DGC, then I suspect those loan costs will be reducing DGC's bottom line.
Question, at the IC meeting yesterday, the Governor asked how DGC monitors the pipeline that went under the lake for leaks? And if there are leaks, how are they fixed?
Have you heard anymore about whether they are shipping CO2 these days? K

Clifford Porter

From: Fine, Karlene K. [kfine@state.nd.us]
Sent: Wednesday, March 28, 2001 3:24 PM
To: 'cporter@lignite.com'
Subject: RE: MDU Confidentiality

No problem in waiting until the May 2 IC meeting for MDU. Since this request is just for the reports and it won't be until the May 2 meeting that the decision is made to fund the reports, I see no problem in waiting. However, I do think the April 19 meeting has to include consideration of the confidentiality request from Westmoreland. Technically I am withholding information without the IC acting on the issue and I'm not sure I can withhold it much longer just on my say-so. K

-----Original Message-----
From: Clifford Porter [mailto:cporter@lignite.com]
Sent: Wednesday, March 28, 2001 9:09 AM
To: Karlene Fine (E-mail)
Subject: MDU Confidentiality

Karlene,
I received a copy of the MDU confidentiality request sent to you and signed by Bruce Imsdahl. I think we can take this to the commission at the same time we take the funding recommendation, if given by the LRC. Do you think we can wait or should we put this before the Commission earlier? No strong feelings concerning the timing on this request.

Clifford

Clifford R. Porter
Director of Research & Development
Lignite Energy Council
Technical Advisor
Lignite Research Council
Director
Lignite Research, Development & Marketing Program
1016 E. Owens Avenue, Suite 200
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701-220-1117 (cell)
701-258-2755 (fax)
cporter@lignite.com
<http://www.lignite.com/>
<http://www.state.nd.us/ndic/#Lignite>
http://www.lignitevision21.com

Clifford Porter

From: Rosemary Wilson [RWilson@Ceednet.Org]

Sent: Wednesday, March 28, 2001 5:16 PM

To: Art Peters (E-mail); Beth Ryan (E-mail); Bob Green (E-mail); Brandon Krogh (E-mail); Brian Sweeney (E-mail); Cathy Woollums (E-mail); Charles Means (E-mail); Clifford Porter (E-mail); Dennis Leonard (E-mail); E. Oakman for Art Peters (E-mail); Eric Hennen (E-mail); Eugene Trisko (E-mail); Fred Starheim (E-mail); Gary Gibbs (E-mail); Greg Schaefer (E-mail); Jerry Bartlett (E-mail); Jim Hockett (E-mail); Joe Ciaccio (E-mail); John Bergene (E-mail); John Knapp (E-mail); John Lewis (E-mail); John Shanahan (E-mail); Joseph Bateman (E-mail); Kelly Mader; Lee Eberley (E-mail); Leonard Levin (E-mail); Marc Himmelstein (E-mail); Mark D. Anderson (E-mail); Mark Strohfus (E-mail); Mary Jo Roth (E-mail); Michael J. Rodenberg (E-mail); Michael Menne (E-mail); Michael Payette (E-mail); Nancy J. Moody (E-mail); Nathan J Noland (E-mail); Patti Leaf (E-mail); Paul H. Loeffelman (E-mail); Paul Reynolds; Quin Shea (E-mail); Rae Cronmiller (E-mail); Robert Fassbender (E-mail); Roger Howard (E-mail); Skip Stevens (E-mail); Steve Griles (E-mail); Steve Miller (E-mail); Terry O'Connor (E-mail); Tim Hagley (E-mail); Tom Mason; Tom Raub (E-mail); Vic Svec (E-mail); VPs; Wayne Penrod (E-mail)

Subject: AEI/Brookings Joint Mercury Study

Importance: High

Hello, everyone. Attached is a recent regulatory analysis of the uncertain costs and benefits of regulating mercury emissions, based on the EPA regulatory determination and major legislative proposals to date. Among the key comments:
--"Given current scientific understanding, the health and environmental improvements are very unlikely to provide an economic justification for the costs of stringent controls on mercury emissions...." "Thus, even the elimination of mercury emissions from US utilities would reduce human exposure by only 5 percent." .
--"Available data suggest that cutting power plants' mercury emissions may reduce cases of subtle and mostly imperceptible neurological effects among children at a cost on the order of $150,000 per case avoided. Other health and environmental benefits appear negligible.
--The authors believe that regulating the price of emissions, rather than the quantify of emissions, would be a preferable approach:" Current legislative and regulatory proposals also ignore the fact that effluent charges may be economically preferable to quantify restrictions for mercury reduction. A modest charge for mercury emissions or for coal combustion emitting mercury may make much more sense than the proposals issued to date." Despite the hint of a mercury tax or some other economic vehicle, I forward this analysis for your information. It contains a lot of thought for such a short document.--Rosemary
-----

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

REGION 8
999 18TH STREET - SUITE 300
DENVER, CO 80202-2466
http://www.epa.gov/region08

MAR 28 2001

Ref: 8P-AR

Francis J Schwindt, Chief
Environmental Health Section
State Department of Health
P.O. Box 5520
Bismarck, North Dakota 58506-5520

Dear Fritz:

The purpose of this letter is to follow up on our January 10, 2001 meeting in Bismarck and on your subsequent March 13, 2001 letter with the Department of Health's commitments regarding the violations of the prevention of significant deterioration (PSD) increments for sulfur dioxide (SO2). As was discussed in our meeting, EPA is very concerned about the PSD increment violations, which have been modeled by the Department of Health in conjunction with Minnkota Power Cooperative's request to increase production at its Milton R. Young coal-fired power plant. Although we know the State denied the permit to increase production at Minnkota, a subsequent analysis submitted to EPA by your staff on April 19, 2000 showed that, even without Minnkota's increase in SO2 emissions, there were still numerous violations of the three-hour and twenty four-hour PSD increments for SO2 modeled in four Class I areas -- Theodore Roosevelt National Park (in all three units) and the Lostwood Wilderness Area, as well as the Medicine Lakes Wilderness Area and the Fort Peck Class I Indian Reservation, both of which are within Montana.

As you know, the Clean Air Act provides that the increments are not to be exceeded and that the State Implementation Plan (SIP) must contain measures assuring that the increments will not be exceeded. In addition, EPA's PSD regulations require that the SIP be revised to correct any increment violations which the State or EPA determines are occurring. (See 40 CFR 51.166(a)(3).) Because we had information that these Clean Air Act requirements were being violated, EPA contemplated issuing a SIP call to require North Dakota to revise its SIP.

In our January 10, 2001 meeting, you explained that the State needs to refine its previous modeling analysis before you could determine the appropriate control strategy to address the violations. You also expressed concern about the imposition of a formal SIP call. Instead, you pledged that the State would initiate refinements to the modeling analysis and would adopt revisions to the SIP as may be necessary to protect the PSD increment based on the revised analysis. I was very pleased with the State's willingness to address the increment violations in a timely manner and appreciate the opportunity to address these violations through a partnership effort with the State in lieu of a formal SIP call. Thus, in light of your March 13, 2001 commitment letter, EPA will not initiate formal action to call for a SIP revision to address these violations. We acknowledge that the State needs to refine the modeling analysis to better determine the appropriate control strategy(ies) to address the violations, and we look forward to working with you and your staff to determine an acceptable modeling protocol. We also look forward to assisting the State in developing an acceptable control strategy(ies) to address the increment violations, including adequate time frames for implementation which may vary depending on the control strategy(ies) ultimately required by the State.

We note the following commitments, as outlined in your March 13, 2001 letter:

- **By April 1, 2001** - The State will develop an air quality modeling protocol.
- **By January 2, 2002** - The State will complete its modeling analysis (or within nine months from the time EPA completes its review of the modeling protocol).
- **By February 1, 2002** - The State will provide EPA with a summary of its modeling analysis.
- **By August 1, 2003** - The State will complete a SIP revision to resolve the increment issue (if the modeling analysis shows that the increment is exceeded).

If the State does not meet these commitments, or if the State and EPA cannot agree on an acceptable modeling protocol or on acceptable control measures, then EPA may decide at some point in the future to initiate a formal SIP call.

As agreed to in our January 10, 2001 meeting, EPA will publish an informational notice in the **Federal Register** in the near future to inform the public of the process by which the State and EPA intend to address these increment violations; however, this information notice will not make the State's commitments legally binding in any way. We will send you a copy once it is published in the **Federal Register**.

If you have any questions regarding this matter, please feel free to contact me at 303-312-6005. We look forward to working with you to resolve the PSD increment issues in these Class I airsheds.

Sincerely,

Richard R. Long, Director
Air and Radiation Program

cc: Jeff Burgess, NDDH
Christine Shaver, NPS
Sandra Silva, USFWS
Deb Madison, Assiniboine and Sioux Tribes
Bob Raisch, MDEQ

Clifford Porter

From: John Dwyer [jdwyer@lignite.com]
Sent: Thursday, March 29, 2001 3:36 PM
To: 'Al Lukes (E-mail)'; 'Bill Lengenfelder Jr. (E-mail)'; 'Brian Bjella (E-mail)'; 'Chuck Reichert (E-mail)'; Dale Preszler (E-mail); 'Dan Butler (E-mail)'; 'Dan Swetich (E-mail)'; 'Dave Loer (E-mail)'; 'Dave Polsfuss (E-mail)'; 'Gordon Westerlind (E-mail)'; Jerry Splonskowski (E-mail); John Dwyer (E-mail); 'Marc Schulz (E-mail)'; 'Marlowe Johnson (E-mail)'; Mike Swenson (E-mail); 'Phil Solseng (E-mail)'; 'Robert (Bob) Wood (E-mail)'; Sandy Neigum (E-mail); Sheryl Massey (E-mail); Steve Sherner (E-mail); 'Terry Hildestad (E-mail)'; 'Vern Laning (E-mail)'; 'Bob Bartosh (E-mail)'; Bruce Browers (E-mail); 'Bruce Kopp (E-mail)'; 'Darryl Galt (E-mail)'; 'David Sogard (E-mail)'; 'Dean Peterson (E-mail)'; 'Doug Kane (E-mail)'; 'Fred Stern (E-mail)'; Jerry Grosz (E-mail); 'Larry Duppong (E-mail)'; Mary Ann Johnson (E-mail); 'Mike Hummel (E-mail)'; Rick Lancaster (E-mail); 'Steve Schultz (E-mail)'; 'Wally Goulet (E-mail)'; Brian Bjella (E-mail); Bruce Kopp (E-mail); Dale Niezwaag (E-mail); 'Dennis Boyd (E-mail)'; 'Fletcher Poling (E-mail)'; Gary Jacobson (E-mail); 'Mark Bring (E-mail)'; 'Wayne Tanous (E-mail)'
Cc: Mary Ann Johnson (E-mail); Deborah Levchak (E-mail); 'Bob Edwards (E-mail)'; 'Cliff Miercort (E-mail)'; 'Ed Russell (E-mail)'; 'Jim Van Epps (E-mail)'; 'John MacFarlane (E-mail)'; 'Martin White (E-mail)'; Ron Harper (E-mail); Ron Tipton (E-mail); 'Andrea Stomberg (E-mail)'; 'Brandon Krogh (E-mail)'; 'Diane Stockdill (E-mail)'; 'Jim K. Miller (E-mail)'; 'John Graves (E-mail)'; 'Keith Ganzer (E-mail)'; 'Mary Jo Roth (E-mail)'; 'Terry Graumann (E-mail)'
Subject: Tax Bill to Governor/Lignite Vision 21 Project Update/SIP Process Outlined by DOH/EPA

SIP-EPA.doc SIP-DOH.doc

This is just a short note to update you on recent developments:

1) Yesterday, the State Senate unanimously approved the House amendments to our coal severance/coal conversion tax bill that reduces the severance tax in half, caps the Great Plains tax on revenues going to the federal government under the purchase agreement, keeps the coal counties and state whole and increases the agreed upon increase in the coal conversion tax. This was a tremendous undertaking with a lot of potential pitfalls and "speed bumps" along the way and my thanks to all those who helped make it a reality. It now goes to the Governor and assuming he is still on board, I expect the bill to be signed next week. SB 2299 also achieves the objectives of making lignite more competitive and addresses the constitutional concerns of the Tax Department and the Attorney General's office. It also avoided provisions authorizing local property tax efforts on the plants and still keeps the tax on our plants at a very competitive position--Again my thanks to all industry lobbyists who helped in this effort;

2) Today, the Lignite Research Council (made up of all industry players and state officials), unanimously approved the applicaton of Great River Energy for $10 million in assistance for development of the Lignite Vision 21 Project. The application now goes to the Indusrial Commission for final consideration, which is expected to take place on April 19th or at its May 2nd meeting. A contract is presently being negotiated with Great River Energy and is expected to be approved by the Commission. Also, the independent reviews of the MDU/Westmorland applications are presently being conducted and will be considered by the Lignite Research Council at its April 26th meeting;

3) The state Health Department (DOH) has successfully negotiated a delay in a SIP call by EPA and I attach letters from both EPA and DOH that describe the agreed upon process. Note there will be a Federal Register of the proceedings which provides the public with notice of all proceedings.

Again, this is just a short update on these issues.

Sincerely,
John Dwyer

March 29, 2001

U.S. Going Empty-Handed to Meeting on Global Warming

By DOUGLAS JEHL

WASHINGTON, March 28 — With an international meeting of environment officials scheduled to begin on Thursday, the United States will be in the position of having no policy on global warming, which will be the main issue at the gathering.

RELATED ARTICLES
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READERS' OPINIONS
• Join a Discussion on Global Warming

The Bush administration reconfirmed today that it opposed the Kyoto Protocol, the international treaty to fight global warming, and would not submit it for Senate ratification.

"The president has been unequivocal," the White House spokesman, Ari Fleischer, said. "He does not support the Kyoto treaty. It is not in the United States' economic best interest."

Mr. Fleischer, who was asked at a White House briefing to clarify the administration's stance, said the administration was developing other strategies to deal with change in the world's climate.

The meeting of the Western Hemisphere's environment ministers will be the first such gathering since the Bush administration announced earlier this month that it would not seek to regulate power plants' emissions of carbon dioxide, a decision that amounted to effective abandonment of the Kyoto accord.

"We're going into the lion's den unarmed," said a senior administration official who expressed deep frustration that a new policy had not yet been formulated.

The American delegate to Thursday's meeting will be Christie Whitman, the administrator of the Environmental Protection Agency, who had advised

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against the decision on power plant emissions but was overruled by the White House. At a news conference on Tuesday, Mrs. Whitman repeated the White House's position that it had "no interest" in carrying out the treaty negotiated in 1997 in Kyoto, Japan.

Administration officials sympathetic to Ms. Whitman's position said she had tried in vain to obtain clear instructions about how to answer questions from United States allies concerned about the carbon dioxide policy. The administration's new stance reverses a campaign pledge made by President Bush and was at odds with the position that Ms. Whitman outlined to other environment ministers just four weeks ago at an international conference on global warming in Italy.

"She's essentially not been given anything to say," one senior official said of the two-day meeting in Montreal, adding that the only thing Ms. Whitman would be able to state authoritatively about the administration's position on global warming was that it was the subject of a cabinet-level review.

Several foreign leaders, including the German chancellor, Gerhard Schröder, have been outspoken in their criticism of the administration for its opposition to the Kyoto accord. Mr. Schröder is to meet with President Bush at the White House on Thursday, and global warming is expected to be high on their agenda.

A senior official who defended the White House position said foreign governments should not be surprised either by Mr. Bush's opposition to the Kyoto accord, which he has criticized since early in the presidential campaign, or by the lack of a policy so early in a new administration.

"Diplomatically, we're hearing a lot of criticism from a lot of countries, and I suppose at every meeting we go to we'll hear more," said the official, who spoke on condition of anonymity. "At the same time, it's been no secret what the president's position on the treaty has been."

The murmurs of dissent within the administration reflected a view attributed to Ms. Whitman that the White House had been unwise to declare its opposition to the Kyoto pact before it could point to an alternative.

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March 29, 2001

U.S. Going Empty-Handed to Meeting on Global Warming

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In a memorandum to Mr. Bush earlier this month, before the decision on carbon dioxide emissions, Ms. Whitman warned that most other industrialized nations regarded the Kyoto accord as "the only game in town."

"There's a real fear in the international community that if the U.S. is not willing to discuss the issue within the framework of Kyoto, the whole thing will fall apart," Ms. Whitman wrote in the memorandum, whose contents were first reported in The Washington Post.

"Mr. President, this is a credibility issue (global warming) for the U.S. in the international community," she wrote. "It is also an issue that is resonating here at home. We need to appear engaged and shift the discussion from the focus on the K-word to action, but we have to build some bonafides first."

The Kyoto accord would require the United States and other industrialized countries to reduce emissions of heat-trapping gases by an average of 5.2 percent by 2012 compared with their 1990 levels. The United States and more than 100 other countries signed the treaty, but no industrial country has yet ratified it. An effort by the Clinton administration to win its ratification by the Senate was defeated 95 to 0.

In the United States, most industry representatives have strongly opposed the accord, warning that it would impose enormous costs on the American economy.

An official of the Global Climate Coalition, which reflects industry views, said today that the Bush administration had a right to sever any association with the Kyoto treaty's specific guidelines for emissions reductions.

"There's a fundamentally more effective way of dealing with climate change

There's a fundamentally more effective way of dealing with climate change, which is one based on technological development, and that's the one we support," the official, Glenn Kelly, said.

But a former Clinton administration official, David B. Sandalow, who helped to negotiate the 1997 accord, said the stance would undercut American credibility.

"It's a textbook case of unilateral diplomacy, which rarely works and always brings resentment," Mr. Sandalow said.

An environmental group, Friends of the Earth, called the American stance "environmental isolationism."

The meeting of environment ministers that begins in Montreal on Thursday will include representatives of Canada, Mexico, Brazil, Argentina and other countries from the Western Hemisphere in advance of a meeting of heads of state in May that will be known as the Summit of the Americas.

In terms of global warming, a more important gathering will take place in July, when heads of state have been invited to Bonn under the auspices of the United Nations Framework Convention on Global Warming, which President George Bush signed in 1992. That meeting had initially been scheduled for May, but was postponed at the request of the current administration.

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Clifford Porter

From: Reimer, Patti J. [preimer@undeerc.org]
Sent: Monday, April 16, 2001 4:20 PM
To: 'tgraumann@otpco.com'; 'cporter@lignite.com'; 'pritchardsg@cormetech.com'; 'DOCONNOR@epri.com'; 'edmundovasquez@alliant-energy.com'; 'kenneth_b_stuckmeyer@ameren.com'; 'byron_veech@illinoispower.com'; 'mark_liefer@dynegy.com'; 'Rene.Mangal@kinectrics.com'; 'blair.seckington@ontariopowergeneration.com'; 'walter.nischt@hal.hitachi.com'; 'Susan.Maley@netl.doe.gov'; 'patton@netl.doe.gov'; 'ziaul_karim@dynegy.com'; 'fgh@topsoe.com'; 'howard.franklin@hal.hitachi.com'
Cc: Benson, Steven A.; Toman, Donald L.; Gunderson, Jay R.; Laumb, Jason; Zygarlicke, Chris J.; Landis, Sheryl
Subject: SCR Blinding Project Conference Call Agenda

SCRConfCall041801.doc

Attached below is a copy of the agenda for the conference call which is scheduled for this Wednesday, April 18, at 1:00 CST. The instructions for the call are as follows:

As soon as you are available for the call, dial (701) 777-4456. You will be prompted to enter a passcode, which is 1445 (be certain to hit the # key after entering the passcode number). You will then hear a beep, which means that you are on the line and connected. Please stay on the line even though no one else is on yet. Steve will be on the line a couple of minutes early. If you have trouble connecting, please call Linda at (701) 777-3206 and ask for assistance.

The meeting at the EERC, scheduled for Wednesday, May 23, will start at 8:30 a.m. and end at 3:00 so you will be able to take the afternoon flight out of Grand Forks (4:25 p.m.). I will send out an agenda for that meeting at a later date. If you have not yet done so, please reply to me as to whether you will be attending this meeting.

<<SCRConfCall041801.doc>>

Thank you,
Patti Reimer

Energy & Environmental Research Center
University of North Dakota
PO Box 9018
15 North 23rd Street
Grand Forks, ND 58202-9018
Phone: (701) 777-5070
Fax: (701) 777-5181
E-mail: preimer@undeerc.org

Clifford Porter

From: Klegstad, Stacie [sklegstad@undeerc.org]
Sent: Friday, May 04, 2001 10:47 AM
To: 'cporter@lignite.com'; 'pritchardsg@cormetech.com'; 'DOCONNOR@epri.com'; 'tgraumann@otpco.com"; 'edmundovasquez@alliant-energy.com'; 'kenneth_b_stuckmeyer@ameren.com'; 'byron_veech@illinoispower.com'; 'mark_liefer@dynegy.com'; 'Rene.Mangal@kinectrics.com'; 'blair.seckington@ontariopowergeneration.com'; 'walter.nischt@hal.hitachi.com'; 'Susan.Maley@netl.doe.gov'; 'patton@netl.doe.gov'; 'ziaul_karim@dynegy.com'; 'fgh@topsoe.com'; 'howard.franklin@hal.hitachi.com'

cz-SCR-Prospectus.doc

May 3, 2001

Dear SCR Blinding Project Members:

Issues with respect to NOx control continue to be at the forefront for many utility decision makers. Regulations for NOx control are leading many utilities to install or at least make plans to install NOx reduction systems such as selective catalytic reduction (SCR) equipment. As you know, low-rank coals are suspected of having tendencies to cause blinding of the SCR catalyst material, which deactivates the catalyst and limits NOx conversion.

The Energy & Environmental Research Center (EERC) has nearly completed the construction of two portable test reactors that can be set up in conjunction with a flue gas slipstream at a full-scale coal-fired boiler to test the deactivation of SCR catalysts. These units will be used to collect information on the mechanisms of SCR blinding for utility boilers firing low-rank coal. Initial evidence from bench-scale work in this project and other studies indicates that low-rank coal inorganics such as calcium, sodium, phosphorus, and sulfur may cause blinding in some SCR systems.

A second phase, or a separate project, of the ongoing SCR Blinding project is being proposed here which would specifically address the impact of cofiring biomass on SCR catalyst performance. Biomass fuel can contain elements simular to those in low-rank coals, but with typically greater amounts of potassium, phosphorus, and chlorine. The list of large utilities that are seriously considering cofiring biomass is growing, and the issue of impacts on SCR performance is real.

At the next SCR Blinding project meeting in Grand Forks, on May 23, 2001, this new project idea will be discussed. If there is enough interest from participants outside the current SCR Blinding project, then a short "side" meeting will be held with all interested parties to discuss the proposed project in detail.

A prospectus describing the project goals, objectives, and work plan for this new effort is enclosed. The cost for the project is estimated at $250,000, which would include one-time commitments from six sponsors at $25,000. I realize that budgets for emissions control upgrading and emissions research support are tight and that the current SCR Blinding project is just ready to launch into field testing, but timing is critical on this second project. We would like to plan ahead, with a shorter project duration and lower project cost.

I encourage you to read the prospectus and let us know if you are interested in participating in a meeting to discuss the impacts of biomass cofiring on SCR catalyst blinding. Thank you for your time, and we appreciate the chance to work with you on this endeavor.

Sincerely,
Christopher J. Zygarlicke
Senior Research Manager

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BACKGROUND

Nitrogen oxide emission limits have been reduced for utility boilers, requiring retrofits to existing units with low-NO_x burners and selective catalytic reduction (SCR) systems. Some utilities are considering the use of biomass as a low-cost alternative fuel because it is environmentally friendly, recycling carbon rather than adding it to the earth's atmosphere as CO_2, which is considered a greenhouse gas. Biomass and low-rank coals often contain larger relative quantities of alkali and alkaline–earth elements (i.e., potassium, sodium, and calcium) in addition to moderate sulfur levels. These constituents have the potential to impair the operation of SCR systems by the formation of sulfate-based deposits on catalyst surfaces, leading to higher NO_x emissions and potentially high ammonia slip. The Energy & Environmental Research Center (EERC) at the University of North Dakota is proposing a test program to determine the degree of catalyst blinding that may occur for coal boilers firing blends of biomass and coal.

TEST PROGRAM

SCR blinding is a slow process that occurs over a period of 500 to 2000 hours. In order to evaluate SCR blinding experimentally, full-scale systems must be tested, because smaller-scale combustion equipment cannot be operated for 4 to 6 months at a time. Two skid-mounted test rigs have been constructed to conduct full-scale evaluation of SCR blinding. These systems consist of a catalyst section, an ammonia injection system, and sampling ports for NO_x at the inlet and exit. The portable systems can be installed in the region ahead of the air heater in a full-scale utility boiler and will isokinetically extract a slipstream from the flue gas duct using an induced-draft fan. The test reactors are fully instrumented with a complete suite of gas analyzers and remote operation equipment. Testing will be done on at least two different boilers burning different coals and different biomass types. Any blinding deposits that form will be analyzed using advanced techniques at the EERC to determine the root causes of blinding and to propose predictive mitigation measures. Results of bench-scale testing and the development of predictive capabilities generated in a parallel U.S. Department of Energy (DOE) project will be shared with this project.

DELIVERABLES

This project aims to provide sponsors with key information, which competitors will not have, with respect to the performance of SCR catalysts under realistic biomass–coal cofiring conditions. Expertise will be gained to fire biomass without impeding SCR performance.

POTENTIAL SPONSORS

Any utility that is currently cofiring biomass or will be in the future and is subject to NO_x emission limits reduction has a stake in this project. The project requires several utility cosponsors that

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will cofund the work and share the benefits of the research.

COST
The total cost for this project is approximately $250,000, which is the minimum cost for performing two 4 to 6-month-long field tests at two sites. Six separate utility commitments of $25,000 will be necessary, totaling $150,000, and DOE joint venture contribution of $100,000 will be sought. Other potential sponsors could include EPRI, boiler vendors, and catalyst vendors. Additional funding beyond the estimated minimum of $250,000 will be put toward additional units or variables tested.

TIME FRAME
The project will be completed within 18 months. Plant selection and field testing at the first plant will occur over the first 8 months, followed by a second 6-month field test, and final reporting during the last 2 months. Since two reactors have already been built under separate funding, simultaneous data collection can be done to shorten the project time line.

CONTACT
Interested parties may obtain a detailed proposal or a more detailed description of the project by contacting:

Christopher J. Zygarlicke
Senior Research Manager
701-777-5123
czygarlicke@undeerc.org

INDUSTRIAL COMMISSION OF NORTH DAKOTA

LIGNITE RESEARCH, DEVELOPMENT AND MARKETING PROGRAM

Governor,
John Hoeven
Attorney General,
Wayne Stenehjem
Commissioner of Agriculture,
Roger Johnson

MEMORANDUM

June 6, 2001

TO: Karlene Fine, Executive Director and Secretary
North Dakota Industrial Commission

FROM: Clifford R. Porter, Director CRP
Lignite Research, Development and Marketing Program

SUBJECT: FY00-XXXVI-100: "Evaluation of Potential SCR Catalyst Blinding During Coal Combustion"; Contractor: Energy & Environmental Research Center; Recommendation for Payment of $22,500 for Second of Seven Quarterly Reports (1/1/01 – 3/31/01).

I have reviewed the second quarterly report (January 1, 2001 – March 31, 2001) from the contractor (Energy & Environmental Research Center) regarding Contract No. FY00-XXXVI-100 for the project titled "Evaluation of Potential SCR Catalyst Blinding During Coal Combustion".

This second of seven quarterly reports is adequate to determine that the contractor has complied with the statement of work.

The contractor has met the terms of contract FY00-XXXVI-100 required for receiving the $22,500 payment for the second quarterly report. I recommend payment of the $22,500.

.

CRP/vg: 24.S.30.A

LIGNITE RESEARCH COUNCIL
John Dwyer, Chairman
Clifford Porter, Director & Technical Advisor
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INDUSTRIAL COMMISSION OF NORTH DAKOTA
Karlene Fine
Executive Director
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Bismarck, N.D. 58505
(701) 328-3722 (701) 328-2820 Fax

INDUSTRIAL COMMISSION OF NORTH DAKOTA

LIGNITE RESEARCH, DEVELOPMENT AND MARKETING PROGRAM

Governor,
John Hoeven
Attorney General,
Wayne Stenehjem
Commissioner of Agriculture,
Roger Johnson

MEMORANDUM

August 14, 2001

TO: Karlene Fine, Executive Director and Secretary
North Dakota Industrial Commission

FROM: Clifford R. Porter, Director CRP
Lignite Research, Development and Marketing Program

SUBJECT: FY00-XXXVI-100: "Evaluation of Potential SCR Catalyst Blinding During Coal Combustion"; Contractor: Energy & Environmental Research Center; Recommendation for Payment of $22,500 for Third of Seven Quarterly Reports (4/1/01 – 6/30/01).

I have reviewed the third quarterly report (April 1, 2001 – June 30, 2001) from the contractor (Energy & Environmental Research Center) regarding Contract No. FY00-XXXVI-100 for the project titled "Evaluation of Potential SCR Catalyst Blinding During Coal Combustion".

This third of seven quarterly reports is adequate to determine that the contractor has complied with the statement of work.

The contractor has met the terms of contract FY00-XXXVI-100 required for receiving the $22,500 payment for the third quarterly report. I recommend payment of the $22,500.

CRP/vg: 24.S.30.A

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Vicki Gilmore

From: Vicki Gilmore [vgilmore@lignite.com]
Sent: Friday, September 07, 2001 1:40 PM
To: Shirley Campbell (E-mail)
Cc: Clifford Porter (E-mail)
Subject: FW: LRC Contracts 87 and 100

Hello, Shirley -

I checked Clifford's files for FY99-XXXI-87 and FY00-XXXVI-100.

For contract FY99-XXXI-87, our file does NOT include a copy of the report that was due March 30, 2001 from the contractor, EERC. Will you please send Clifford a copy of your copy of the report so he can review it prior to making his recommendation for payment.

For contract FY00-XXXVI-100, we DID receive a copy of the third of seven quarterly status reports (dated April 1 - June 30, 2001) from the contractor, EERC. On August 14, 2001, Clifford sent a memo to Karlene recommending the payment of $22,500 for this third of seven quarterly status reports. In case you did not receive that memo, I've attached a copy. Let me know if you need a copy of the actual memo that Clifford initialed and mailed to you, or will this e-mail version suffice?

Thanks.

Vicki Gilmore
Lignite Energy Council
vgilmore@lignite.com <mailto:vgilmore@lignite.com>

-----Original Message-----
From: Campbell, Shirley K. [mailto:scampbel@state.nd.us]
Sent: Thursday, September 06, 2001 9:44 AM
To: 'Porter, Clifford'
Subject: LRC Contracts

Just thought I would let you know I am still waiting to hear from you on Contracts 87 and 100. I have their reports and am waiting for you memo to pay. If you do not have copies of these reports, please let me know.

Thanks,

Shirley

PS - paper clip day tomorrow!!

Clifford Porter

From: Reimer, Patti J. [preimer@undeerc.org]
Sent: Monday, October 15, 2001 2:33 PM
To: 'tgraumann@otpco.com'; 'cporter@lignite.com'; 'pritchardsg@cormetech.com'; 'DOCONNOR@epri.com'; 'edmundovasquez@alliant-energy.com'; 'kenneth_b_stuckmeyer@ameren.com'; 'Dean_Engelman@dynegy.com'; 'mark_liefer@dynegy.com'; 'Rene.Mangal@kinectrics.com'; 'blair.seckington@ontariopowergeneration.com'; 'walter.nischt@hal.hitachi.com'; 'Susan.Maley@netl.doe.gov'; 'ziaul_karim@dynegy.com'; 'fgh@topsoe.com'; 'howard.franklin@hal.hitachi.com'
Cc: Benson, Steven A.; Laumb, Jason; Zygarlicke, Chris J.; Toman, Donald L.; Gunderson, Jay R.; Landis, Sheryl
Subject: SCR Blinding Project Conference Call

The next SCR Blinding Project conference call will be held on Thursday, October 25, at 1:00 p.m. CST. The numbers to call in are the same (701) 777-4456, passcode 1445 (be sure to hit the # key after entering the passcode). An agenda for this meeting will be senet at a later date. Please let me know whether you will be participating in this call or not.

Thank you,
Patti Reimer
Administrative Assistant

Fine, Karlene K.

From: Landis, Sheryl [slandis@undeerc.org]
Sent: Wednesday, October 31, 2001 9:44 AM
To: 'Fine, Karlene K.'
Subject: RE: Contract FY00-XXXVI-101; Fund 4869

File #100

Yes, I am comfortable with that letter and so is the EERC Project
Manager,
Steve Benson. Please send, and thanks.
Sheryl

-----Original Message-----
From: Fine, Karlene K. [mailto:kfine@state.nd.us]
Sent: Tuesday, October 30, 2001 4:23 PM
To: 'Landis, Sheryl'
Subject: RE: Contract FY00-XXXVI-101; Fund 4869

Sheryl--I've attached a draft letter for your review. Would this be sufficient for your needs? Karlene

-----Original Message-----
From: Landis, Sheryl [mailto:slandis@undeerc.org
<mailto:slandis@undeerc.org>]
Sent: Monday, September 10, 2001 8:55 AM
To: 'kfine@state.nd.us'
Cc: 'cporter@lignite.com'; Benson, Steven A.
Subject: Contract FY00-XXXVI-101; Fund 4869

Karlene,

Would it be possible for you to fax me this week the necessary approval
for
subject contract granting our request to keep certain information
confidential? I believe the Industrial Commission approved the request
in
January's meeting.

We sure would appreciate receiving that approval.

Thanks.
Sheryl E. Landis, Manager
Contracts and Intellectual Property
Energy & Environmental Research Center
University of North Dakota
(701) 777-5124 phone
(701) 777-5181 fax

INDUSTRIAL COMMISSION OF NORTH DAKOTA

LIGNITE RESEARCH, DEVELOPMENT AND MARKETING PROGRAM

Governor,
John Hoeven
Attorney General,
Wayne Stenehjem
Commissioner of Agriculture,
Roger Johnson

MEMORANDUM

November 2, 2001

TO: Karlene Fine, Executive Director and Secretary
North Dakota Industrial Commission

FROM: Clifford R. Porter, Director
Lignite Research, Development and Marketing Program

SUBJECT: FY00-XXXVI-100: "Evaluation of Potential SCR Catalyst Blinding During Coal Combustion"; Contractor: Energy & Environmental Research Center; Recommendation for Payment of $22,500 for Fourth of Seven Quarterly Reports (7/1/01 – 9/30/01).

I have reviewed the fourth quarterly report (July 1, 2001 – September 30, 2001) from the contractor (Energy & Environmental Research Center) regarding Contract No. FY00-XXXVI-100 for the project titled "Evaluation of Potential SCR Catalyst Blinding During Coal Combustion".

This fourth of seven quarterly reports is adequate to determine that the contractor has complied with the statement of work.

The contractor has met the terms of contract FY00-XXXVI-100 required for receiving the $22,500 payment for the fourth quarterly report. I recommend payment of the $22,500.

CRP/vg: 24.S.30.A

LIGNITE RESEARCH COUNCIL
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INDUSTRIAL COMMISSION OF NORTH DAKOTA
Karlene Fine
Executive Director
600 East Boulevard, State Capitol
Bismarck, N.D. 58505
(701) 328-3722 (701) 328-2820 Fax

Vicki – please draft memo from
Jill to John

Same subject:

I have reviewed the ~~draft~~ 5th quarterly report

~~The contractor . . .~~
I recommend payment of the report. $22,500

– Make sure dates match up

INDUSTRIAL COMMISSION OF NORTH DAKOTA

LIGNITE RESEARCH, DEVELOPMENT AND MARKETING PROGRAM

Governor,
John Hoeven
Attorney General,
Wayne Stenehjem
Commissioner of Agriculture,
Roger Johnson

Vicki please type

MEMORANDUM
~~November 2, 2001~~
March 6, 2002

John ~~Clifford?~~

TO: Karlene Fine, Executive Director and Secretary
North Dakota Industrial Commission

FROM: John Dwyer ~~Clifford R. Porter~~, Acting Director
Lignite Research, Development and Marketing Program

SUBJECT: FY00-XXXVI-100: "Evaluation of Potential SCR Catalyst Blinding During Coal Combustion"; Contractor: Energy & Environmental Research Center; Recommendation for Payment of $22,500 for ~~Fourth~~ fifth of Seven Quarterly Reports (~~7/1/01 – 9/30/01~~ 10/1/01 – 12/31/01).

I have reviewed the ~~fourth~~ fifth quarterly report (~~July 1~~ October 1, 2001 – ~~September 30~~ December 31, 2001) from the contractor (Energy & Environmental Research Center) regarding Contract No. FY00-XXXVI-100 for the project titled "Evaluation of Potential SCR Catalyst Blinding During Coal Combustion".

This ~~fourth~~ fifth of seven quarterly reports is adequate to determine that the contractor has complied with the statement of work.

The contractor has met the terms of contract FY00-XXXVI-100 required for receiving the $22,500 payment for the ~~fourth~~ fifth quarterly report. I recommend payment of the $22,500.

~~CRP~~/vg: 24.S.30.A

LIGNITE RESEARCH COUNCIL
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Roger Johnson

INDUSTRIAL COMMISSION OF NORTH DAKOTA

LIGNITE RESEARCH, DEVELOPMENT AND MARKETING PROGRAM

http://www.state.nd.us/ndic

MEMORANDUM
March 19, 2002

TO: Karlene Fine, Executive Director and Secretary
North Dakota Industrial Commission

FROM: John W. Dwyer, Acting Director
Lignite Research, Development and Marketing Program

SUBJECT: FY00-XXXVI-100: "Evaluation of Potential SCR Catalyst Blinding During Coal Combustion"; Contractor: Energy & Environmental Research Center; Recommendation for Payment of $22,500 for Fifth of Seven Quarterly Reports (10/1/01 – 12/31/01).

I have reviewed the fifth quarterly report (October 1, 2001 – December 31, 2001) from the contractor (Energy & Environmental Research Center) regarding Contract No. FY00-XXXVI-100 for the project titled "Evaluation of Potential SCR Catalyst Blinding During Coal Combustion".

This fifth of seven quarterly reports is adequate to determine that the contractor has complied with the statement of work.

The contractor has met the terms of contract FY00-XXXVI-100 required for receiving the $22,500 payment for the fifth quarterly report. I recommend payment of the $22,500.

JWD/vg: 24.S.30.A

LIGNITE RESEARCH COUNCIL

John Dwyer, Chairman
jdwyer@lignite.com
Lignite Research Council
P.O. Box 2277
Bismarck, ND 58502

Phone: (701) 258-7117 FAX: (701) 258-2755

INDUSTRIAL COMMISSION OF NORTH DAKOTA

Karlene Fine
Executive Director & Secretary
kfine@state.nd.us
Industrial Commission of North Dakota
State Capitol
600 East Boulevard Avenue
Bismarck, ND 58505

Phone: (701) 328-3722 FAX: (701) 328-2820

MEMORANDUM
March 19, 2002

TO: John Dwyer, President
Lignite Energy Council

FROM: Jeff Burgess, Manager of Environmental Services
Lignite Vision 21 Program

SUBJECT: Contract No. FY00-XXXVI-100 ("Evaluation of Potential SCR Catalyst Blinding During Coal Combustion"; Contractor: Energy & Environmental Research Center (EERC); Recommendation for Payment of $22,500 for Fifth of Seven Quarterly Reports (10/1/01- 12/31/02)

Pursuant to the above-referenced contract, I have received and reviewed the fifth of seven quarterly reports required from the contractor (EERC) under the terms of Contract No. FY00-XXXVI-100. It is my determination that the contractor has met the terms of the contract for receiving the $22,500 payment for the fifth of seven quarterly reports. Therefore, I recommend the payment of $22,500.

Jeff Burgess

JB/vg:24.S.30.A

INDUSTRIAL COMMISSION OF NORTH DAKOTA

LIGNITE RESEARCH, DEVELOPMENT AND MARKETING PROGRAM

MEMORANDUM
June 6, 2002

TO: Karlene Fine, Executive Director and Secretary
North Dakota Industrial Commission

FROM: Harvey M. Ness, Director and Technical Advisor
Lignite Research, Development and Marketing Program

HMN 6/6/02

cc: John W. Dwyer, Chairman
Lignite Research Council

SUBJECT: FY00-XXXVI-100: "Evaluation of Potential SCR Catalyst Blinding During Coal Combustion"; Contractor: Energy & Environmental Research Center; Recommendation for Payment of $22,500 for Sixth of Seven Quarterly Reports (1/1/02 – 3/31/02).

I have reviewed the fifth quarterly report (January 1, 2002 – March 31, 2002) from the contractor (Energy & Environmental Research Center) regarding Contract No. FY00-XXXVI-100 for the project titled "Evaluation of Potential SCR Catalyst Blinding During Coal Combustion".

This sixth of seven quarterly reports is adequate to determine that the contractor has complied with the statement of work.

The contractor has met the terms of contract FY00-XXXVI-100 required for receiving the $22,500 payment for the sixth quarterly report. I recommend payment of the $22,500.

HMN/vg: 24.S.30.A

LIGNITE RESEARCH COUNCIL
John Dwyer, Chairman
Harvey Ness, Director & Technical Advisor
P.O. Box 2277
Bismarck, N.D. 58502
(701) 258-7117 (701) 258-2755 Fax

INDUSTRIAL COMMISSION OF NORTH DAKOTA
Karlene Fine
Executive Director
600 East Boulevard, State Capitol
Bismarck, N.D. 58505
(701) 328-3722 (701) 328-2820 Fax

MEMORANDUM

August 13, 2002

TO: Karlene Fine, Executive Director and Secretary
North Dakota Industrial Commission

FROM: Harvey M. Ness, Director and Technical Advisor
Lignite Research, Development and Marketing Program hmn 8.13.02

cc: John W. Dwyer, Chairman
Lignite Research Council

SUBJECT: FY00-XXXVI-100: "Evaluation of Potential SCR Catalyst Blinding During Coal Combustion"; Contractor: Energy & Environmental Research Center; Recommendation for Payment of $22,500 for Seventh Quarterly Report (4/1/02 – 6/30/02).

I have reviewed the seventh of seven quarterly reports (April 1, 2002 – June 30, 2002) from the contractor (Energy & Environmental Research Center) regarding Contract No. FY00-XXXVI-100 for the project titled "Evaluation of Potential SCR Catalyst Blinding During Coal Combustion".

This seventh quarterly report is adequate to determine that the contractor has complied with the statement of work.

The contractor has met the terms of contract FY00-XXXVI-100 required for receiving the $22,500 payment for the seventh quarterly report. I recommend payment of the $22,500.

HMN/vg: 24.S.30.A

Campbell, Shirley K.

file 100/

From: Harvey Ness [hness@lignite.com]
Sent: Wednesday, November 13, 2002 9:19 AM
To: 'Campbell, Shirley K.'
Subject: RE: Status of 100

Karlene, Shirley Spoke with Steve Benson. The project will continue for another 9 months (roughly). A test unit will be installed at the Coyote Plant in December (late) followed by a six month test program. Add another three months to analyze the data and prepare the final report. Steve will [redacted]

In view of the long delay, I asked Steve to submit an extension request.

Harvey

-----Original Message-----
From: Campbell, Shirley K. [mailto:scampbel@state.nd.us]
Sent: Tuesday, November 12, 2002 3:15 PM
To: Ness, Harvey
Subject: Status of 100

I have talked to Karlene and she said she has not received anything as far as an extension from the EERC for contract 100. She said if it is only going to be a couple months until we get the final report, they don't need an extension, they started six months late.

Shirley