REINHOLD ENVIRONMENTAL Ltd.

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COAL KEEPS THE LIGHTS ON…

In situ SCR Catalyst Cleaning

Presented By Michael Ware
Director, PGI/SCR Solutions

What Do We Know?

- Proper testing, management and *maintenance* are critical to catalyst life.
- Catalyst loose performances because of fouling.
- Catalyst plugging is a still major problem.

Poisoning or blinding *both* serve the same function of reducing the potential or 'life' of the catalyst.

Properly maintained catalyst are better suited for regeneration resulting in significant savings.

The key to successfully operating a selective catalytic reduction (SCR) system is proper management and *maintenance* of the catalyst itself.

REMOVING BLOCKAGE

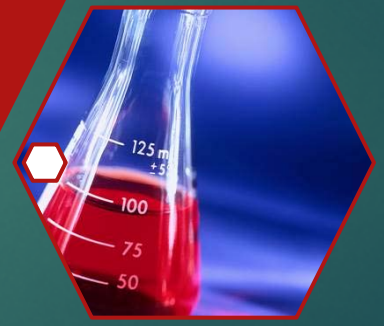
SCR Is affected due to a number of particulates

Fine Fly Ash

LPA

Ammonium Sulphate

/Bisulphate

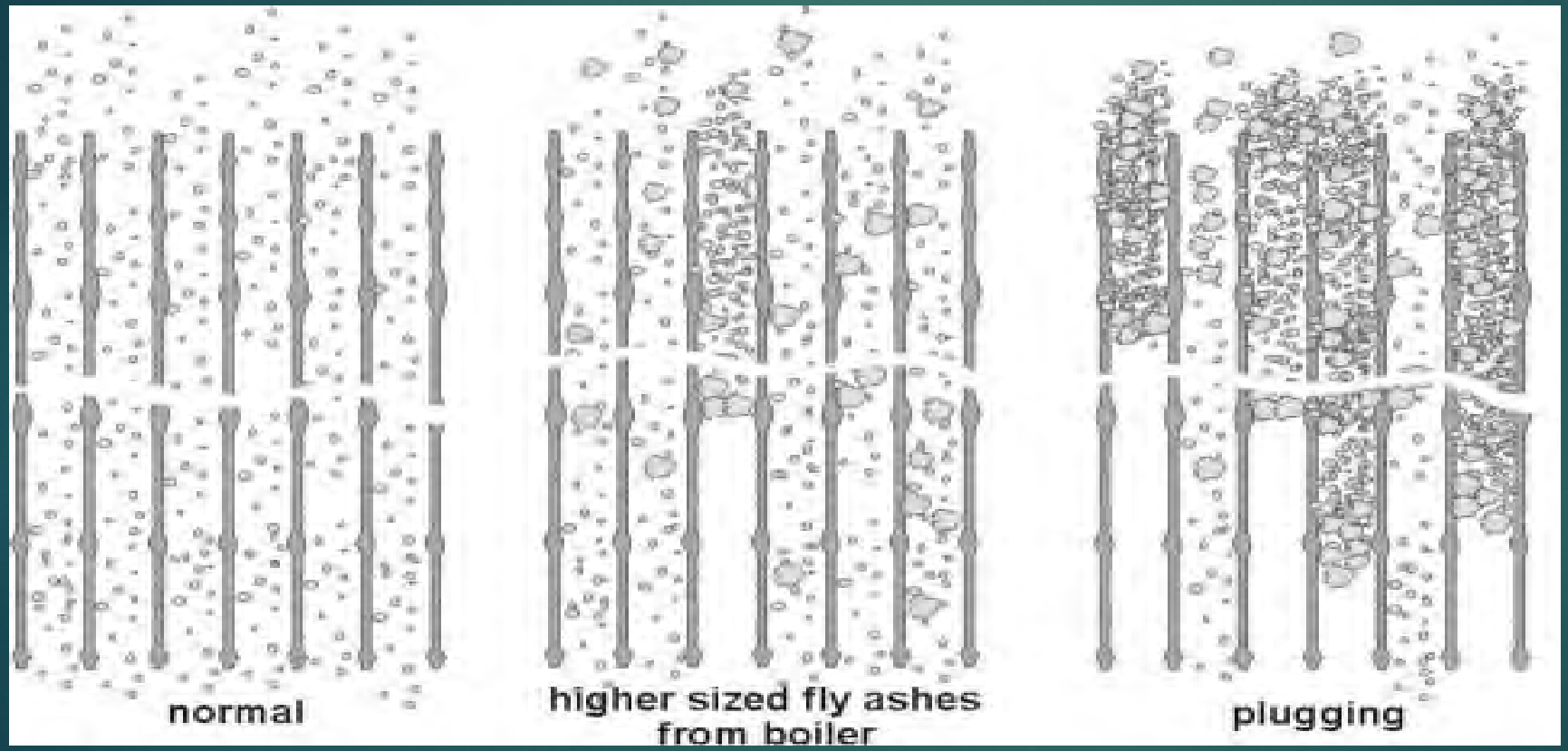


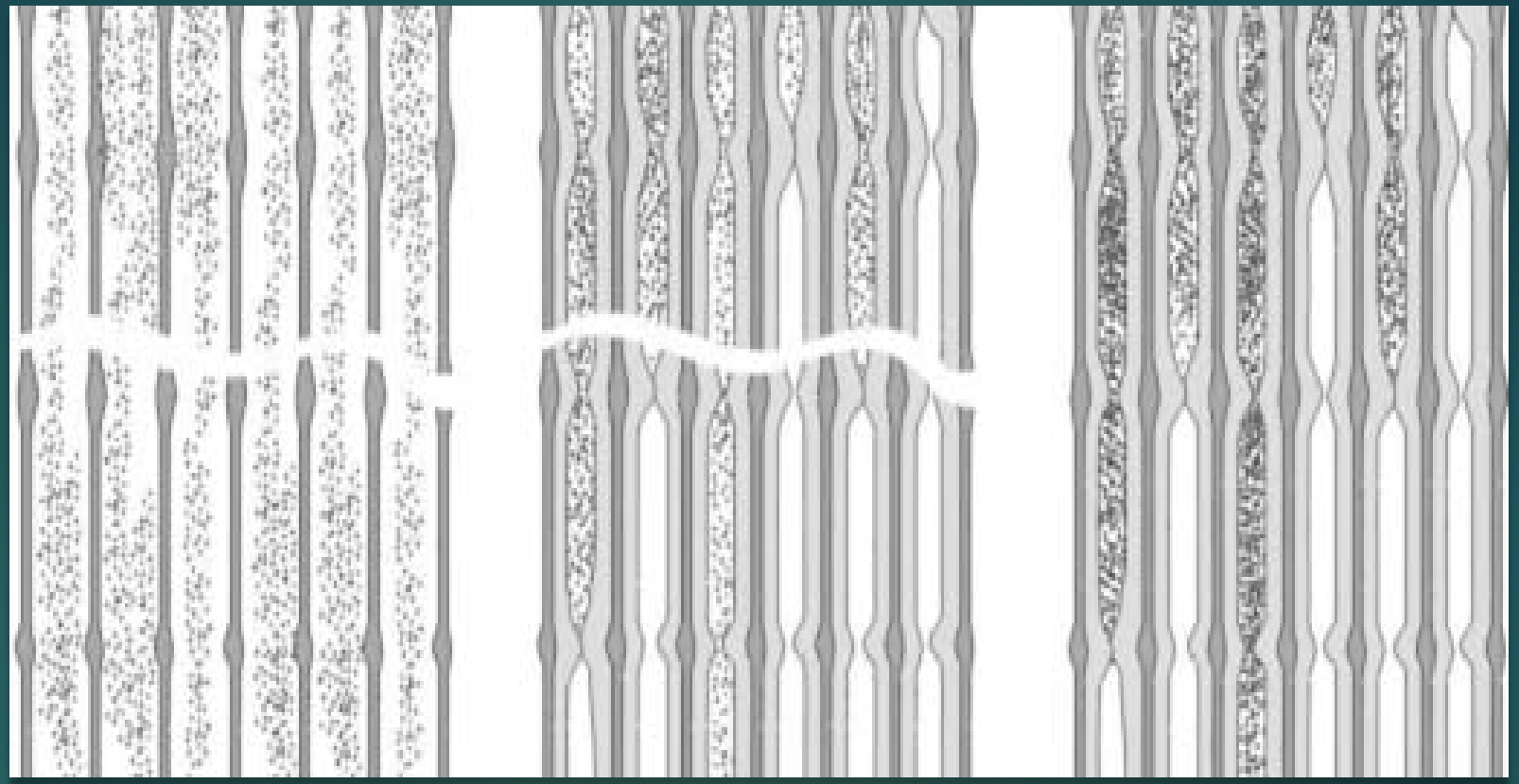
THE KEY TO EFFICIENCY

SCR CATALYST BLOCKAGE

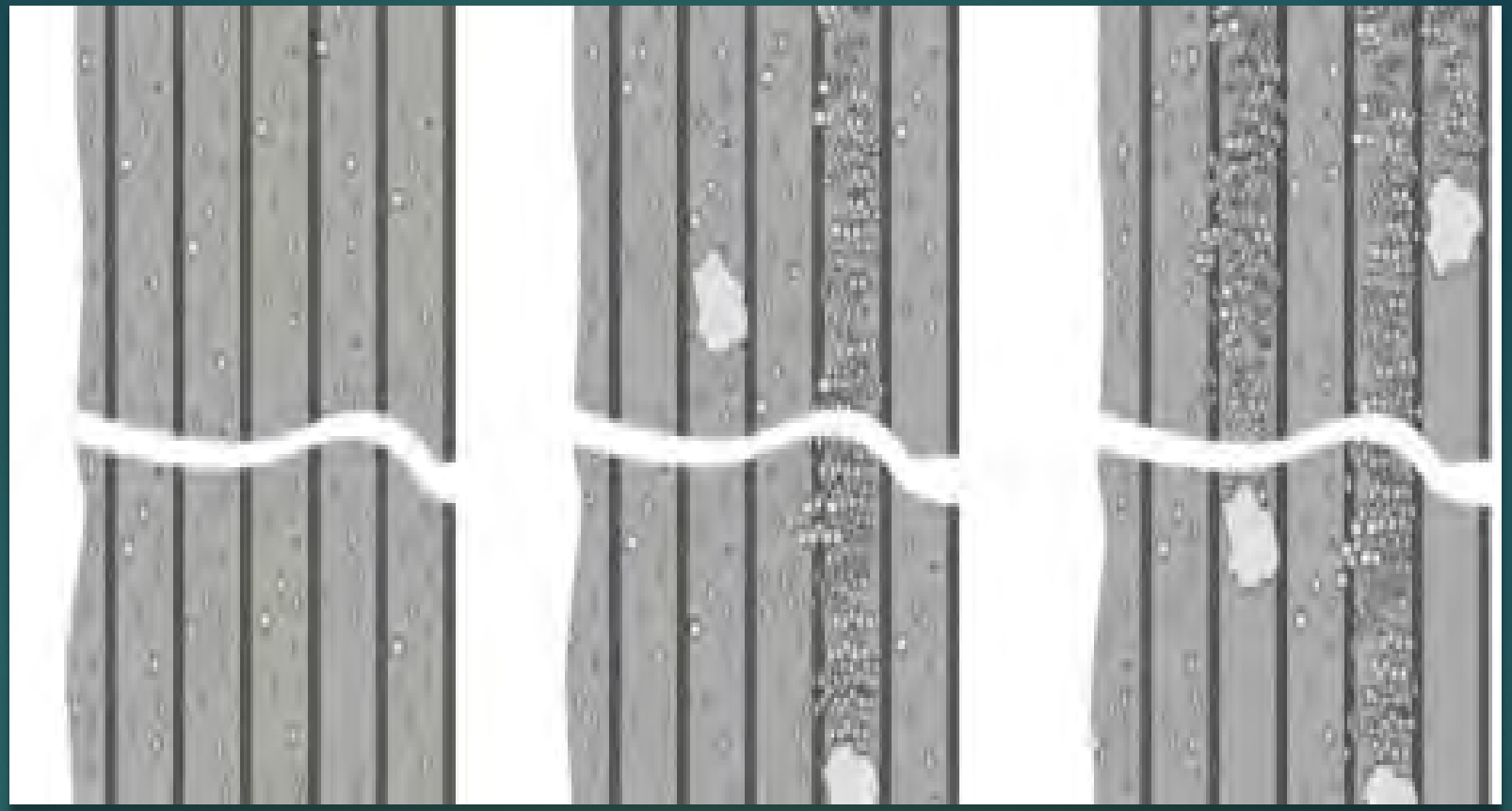
EXAMPLES

FLY ASH PLUGGING





MgO PLUGGING



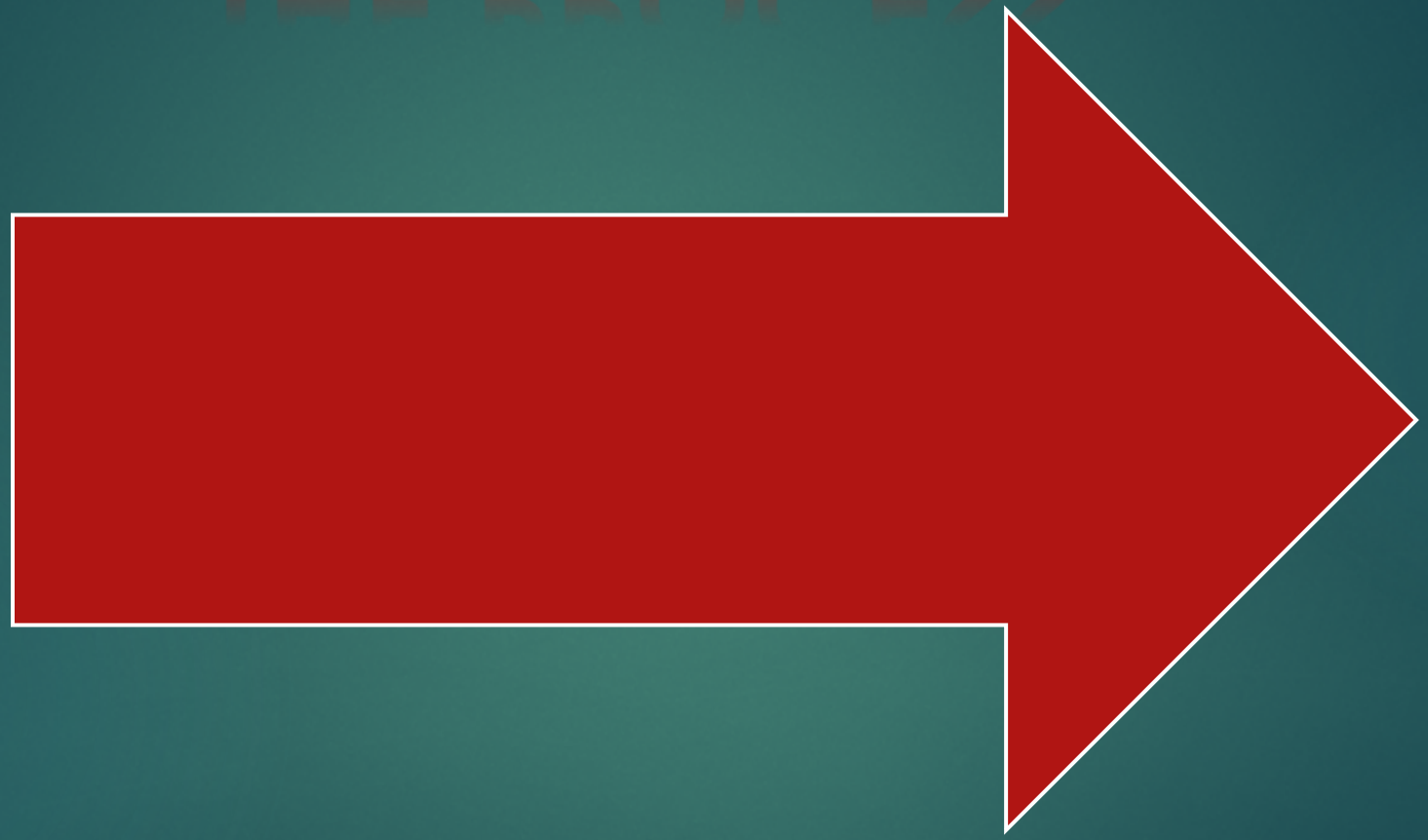
POPCORN PLUGGING

CATALYST CLEANING PURPOSE

Catalyst for coal-fired plants get plugged with ash and contaminated with arsenic and calcium reducing the surface area and plugging the catalyst. (This, in turn, increases pressure drop and ammonia slip). Therefore, proper cleaning of the SCR unit and the catalyst are the first line of defense against problems between outage periods.

Simply vacuuming the fly ash off the tops of the catalyst screens does not effectively clear the catalyst surface or pores from physical or chemical poisoning substances.
Proper cleaning of the entire SCR unit, including the catalyst surface and pores will reduce pressure drop and ammonia slip, as well as *prolong catalyst life*.

THE PROCESS



The Process Starts Where Traditional Cleaning Ends:

- Scrappers and lances are used to remove hardened ash from SCR Reactor area.

- Fly ash is vacuumed from catalyst layer, including:

  - ✓ All beams
  - ✓ Tops of screens
  - ✓ Under Screens

ADDITIONAL PROCESS INVOLVED:

- Screens are removed
- Specialized vibration equipment is installed beneath the catalyst layers
- Crusting is removed from catalyst surface using dry-cleaning method
- Specialized Vacuum/Air Hood Equipment is applied to each catalyst module

Click Arrow to Play Video

Click Arrow to Play Video

CATALYST CLEANING RESULTS

The catalyst are effectively cleared of both chemical and physical deactivation substances

Decrease in Pressure Drop
Increasing Reaction Surface

Decrease in Ammonia Slip

Increase in Plant Efficiency

Reduction of catalyst poisoning

Reduced Risk of Boiler Shutdown

RESULTS & TESTIMONIALS

Michael,

I've attached a brief report I just put together about the change seen in catalyst plugging following your cleaning efforts at Thomas Hill. Definite improvement was noted in all layers, especially in layers 1 and 2. As you indicated, given more time I am sure you could have removed even more of the impacted ash.

Thank you for mobilizing your outfit on such short notice and performing this work so quickly at our plant. Your crews did an excellent job given the time limitation they had.

Thanks,

Tom Salt
Mechanical Engineer
Associated Electric Coop. Inc.
Thomas Hill Energy Center
(660) 261-3231

RESULTS & TESTIMONIALS CONTINUED.....

Unit 1 SCR Cleaning Report Fall 2011
10/24/2011
The Thomas Hill Unit 1 SCR consists of three layers of 1150 mm length Ceram catalyst with 45 modules per layer. Catalyst cleaning by SCR Solutions was performed in this SCR for four 12 hour shifts, starting on 10/22/11, with a six man crew per shift. Vacuum hose, air lances and SCR's hood/pneumatic vibration equipment were employed in the process. The vibration equipment was only used on the top two layers because access was not available to place the equipment below the third level. Furthermore only limited cleaning was performed on the third layer due to the time limitation placed upon the contractor in order to kept the cleaning costs within the amount of the purchase order. The contractor project manager indicated that with sufficient time improved cleaning could have been realized. The estimated average plugging per layer before and after this cleaning effort are given below. Charts indicating plugging across each layer are also presented below. Prior to SCR Solutions' work the catalyst had been vacuumed and cleaned by AECI personnel using traditional cleaning methods. SCR Solutions appears to have reduced the plugging in layers 1 and 2 around 50% and in layer 3 around 20%.

Table 1 Unit 1 SCR plugging layer averages before and after SCR Services' 48 hour cleaning efforts

	Before	After
Layer 1	34%	17%
Layer 2	26%	12%
Layer 3	26%	20%

Traditional Cleaning

SCR Catalyst Cell Plugging

Thomas Hill Unit 1

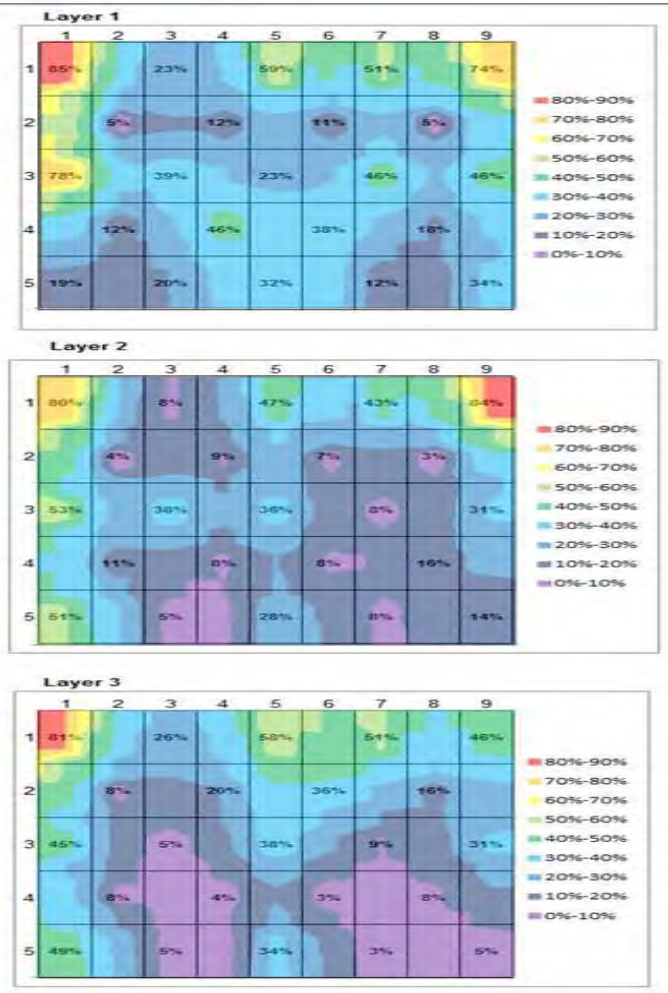
Date 10/20/2011

Condition Vacuumed

Layer Average

Layer 1	34%
Layer 2	26%
Layer 3	26%

North



SCR Solutions Cleaning

SCR Catalyst Cell Plugging

Thomas Hill Unit 1

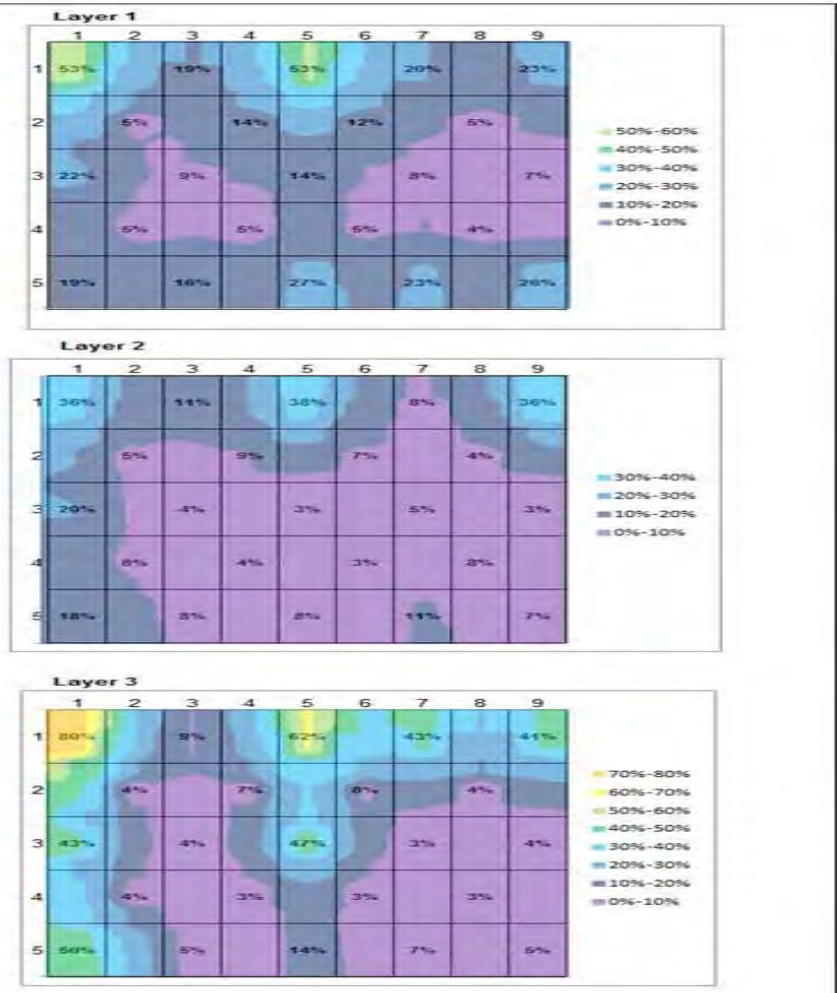
Date 10/24/2011

Condition Post SCR Services

Layer Average

Layer 1	17%
Layer 2	12%
Layer 3	20%

North



SCR On-line Cleaning

PRESENTED BY

MICHAEL WARE OF SCR SOLUTIONS, PGI

HIGH TEMP ENTRY

Through a series of lock outs, systems checks and atmospheric monitoring, a safe working environment is assured and maintained throughout the project

Safe Environment

Air handlers move high volumes of conditioned, ambient air into the SCR to facilitate the cool down and maintain a more tolerable working climate for the entrant.

Worker Protection

1. Specially designed HT suits and under garments protect the entrant and the stand by watchman from thermal burns by hot fly ash and the high temperatures associated with boiler operations
2. Internal cool vests supply cool air to the suited worker and watchman to protect against heat stress and fatigue.
3. Body harnesses and retrieval lines are worn in the event the entrant requires assistance egressing the work space.
4. Radio contact is maintained with the worker throughout the process.

Worker Protection

1. Supplied air respirators are worn by the entrant and watchman to protect against exposure to any air borne contaminants
2. An automatic, secondary air supply is utilized to insure there is no interruption of breathing air to the worker and watchman
3. A self contained breathing air (SCBA) supply bottle is worn by the workers to provide a third, independent source of breathing air.
4. All equipment is OSHA and NIOSH approved

Independent Corporate Safety Audit

- **Daniel H Drew@AEPIN** To: Robert!. Rohrer/OVEC/US@OVEC, Ray Wilson/OVEC/US@OVEC,
- nc oc DM Gregory D. Muncie/OVEC/US@OVEC
- 05.25 HM cc; Nathan E Kirk/RO1/AEPIN@AEPIN, Virgil A Vanover/AEPIN@AEPIN,
- Victor R Adams/AEPIN@AEPIN, Chao P Lin/OR4/AEPIN@AEPIN, Darren C Hanby/OR1/AEPIN@AEPIN, James D Benes/OR2/AEPIN@AEPIN, Mark A Gray/OR3/AEPIN@AEPIN Subject: Clifty Creek Plant Proposed On-Line Cleaning Method (SCR Reactor in Isolated Bypass Operation)
- AEP Engineering Services, Air Emissions & Control Emissions (AECE) section employees Chao Lin (Senior Engineer, SCR Lead Engineer) and Dan Drew (AECE manager) visited the plant on Monday, March 19 to witness a demonstration of the proposed SCR "On-Line" cleaning operation and then discuss the cleaning with stakeholders. Demonstration was performed on CC Unit 4 with the unit out of service. SCR catalyst upper layer cleaning is proposed with the respective SCR reactor fully isolated and in full bypass operation mode with all isolations closed and pinned locked closed.

Independent Corporate Safety Audit (Continued)

- We initially met with Clifty Creek folks (i.e., Buddy and others) to better understand goal and objective of cleaning and review cleaning process and general procedures. We next went to Unit 4 SCR to review a cleaning demonstration and associated protocol and procedures. Finally, we had a sit-down discussion with stakeholders. Reference FAR link below for a few select photos from demonstration that were included in Carl's memo below.
- Contractor create a cleaning process QA Standard Operating procedure (SOP) prior to any live SCR cleaning operation for Clifty Creek. SOP would be expected to include a checklist of items to ensure items are checked as good prior to initiating any cleaning. Items that would be expected to be included would be all worker PPE status; all internal box high temperature protection sealing details for breathing air, compressed air line protection, worker emergency retraction cable condition, air temperature monitor/probe position, maximum temperature limitation, maximum time duration for worker exposure, etc. It would be suggested that contractor craft a draft SOP prior to cleaning for general
review and comment by CC.
- Contractor evaluate special suit tear/wrap threshold for repair or replacement and include on an SOP checklist for each time worker rotates out of the reactor for break.
- Contractor determine method and location for air temperature probe prior to entering for cleaning or environment check. Also recommend that air temperature be a continual digital readout to outside personnel and hole watch support folks.

Independent Corporate Safety Audit (Continued)

- Contractor use alternate temperature monitor to evaluate ash and steel structure temperature gradient as compared to internal air temperature to assure worker PPE has adequate margin for any localized temperature gradient.
- Contractor use alternate temperature monitor to evaluate ash and steel structure temperature gradient as compared to internal air temperature to assure worker PPE has adequate margin for any localized temperature gradient.
- Contractor provide an allowance for initial live cleaning to make frequent and pre-timed worker health safety evaluation both in and out of the reactor to validate cleaning process and procedure. This may be enter and exit with no work performed within 5 minutes or possibly less following SOP temperature is achieved for safe reactor entry (i.e.. 250F or less).
- Contractor have provision for worker hole watch to have live voice communication with worker.
- Contractor define procedure to ensure that visual contact is not compromised from worker to hole watch everywhere inside reactor. This will require cleaning from both reactor access doors rather than just one door based on internal obstructions for viewing.
- Contractor ensure that any equipment or worker PPE is fully protected including all attachments, connection seals, etc. for design temperature (i.e., 500F continuous).
- Contractor fully evaluate all worker suit PPE details to ensure for temperature protection including any need for velcro closure straps on hood to suit.

Independent Corporate Safety Audit (Continued)

- Initially cleaning to include AEP S&H personnel for worker evaluation with CC and contractor's folks to validate SOP and protocol. It would also be encouraged for KC folks to possibly attend to better understand process/procedure should they consider in future.
- CC to validate SCR reactor cool-down temperature gradient for isolated SCR reactor to include in the SOP. It was suggested during visit that the cool-down temperature gradient be consistent with the warm-up gradient with effort by contractor to mitigate any direct cooling to steel or structure but direct cooling air supply to air space inside reactor.
- In closing, for CC to proceed (based on AEP's review and consideration of cleaning process), I believe recommendation lies within AEP's Safety & Health (S&H) folks who I understand are agreeable for CC to proceed with defined plans and associated safeguards as well as defined and documented QA SOP. I would request that AEP S&H confirm general agreement directly to CC staff. From an SCR equipment perspective, the equipment and associated structure should be fine with temperature gradients maintained as discussed above.

Independent Corporate Safety Audit (Continued)

- Please call or reply to me with any questions or comments.
- Thanks, Dan
- CC: Chao, if you have any supplementary visit suggestions please send note to defined stakeholders. PS: All, everyone in discussions during site visit were in full agreement that Safety is No. 1 Priority in all we do and will not be compromised.
- AEP Engineering Services
- Manager, Air Emissions Control Equipment (AECE) Section
- Audinet: 200-3299
- Phone: 614-716-3299
- Cell: 614-403-0335
- Email: dhdrew@aep.com
- Carl W Burton/AEPIN
- 03/16/2007 03'50 PM To Nathan E Kirk/RO1/AEPIN, Virgil A Vanover/AEPIN, Victor R
- Adams/AEPIN cc Subject SCR Cleaning
- Information and pictures from the SCR Cleaning demonstration at Clifty Creek on 3/14/07.

Independent Corporate Safety Audit (Continued)

- Facts:
- Normal SCR temperature when unit is on-line with dampers open- 700deg
- Normal SCR temperature when unit is on-line with dampers closed (during an actual cleaning)- 400deg
- Outer suit used by contractor good to 2000deg
- Inner layer against skin good to 1200deg
- Rescue harness good to 2000deg
- Outer suit has built in supplied air-line respirator with an emergency escape pack.
- Contractor had a 10,000cfm cooling unit that would supply between 40 and 70deg air into the SCR depending on outside temperatures.
- The contractor demonstration consisted of a crew of trained employees who all speak English. One entrant with a full body suit with head, hand, and foot protection which also had a rescue harness that was 100% attached to a rescue winch outside the manway on a nearby structural beam. As he entered the manway a second identically outfitted rescue crew member was attached to another rescue winch and posted outside the manway with constant eyesight of the entrant. After a few minutes a trial run of an emergency was given. The rescue crew member sounded an air horn to alert the entrant. At that point a third crew member manned the rescue winch of the entrant in case he was not able to get out under his own power and a fourth employee assisted on the cat-walk at the base of the stair access to pull the slack out of the supplied air hoses as the entrant made his exit. The entrant was observed to move very well in spite of the bulky suit and was completely out of the SCR box in under 30 seconds.

Independent Corporate Safety Audit (Continued)

- There was discussion afterward for the need to set a temperature limit (estimated to be 250deg by contractor) that would be the ceiling for the process. Contractor felt comfortable that the cooling unit would have the ability to keep the ambient temperatures well below that level and possibly to 100deg. Also time limits would need to be established for how long an entrant could remain in the various temperatures after they are established. Contractor also stated that other equipment (cooling vests, hands free communication equipment) could be bought if they proceed with this work for OVEC/IKEC and AEP.
- Although initially upon hearing about a damper closed with unit on line cleaning, I was skeptical to say the least. But after seeing and hearing the planning that contractor has put together, I am convinced it could be done. In my opinion when you consider the temperatures, the protection that the entrant will have, and the rescue / communication practices it seems that we are well within a safe level.
- Carl W. Burton Clifty Creek FGD Project
- Audinet 240-3110
- Direct (812) 265-7110
- Cell (606) 316-0126
- [attachment "kelly 004.jpg" deleted by Daniel H Drew/OR4/AEPIN] [attachment "kelly 001.jpg" deleted by Daniel H Drew/0R4/AEPIN] [attachment "kelly 002.jpg" deleted by Daniel H Drew/0R4/AEPIN] [attachment "kelly 003.jpg" deleted by Daniel H Drew/OR4/AEPIN]

SCR High Temperature On Line Vacuuming Services/Equipment/Manpower

- EQUIPMENT
- Positive Displacement Vacuum Unit
- High temperature vacuum line
- Fire retardant PPE
- Supplied breathing air system
- Climate control unit,
- High temperature suits
- Rescue equipment
- **MANPOWER**
- Project Supervisor One
- Vacuum Unit Operator One
- Vacuum Techs Four

- SERVICES
- Complete Job Safety Analysis
- Set up equipment
- Open Manways
- Vacuum fly ash
- Blow down catalyst canisters
- Cool down unit

SCR Solutions
On Line Cleaning Procedure

- Objective: Safe and productive high temperature, on line cleaning of the selective catalyst reduction baskets by vacuum and air blowing.
- **MANPOWER**
- Project Supervisor
- Vacuum unit operator
- Entry Technician
- Standby Rescue Assistant
- Hole Watch
- Equipment Assistant
- **Equipment**
- High Volume vacuum unit
- 10,000 cfm Air Handler
- Supplied air breathing system
- High temperature personal protection equipment *
- Rescue equipment
- High volume air compressor.
- Temperature monitoring equipment.

- **Actual Procedure**
- Project Supervisor performs pre-job safety meeting with crew to discuss all phases of project and discuss potential hazards. Review Job Safety Analysis form.
- **I. Set Up - Estimated Time 12 hours**
- Set up chiller, air mover and ducting for cooling of unit
- Wire units and test for proper operation.
- Set up vacuum equipment.
- Lift and attach rescue equipment, test.
- Lift and set up supplied breathing air system, test
- Inventory all high temperature personal protection.

On Line Cleaning Procedure (Continued)

- **II. Lock Out Tag Out Louvers**
- Meet with plants designated operations supervisor.
- Discuss procedure of LO/TO
- Go jointly to unit and install locks and tags on all electrical boxes responsible for louver operation.
- Insert pins into all four louver actuators. Install locks into holes of pins.
- Place **all** keys into designated lock box. IKEC operations will install a lock on the lock box and a contractor supervisor will install a lock as well. Each keeps own key.
- **III. Install Thermal Shield - Estimated Time 4 hours**
- Open manways into level 8.
- Suit up workers with heat protection equipment.
- Insert ducting for unit cool down, Cooling temperature est 60 degrees
- Supervisor notifies unit control room of entry.
- **Control room puts up sign, "SCR Entry in Progress" Any time during entry should the ID fan trip, the control room will contact contractor supervisor and the worker will exit immediately.**
- Spread thermal protection tarps on top area.
- Suit up worker with high temperature protection for entry.
- Review rescue sequence with all personnel, test equipment.
- Insert worker to arrange tarps that can't be reached from manway
-
- Hole watch will be suited with high temp protection and will maintain constant visual with entrant.
- Standby rescue will be suited up at all times and will remain outside unit should entry rescue ever be needed as noted below.
- Supervisor notifies control room of SCR exit. Control room takes down "SCR Entry in Progress" sign.

On Line Cleaning Procedure (Continued)

- **II. Vacuum Fly Ash**
- Move Equipment to level 7.
- Start cooling system and check temperatures
- Suit up hole work personnel with high temp protection.
- Vacuum all possible fly ash from exterior.
- Suit up entry technician and rescue assistant for inside work.
- Check and record ambient and conductive temperature.
- Supervisor notifies control room of entry.
- **Control room puts up sign, "SCR Entry in Progress" Any time during entry should the ID fan trip, the control room will contact contractor supervisor and the worker will exit immediately.**
- Position hole watch and insert entry technician.
- Entry technician to stand on thermal shield for foot protection if needed.
- Vacuum all fly ash on top of catalyst baskets as needed.
- Entry work in full heat protection not to exceed 3 hour periods
- Remove screens and vacuum below.
- Supervisor notifies control room upon worker exit.

- **III. Blow Down Catalyst Baskets**
- Start compressor and position equipment for air blow.
- Suit up entrant for high temperature work.
- Follow procedure for entry with control room.
- Check operation of air conditioner.
- Position Hole Watch and insert entry technician.
- Blow down each catalyst basket as needed.
- Re-install screens and exit unit.
- **IV. Remove Thermal Shield**
- Return to manways for level 8.
- Suit up workers for high temp protection.
- Follow procedure for entry with control room.
- Pull thermal shield from level 8.
- Close manways, return unit to operation.

Rescue Procedure

- **I. Equipment Set Up**
- Position personnel retrieval devices (120 foot tether) so that there is an upward motion should rescue become necessary.
- Check to see that unit is operating properly and is easily accessible.
- Inspect high temp body harness for integrity and insure there are no frays or damage in any way.
- **n. Duties of Personnel**
- Hole Watch is to be positioned at hole with high temperature protection and keep constant visual contact with entrant at all times. The Hole Watch is the key man to alert the team as to when a rescue is necessary.
- Stand by Assistant is to be suited for entry whenever there are personnel in the unit.
- Equipment Assistant is the person that will work the retrieval device for rescue.
- Supervisor is to direct the entire operation and insure compliance to procedures.
- **III. Rescue Sequence 1, Louver Failure or ID Fan Trip**
- Supervisor gets notification from control room.
- Supervisor alerts hole watch. Hole watch sounds air horn to alert team and handles life line for entrant. Entrant exits immediately.
- Equipment assistant positions himself at retrieval device and only begins retrieval handle cranking as directed by supervisor or hole watch. Stand by watchman positions air mask and hood with help of supervisor and positions self at manway to assist in any way.
- Should entrant need assistance in unit it is the duty of rescue assistant to help situation as directed by supervisor.
- If needed supervisor alerts plant personnel to need for medical assistance.

Rescue Procedure (Continued)

- **IV. Rescue Sequence 2, Entrant Injured, No High Temp Issue From Louver Failure or ID Fan Trip**
- Hole Watch determines entrant is injured and needs assistance exiting unit.
- Hole Watch sounds horn alerting supervisor and team of impending rescue.
- Supervisor notifies control room of situation.
- Hole Watch enters unit and waits for Rescue assistant to hand in Stokes Basket.
- Rescue Assistant hands in Stokes from Equipment Assistant. Hole Watch proceeds to Entrant and positions in Stokes basket. Stokes basket is pulled from unit by rope. Supply of first aid is administered once injury is determined.
- Hole watch exits unit simultaneously.

COMPANIES OF SUCCESSFUL APPLICATION

- American Electric Power (AEP)
- Kentucky Utilities (KU)
- Louisville Gas & Electric (LG&E)
- Associated Electric Cooperative (AECI)
- Wisconsin Public Services (WPS)
- Duke Energy (East Bend Station)

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