2013-2014 Coal Creek Station Scrubber Hg Removal Testing

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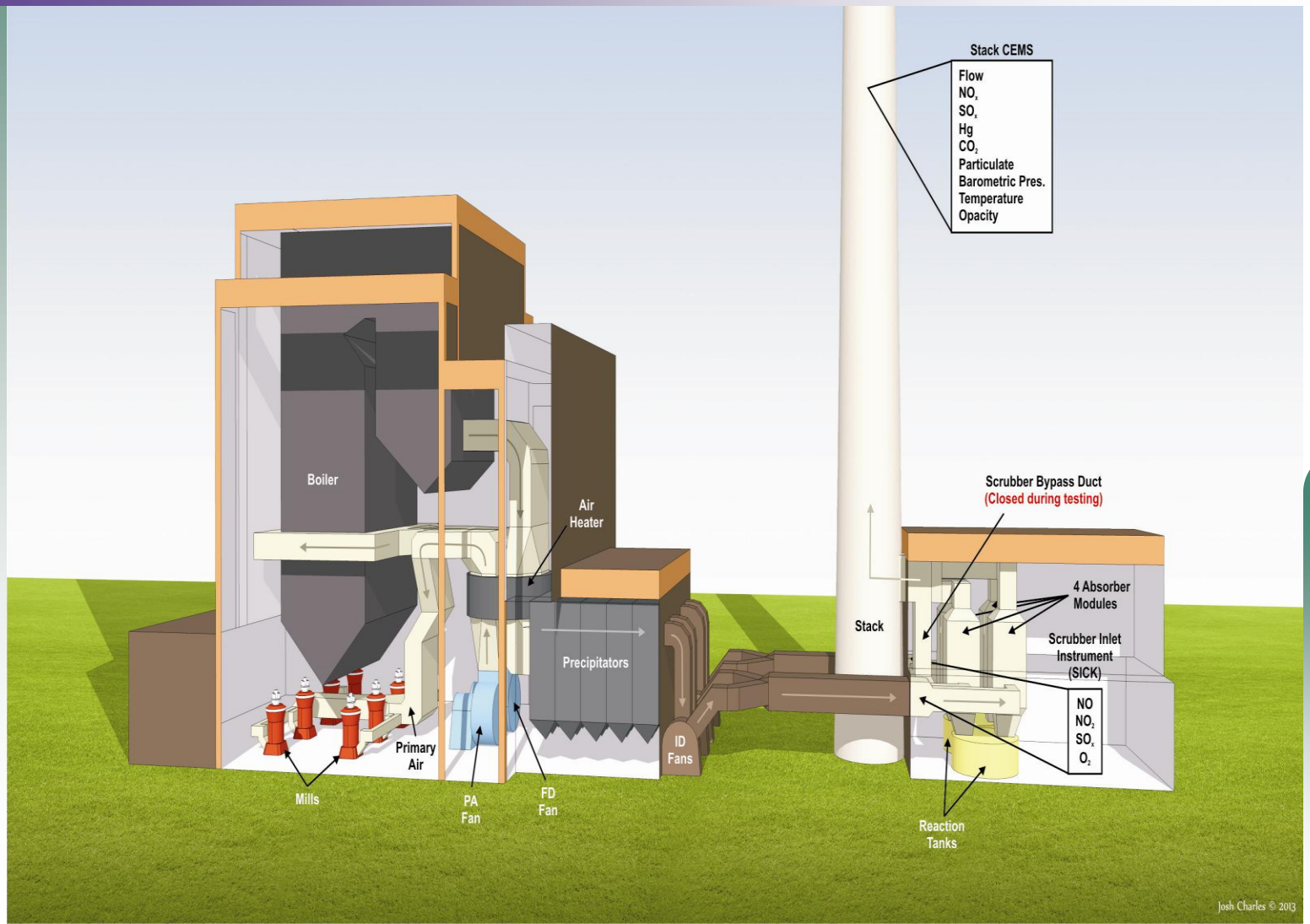
CCS System Overview



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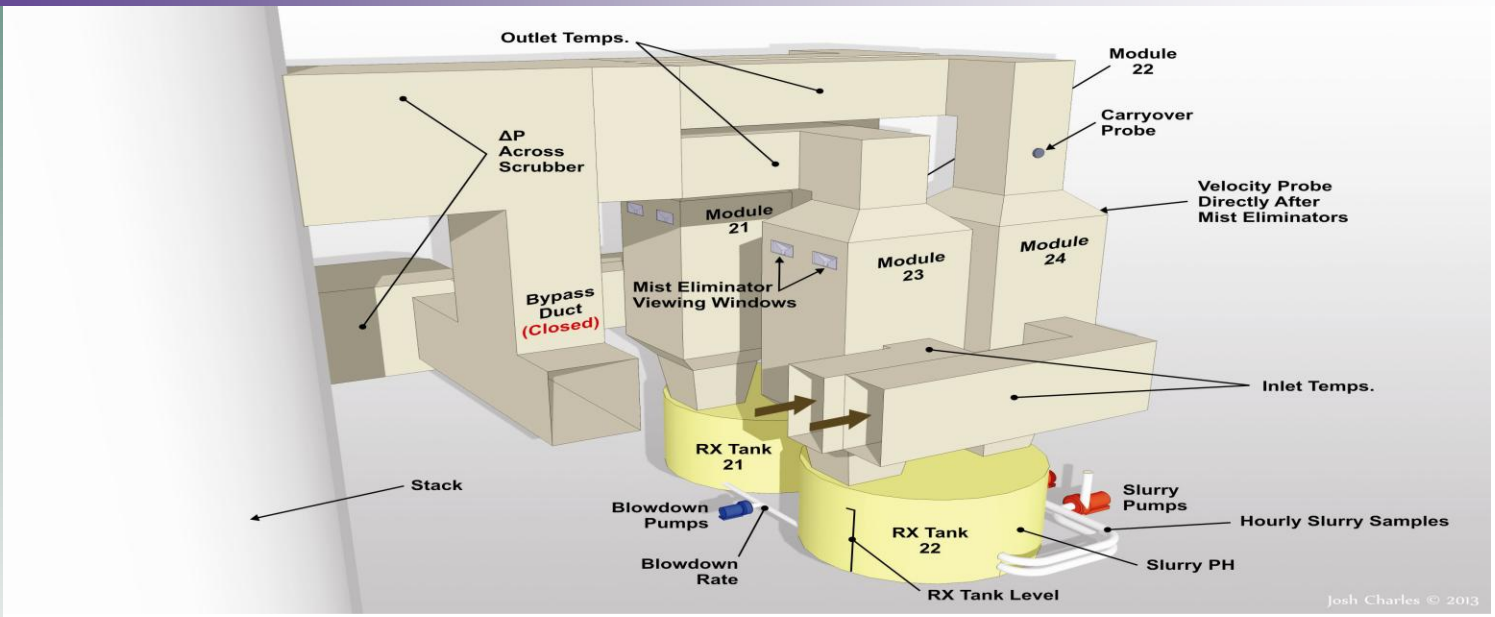
Scrubber Overview



- CCS currently scrubs 85% of its flue gas in both units
- By 2017 both units @ CCS need to scrub 100% of flue gas to meet Regional Haze requirements.
- Currently between both units CCS uses around 65,000 tons of lime per year at a cost of $9.5 million.

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Why Remove Hg in the Scrubber?

- 1) Efficient liquid to gas interface already installed
- 2) FGD system is on the back-end of the power plant.
- 3) Rx tanks make capital equipment install of scrubber additive system technically simple and inexpensive.(compared to millions for DSI systems)

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Scrubber Hg Removal 101

1) Hg enters scrubber in 2 forms- oxidized and elemental

2) Two steps to successful removal -> Hg must be oxidized, and then precipitated to solids(stable form) to have a chance of being efficiently removed by the FGD system.

3) In regular operation, some oxidation occurs, and the FGD removes some Hg, however “help” is needed in both areas to meet MATS limits.

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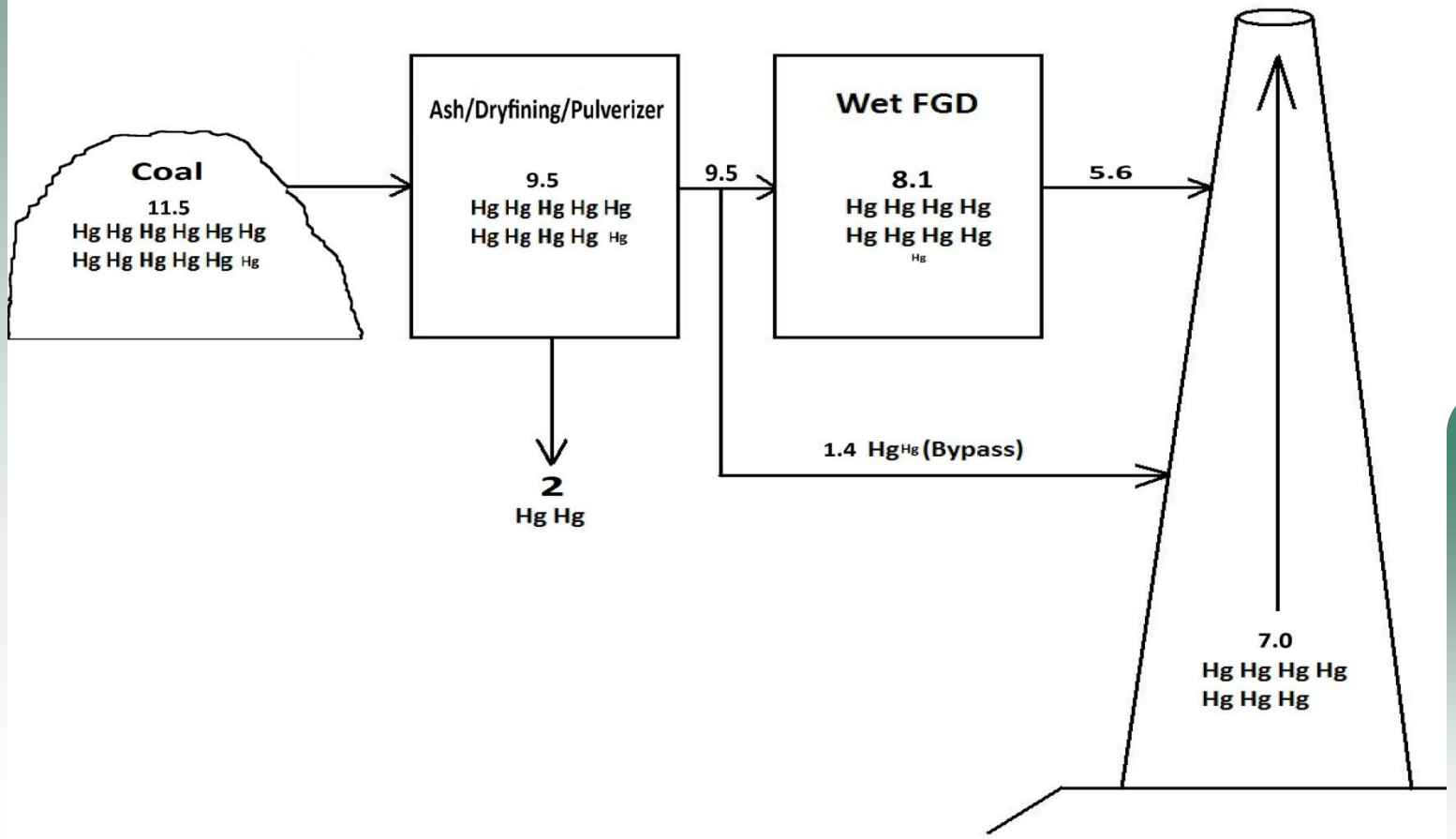
Coal Creek Hg Balance (#/TBTU)



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5 Overall Tests Run

- *1) NaHS FGD additive with H2S gas injection (B&W sponsored)*
- 2) Baseline CaBr on coal
- 3) Regular activated carbon additive to Rx tanks
- 4) Brominated activated carbon additive to Rx tanks.
- 5) KLeeNscrub FDG additive to Rx tanks.(EES Corp)

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Test #1 - NaHS / H2S Additive

Theory: H2S gas at the ID fans would oxidize Hg, NaHS additive would allow FGD to capture.

-NaHS was injected into the suction of the spray pumps.

-H2S cylinders were used to inject H2S gas @ 1-2 ppm at the inlet of the ID fans

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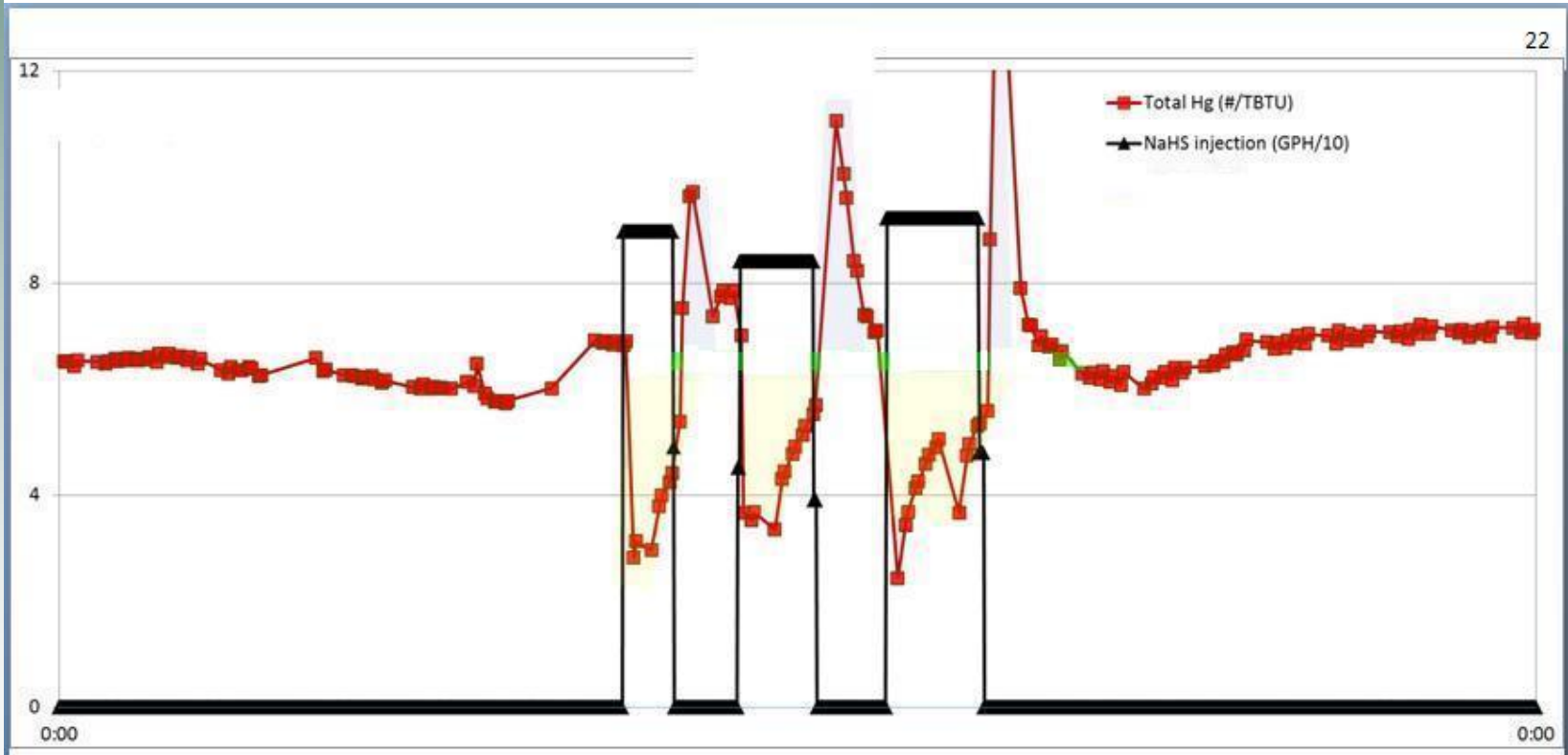
NaHS / H2S Additive Results



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NaHS / H2S Conclusions

- H2S *was* converting *some* amount of Hg to oxidized HgS as black dust was found in CEMS tubing

- **NaHS was ***not*** moving Hg to stable form in FGD system**

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Test #2 - CaBr Baseline Test

- **Goal:** find application rate of CaBr needed to meet MATS with CaBr alone.
- Without any additive to the FGD to help precipitate Hg to solids, Hg removal efficiency will be low.
- Re-emmission will **always** be a problem when Hg is not transferred to stable solids

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Comments on CaBr Corrosion

- Some studies have shown corrosion in units applying greater than 100ppm CaBr on coal feed.
- Data is not conclusive but the industry “feel” is that the smaller the amount of CaBr on the front end, the better.

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CaBr Baseline Test

- Pulsating drip onto single feeder

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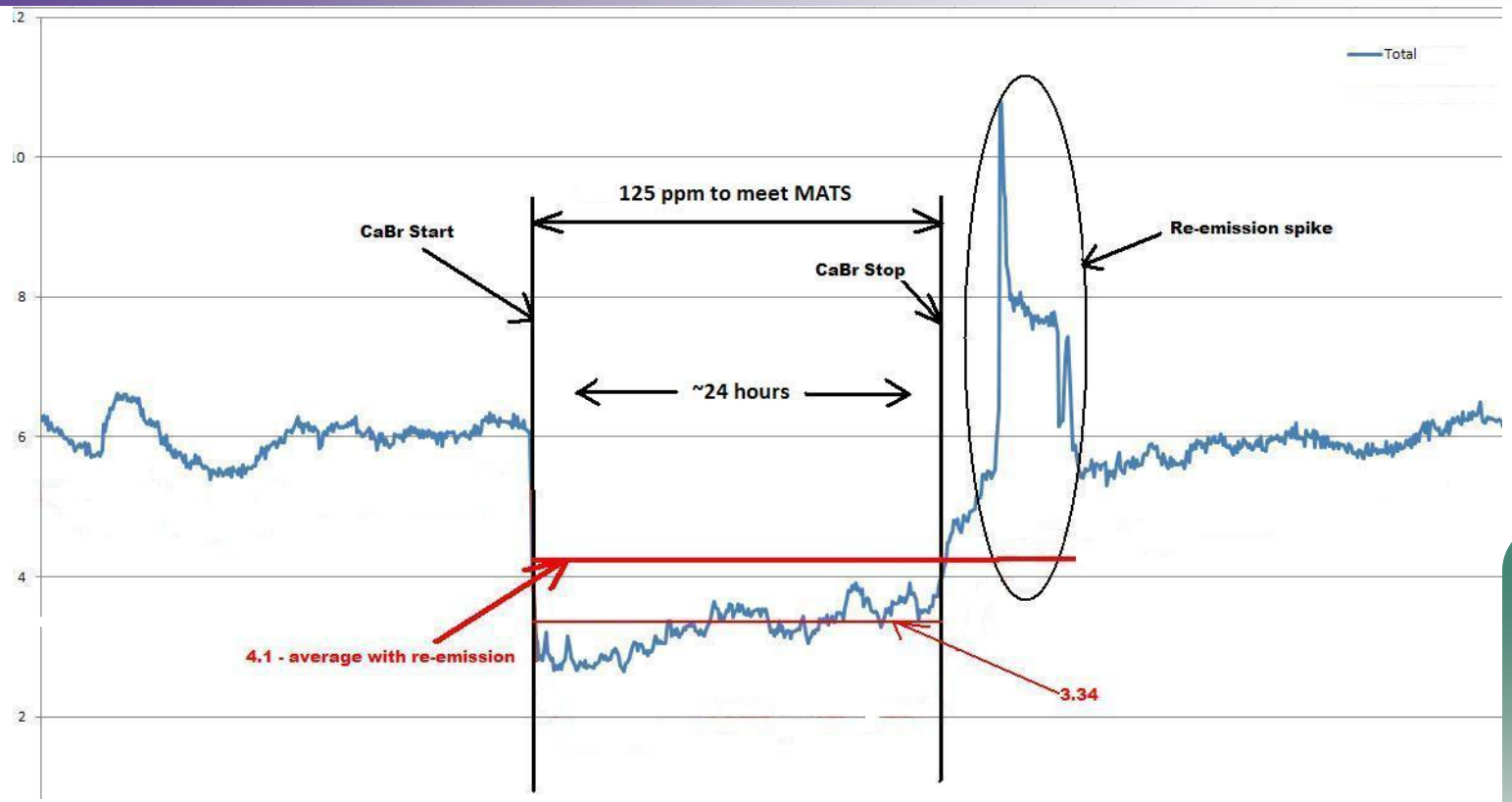
CaBr Baseline Results



Extrapolated CaBr rate to reach 4.5 MATS=> **125 ppm**

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CaBr Baseline Conclusion

- High rate of feed and re-emitting spike show that the FGD needs treatment to hold Hg and thus have a higher Hg removal efficiency.

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Test #3 - Activated Carbon Addition to FGD

- **Theory:** AC addition to Rx tanks will hold captured oxidized Hg in stable solids and allow removal from system over time.
- Initial 800# dose added to each tank
- Maintenance dose of 36#/hour added for duration of test

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Activated Carbon Addition to FGD (cont)

Initial 800# per Rx Tank dose applied through sand blasters.

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Activated Carbon Addition to FGD (cont)

- Hopper placed on 2nd floor(top of Rx tank level) for loading 36# hourly doses.

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Activated Carbon Addition to FGD (cont)

- 36# hourly dose was “sluiced” into tank using a custom designed drum and 2” drain hose.

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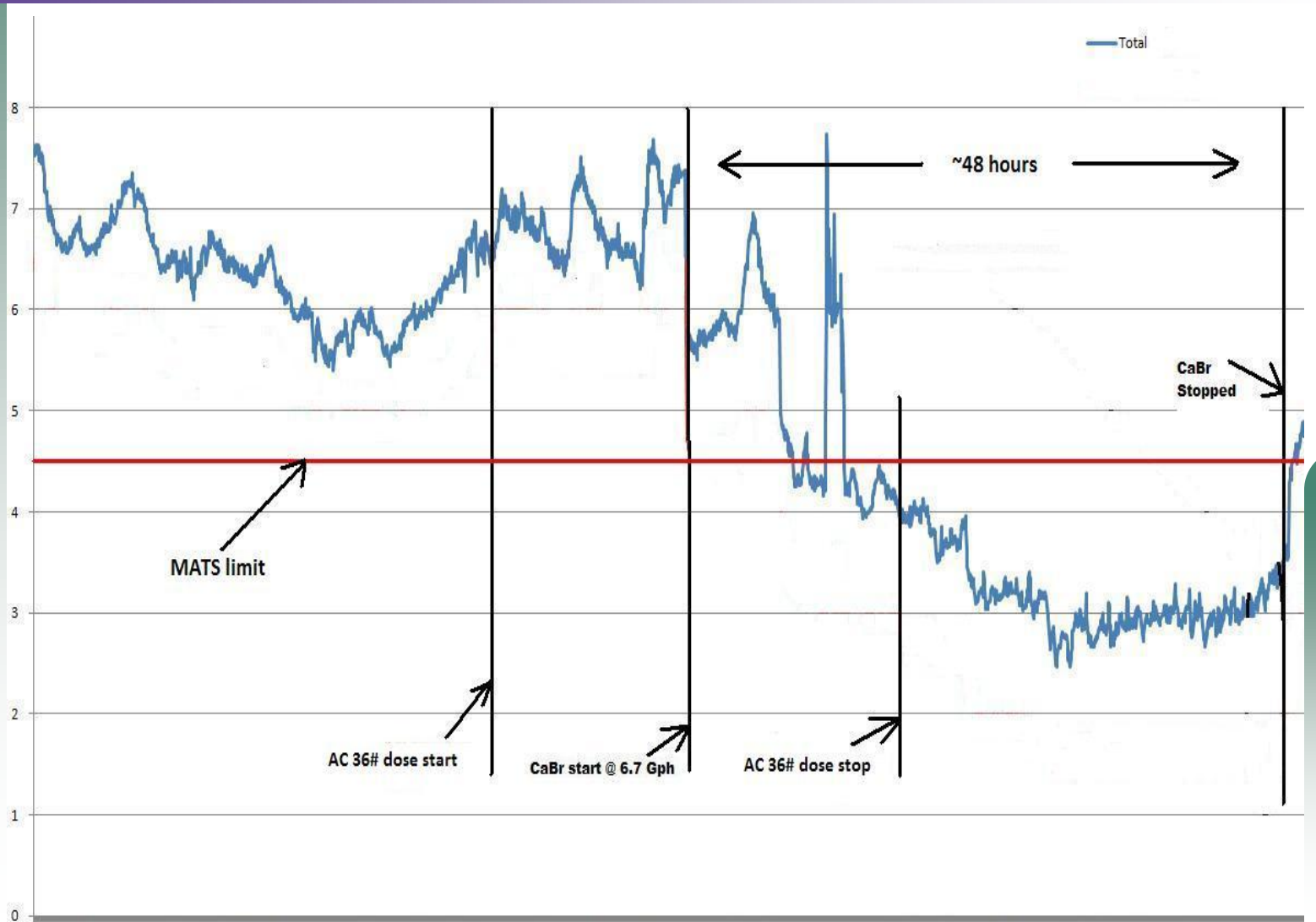
Activated Carbon Addition Results



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Activated Carbon Addition to FGD Results

- AC in Rx tank at applied dose along with ~60 ppm CaBr on coal feed is an effective MATS solution

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Test #4 - Brominated Activated Carbon Test

- **Theory:** AC addition to Rx tanks will hold captured oxidized Hg in stable solids and allow removal from system over time.
- Initial 800# dose added to each tank
- Maintenance dose of 36#/hour added for duration of test

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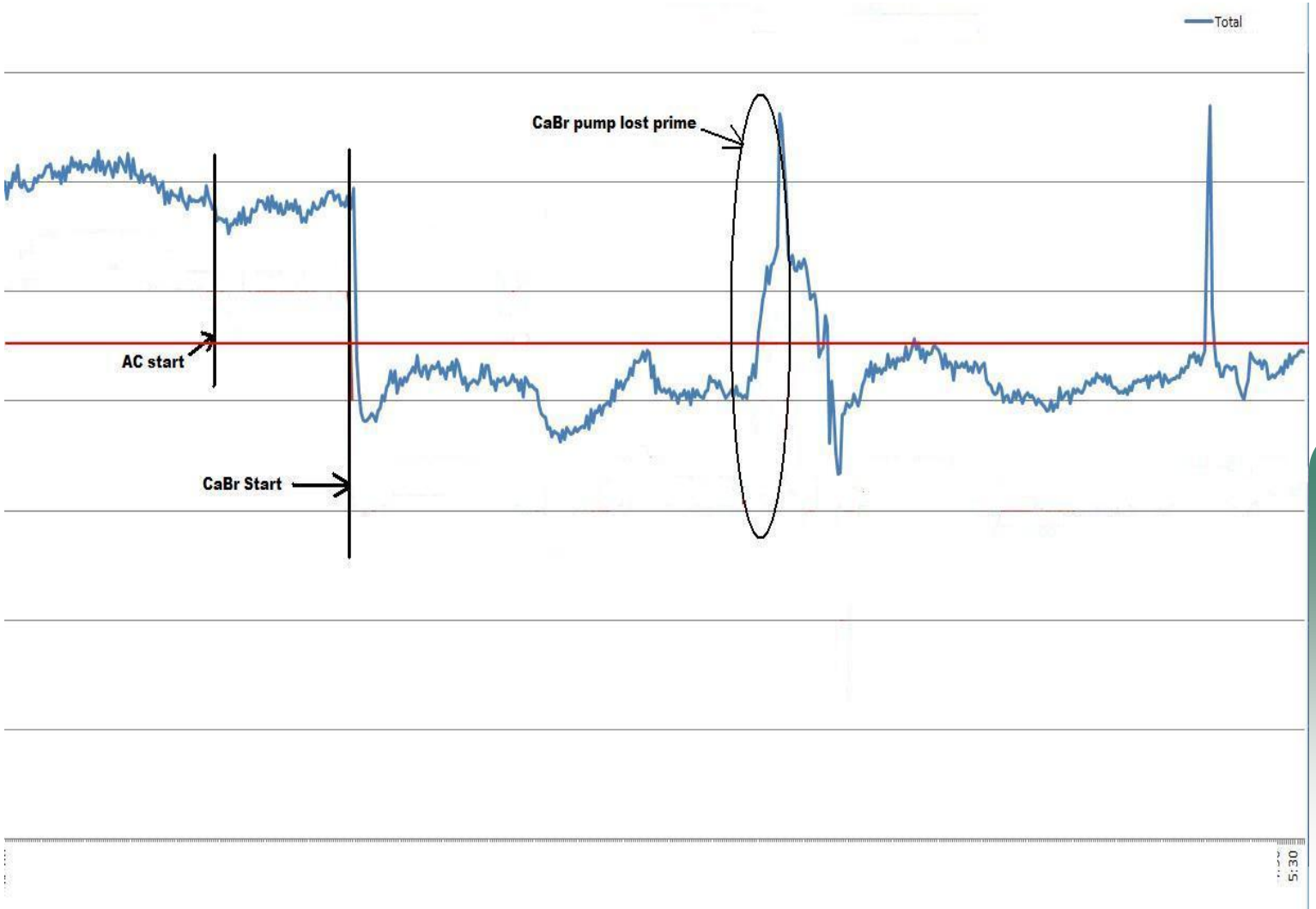
Brominated Activated Carbon Test Results



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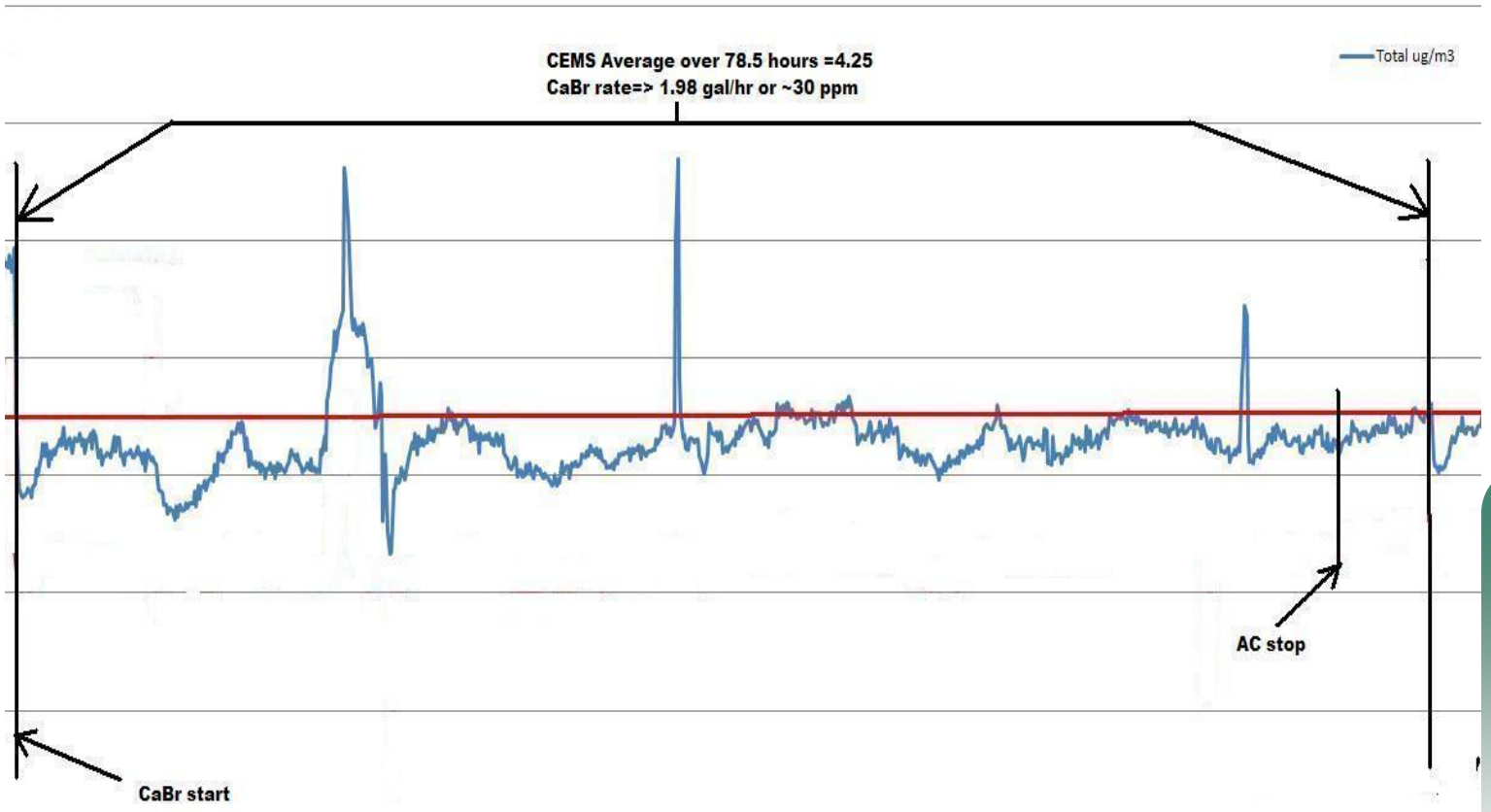
Brominated Activated Carbon Test Results(cont)



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Brominated Activated Carbon Test Conclusion

- CaBr rate for MATS -> **1.84 gal/hr** or **28 ppm**
- **Brominated AC was oxidizing some amount of Hg in the towers to reduce need of CaBr on the coal**

******Best Results so far******

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Test #5 - KLeeNscrub Additive Test

- **Theory:** KLeeNscrub addition to Rx tanks will precipitate captured oxidized Hg into stable solids and allow removal from system over time.(same theory as AC)

- Note: to be economically competitive with AC, KS rates will have to be around 2.4 gallons/hour for entire FGD(both Rx tanks)

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KLeeNscrub Additive Test-Setup

- Injection to the suction of the spray pumps(similar to NaHS test)
- Sulfide Probe - used to measure free S- ions in Rx tanks

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KLeeNscrub Additive Test Week 1 Results

- KLeeNscrub started at high rate of 12 Gal/hr for initial starting dose.
- After sulfide limit of -200 reached CaBr started and tuned to reach MATS goal of 4.5 lbs/TBtu
- Sulfide pump problems prevented rates from being lowered to the goal of 2.4 gal/hr for significant period of time
- Unit 2 trip and runback on U1 cut testing short

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KLeeNscrub Additive Test Week 1 Results(cont)

- KLeeNscrub rates were initially disappointing due to pump limitations, and a test cut short

- ***KLeeNscrub AND non-brominated AC needed almost **exactly** the same CaBr to meet MATS***

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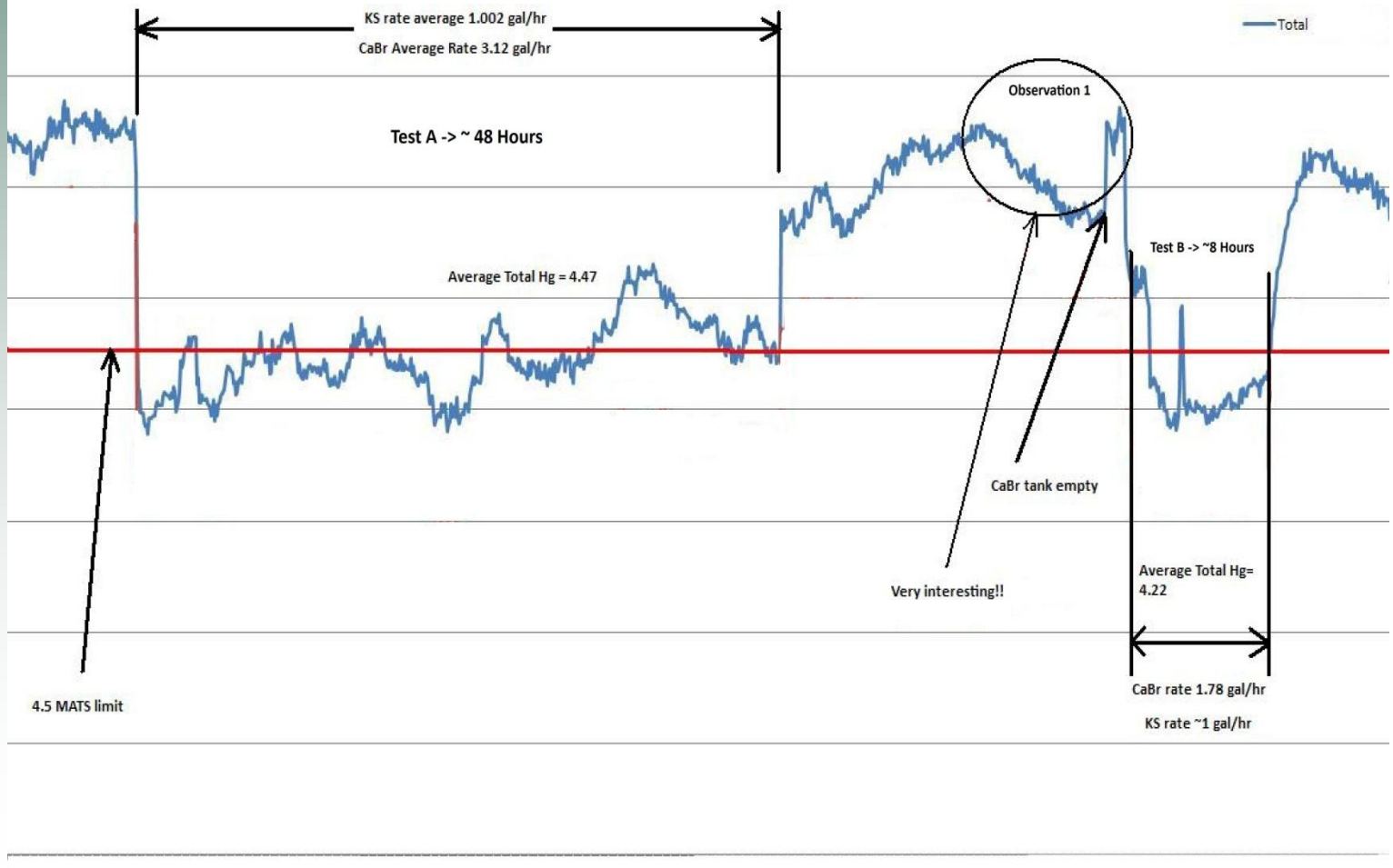
KLeeNscrub Week 2 Results



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KLeeNscrub Additive Test Week 2 Results

Test A-

Extrapolating for 4.47/4.5 test results->

CaBr rate for MATS -> **3.1 gal/hr** or **48 ppm**

Test B(CaBr feed to FGD)-

Extrapolating for 4.22/4.5 test results->

CaBr rate for MATS -> **1.67 gal/hr** or **25 ppm**

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KLeeNscrub Conclusion

- 1 gal/hr KLeeNscrub estimated to meet MATS
- Addition of CaBr to Scrubber reduces need to feed the coal->ratio unknown
- Note: Liquid FGD additive is especially attractive as it requires very little capital install $$

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Future Testing

- To date, KLeeNscrub FGD additive is the most economical solution for MATS @ CCS
- Next test will be a 30 day KLeeNscrub run in early 2014 and focus on finding the amount of CaBr that can be moved from the coal to the FGD system.
- 30 day test will also focus on BOP issues.

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Overall Conclusions – FGD Hg Removal

- 1) untreated, scrubber Hg removal efficiency drops as oxidation percentage is raised

- 2) With treatment, Hg removal efficiency can be raised to close to 100% to minimize upstream oxidation needs

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Thank You

- Entire CCS Flue/Operations cores

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Contact

- Jared Pozarnsky
- Email-> jpozarnsky@grenergy.com
- Phone- 701-442-7067

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