# Results from the First Year of Operation of a Circulating Fluidized Bed Dry Scrubber with High-Sulfur Coal at AES Greenidge Unit 4

**Douglas J. Roll, P.E.**
*AES Greenidge LLC*

**Daniel P. Connell**
*CONSOL Energy Inc., Research & Development*

**Wolfe P. Huber, P.E.**
*U.S. Department of Energy, National Energy Technology Laboratory*

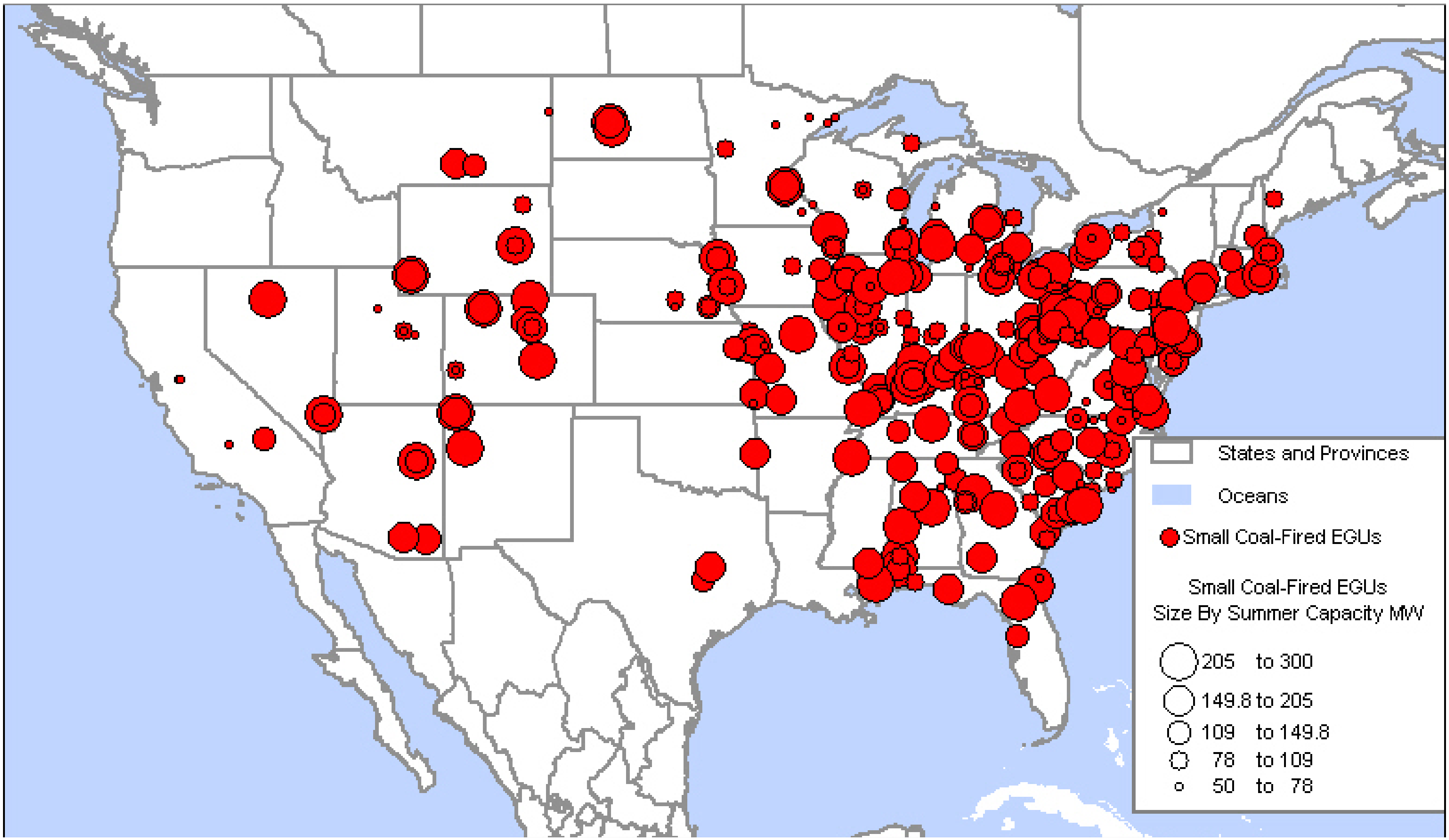
*Baltimore, MD* *May 8, 2008*

# Greenidge Multi-Pollutant Control Project

- Part of U.S. DOE's Power Plant Improvement Initiative
- Participants
  - CONSOL Energy Inc. (administration, testing, reporting)
  - AES Greenidge LLC (host site, operations)
  - Babcock Power Environmental Inc. (EPC contractor)
- Funding
  - U.S. Department of Energy, National Energy Technology Laboratory
  - AES Greenidge LLC
- Goal: Demonstrate a multi-pollutant control system that can cost-effectively reduce emissions of $NO_x$, $SO_2$, mercury, acid gases ($SO_3$, HCl, HF), and particulate matter from smaller coal-fired power plants

# Existing Coal-Fired EGUs

## 50-300 $MW_e$



# Existing Coal-Fired EGUs

## 50-300 $MW_e$

- ~ 420 units not equipped with FGD, SCR, or Hg control
  - Represent almost 60 GW of installed capacity
  - Greater than 80% are located east of the Mississippi River
  - Most have not announced plans to retrofit
- Difficult to retrofit for deep emission reductions
  - Large capital costs
  - Space limitations
- Increasingly vulnerable to retirement or fuel switching because of progressively more stringent environmental regulations
  - CAIR, Hg MACT, CAVR, state regulations
- Need to commercialize technologies designed to meet the environmental compliance requirements of these units

# AES Greenidge Unit 4
## (Boiler 6)

- Dresden, NY
- Commissioned in 1953
- 107 $MW_e$ (EIA net winter capacity)
- Reheat unit
- Boiler:
  - Combustion Engineering tangentially-fired, balanced draft
  - 780,000 lb/h steam flow at 1465 psig and 1005 °F

- Fuel:
  - Eastern U.S. bituminous coal
  - Biomass (waste wood) – up to 10% heat input
- Existing emission controls:
  - Overfire air (natural gas reburn not in use)
  - ESP
  - No FGD - mid-sulfur coal to meet permit limit of 3.8 lb $SO_2$/mmBtu

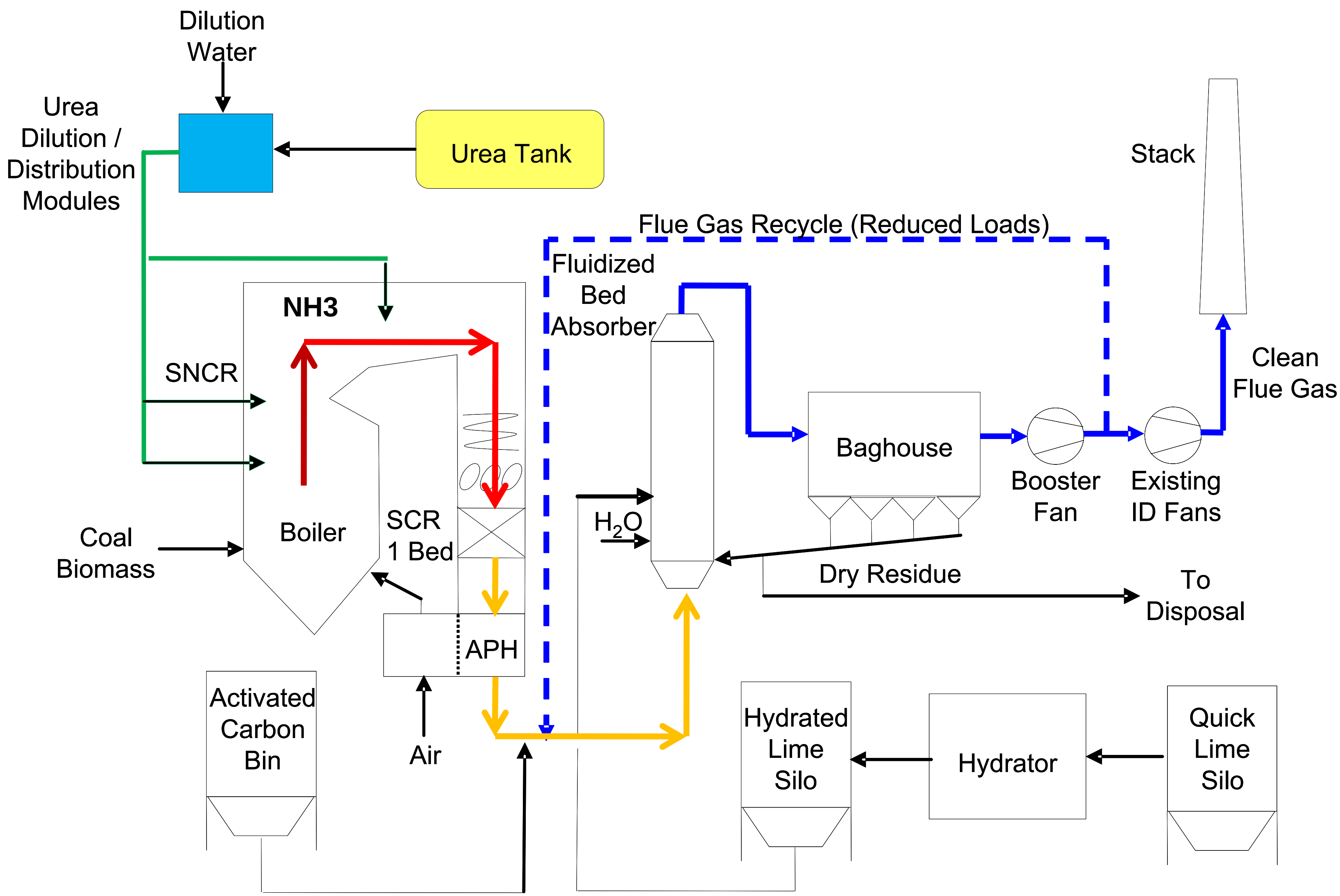
# Design Objectives

- Deep emission reductions
- Low capital costs
- Small space requirements
- Applicability to high-sulfur coals
- Low maintenance requirements
- Operational flexibility

# Multi-Pollutant Control Process

- Combustion modifications
  - Low-$NO_x$ burners and overfire air
  - Installed outside of DOE scope
- $NO_x$OUT CASCADE® hybrid SNCR/SCR (Fuel Tech)
  - Urea-based, in-furnace selective non-catalytic reduction
  - Single-bed, in-duct selective catalytic reduction
- Activated carbon injection
- Turbosorp® circulating fluidized bed dry scrubber (Austrian Energy / Babcock Power Environmental)
- Pulsejet baghouse

# Process Flow Diagram



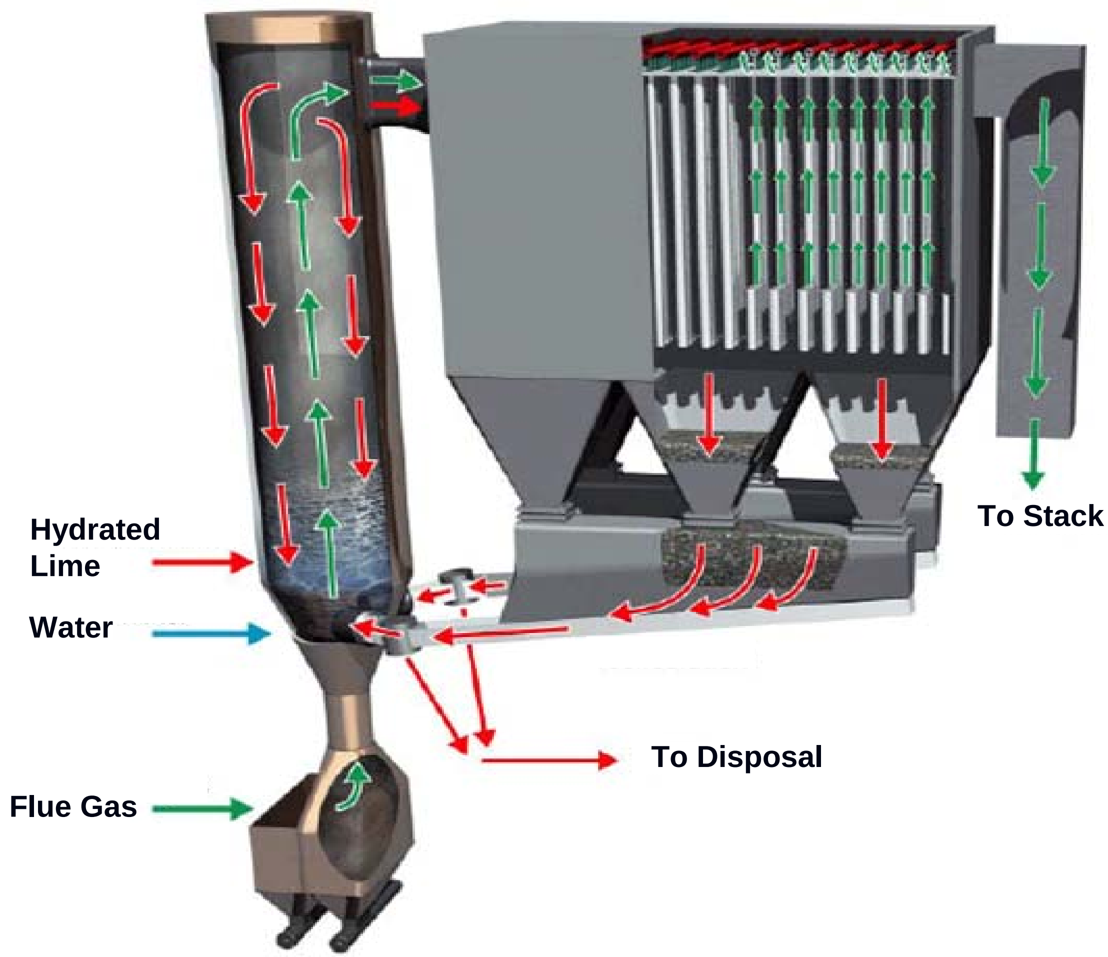
# Guarantee Tests

March-May 2007, 2.4-3.2% Sulfur Eastern U.S. Bituminous Coal

| Parameter | Performance Target | Measured Performance |
|---|---|---|
| $NO_x$ emission rate | ≤ 0.10 lb/mmBtu | 0.10 lb/mmBtu* |
| $SO_2$ removal | ≥ 95% | 96% |
| Hg removal<br>Activated C Injection<br>No Activated C Injection | ≥ 90% | <br>≥94%<br>≥95% |
| $SO_3$ removal | ≥ 95% | 97% |
| HCl removal | ≥ 95% | 97% |
| HF removal | ≥ 95% | Indeterminate |

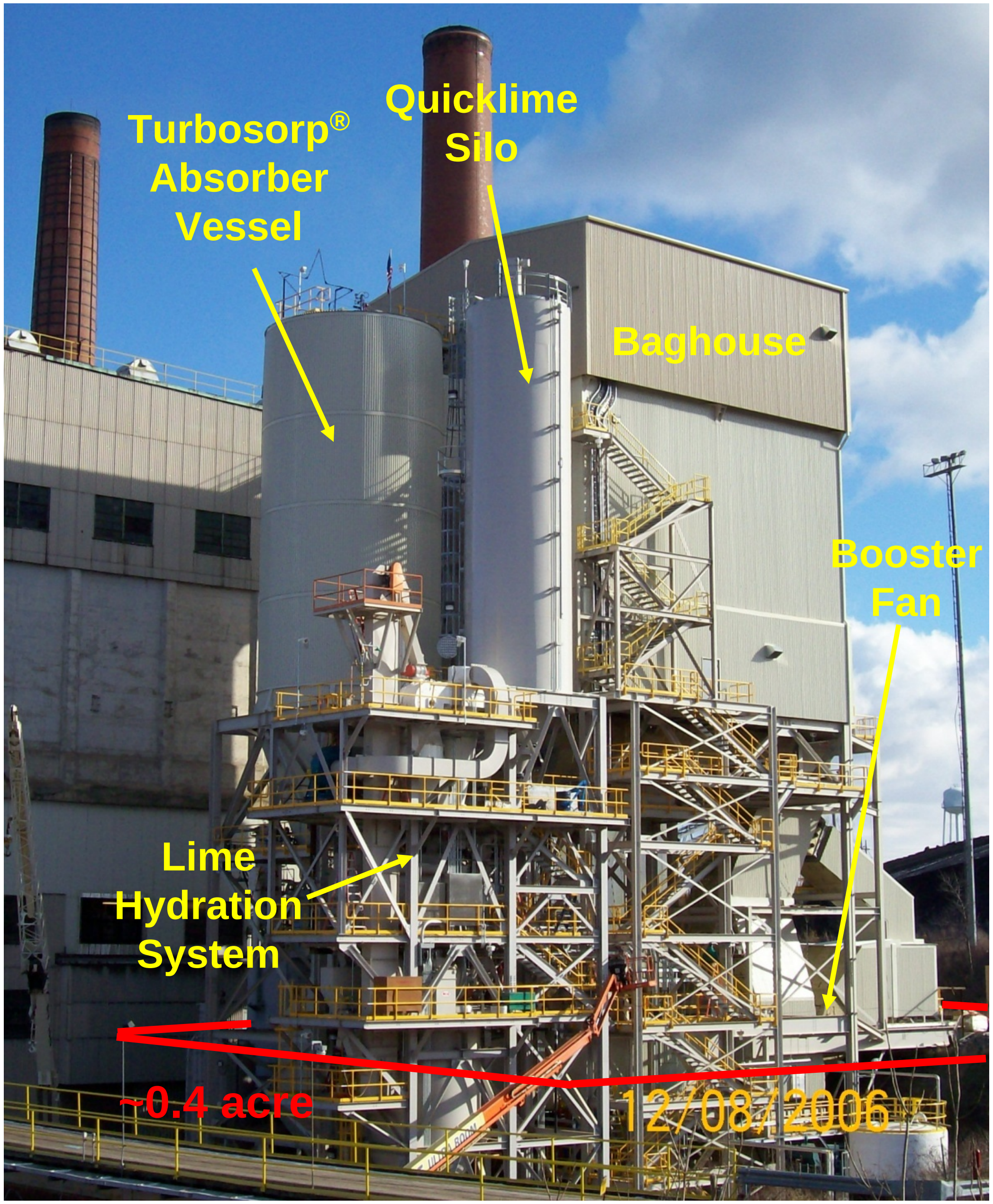
* Performance of hybrid $NO_x$ control system has been affected by large particle ash and ammonia slip. Plant typically operates at 0.10-0.15 lb/mmBtu to maintain acceptable combustion characteristics.

# Turbosorp® System



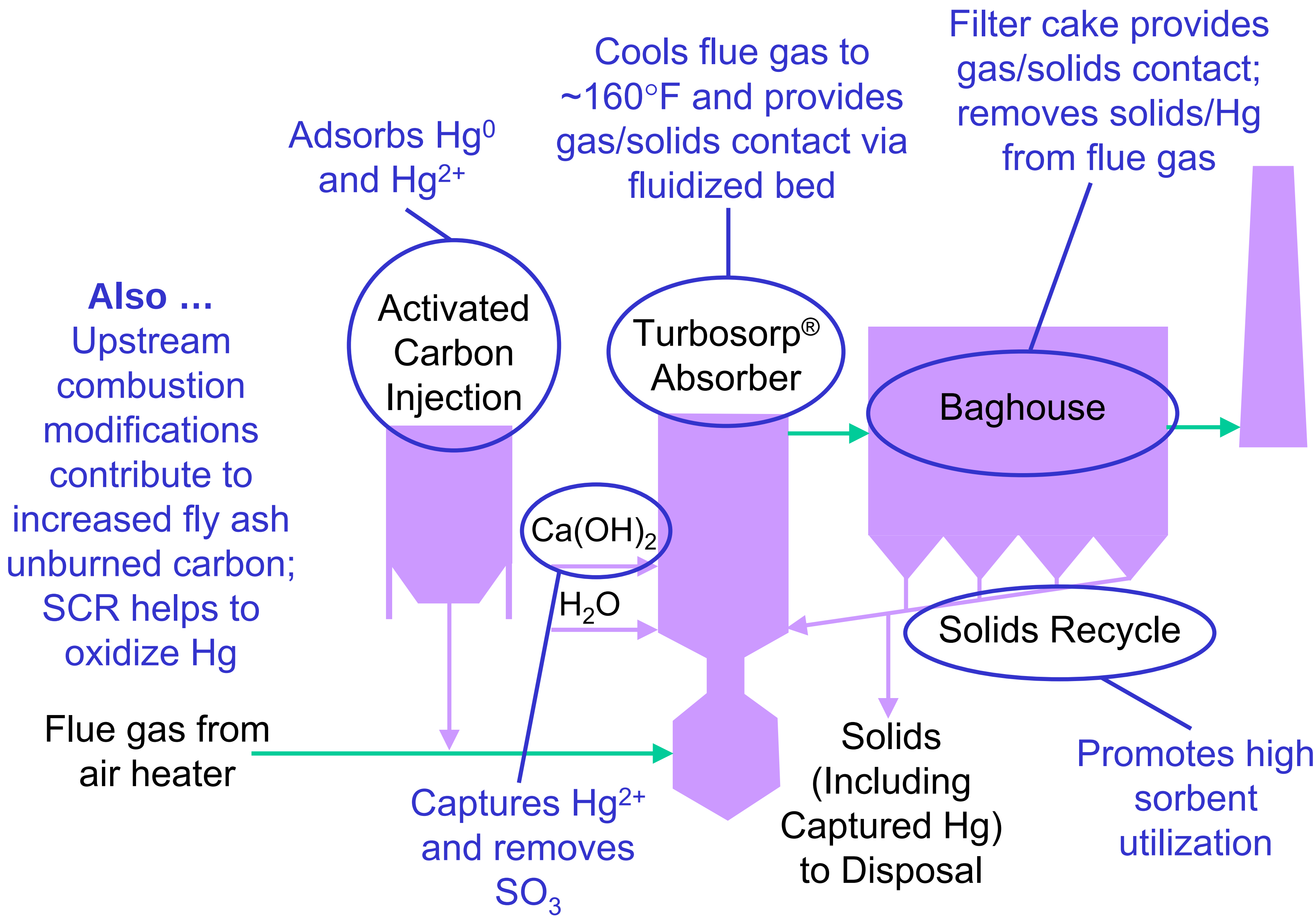

- Completely dry
- Separate control of hydrate, water, and recycled solid injection
- High solids recirculation
- Applicable to high-sulfur coals
- 15-25% lower reagent consumption than spray dryers
- Low capital and maintenance costs relative to other FGD technologies

# AES Greenidge Installation

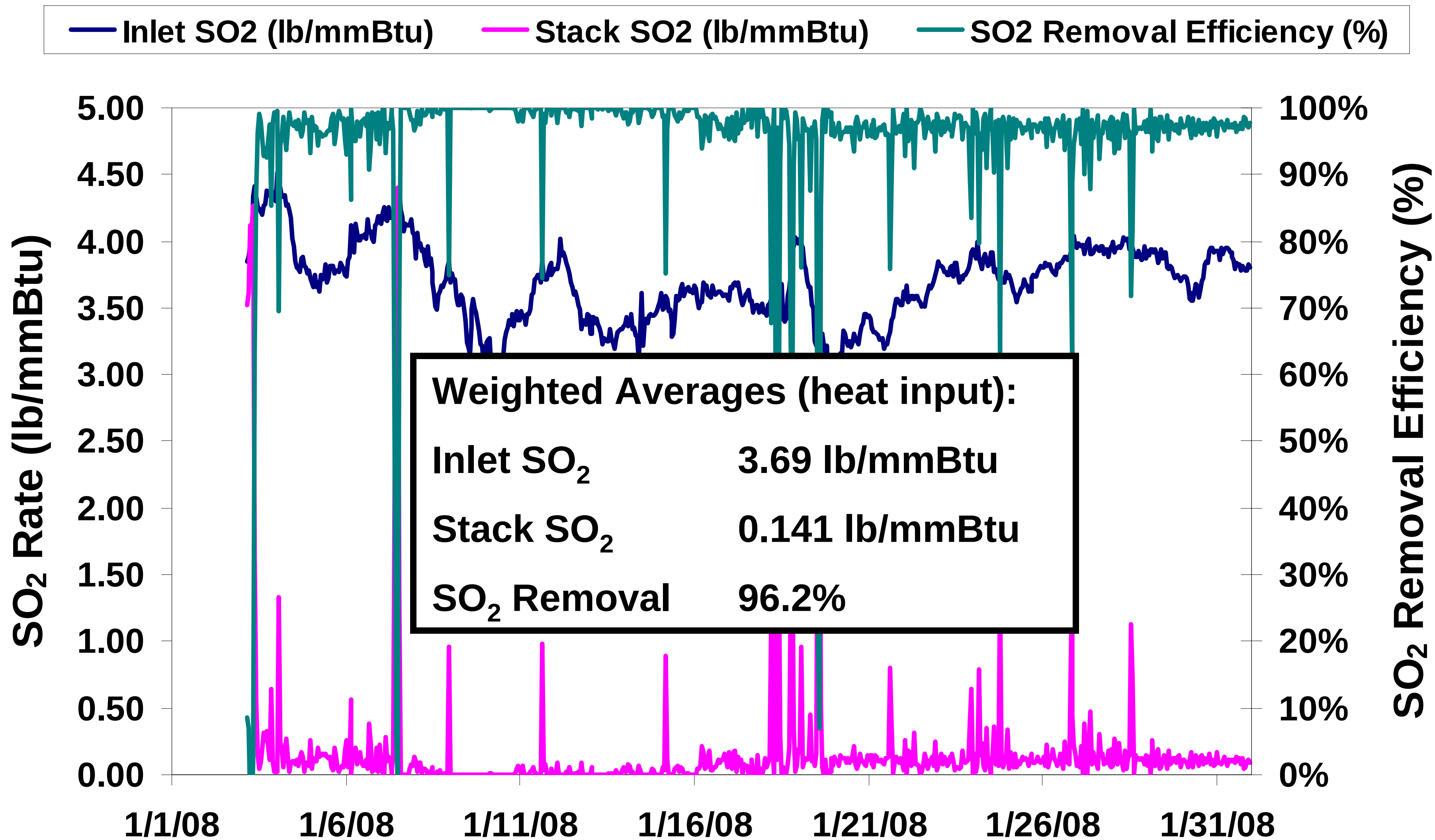



- Small footprint
- Carbon steel construction
- Includes:
  - Activated carbon injection system
  - Onsite lime hydration system
  - Eight-compartment pulsejet fabric filter
  - Booster fan
- Uses existing stack (liner not required)
- Ca/S is 1.6-1.7 for 4.0 lb $SO_2$ / mmBtu fuel

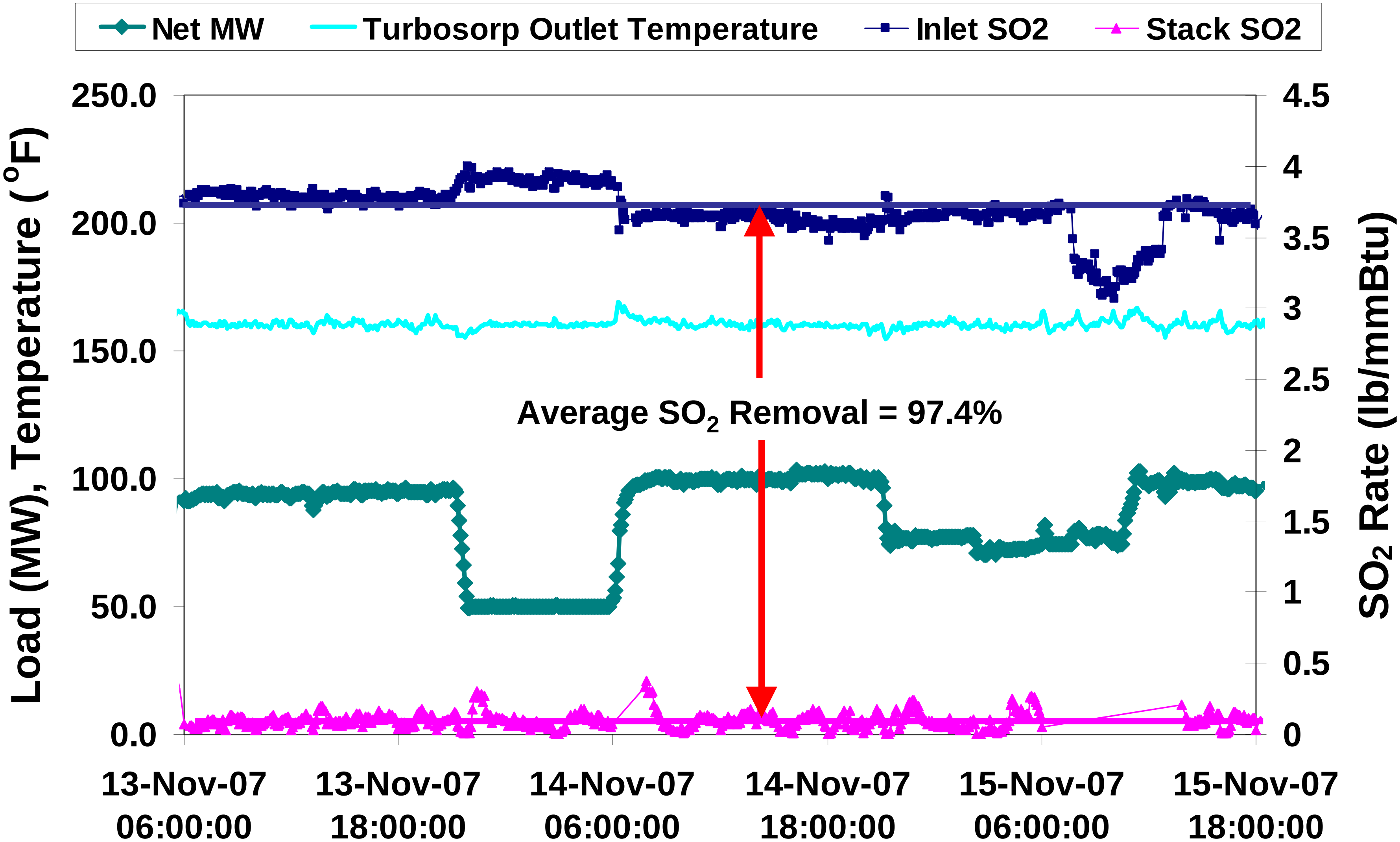
# Turbosorp® System
## Mercury Control



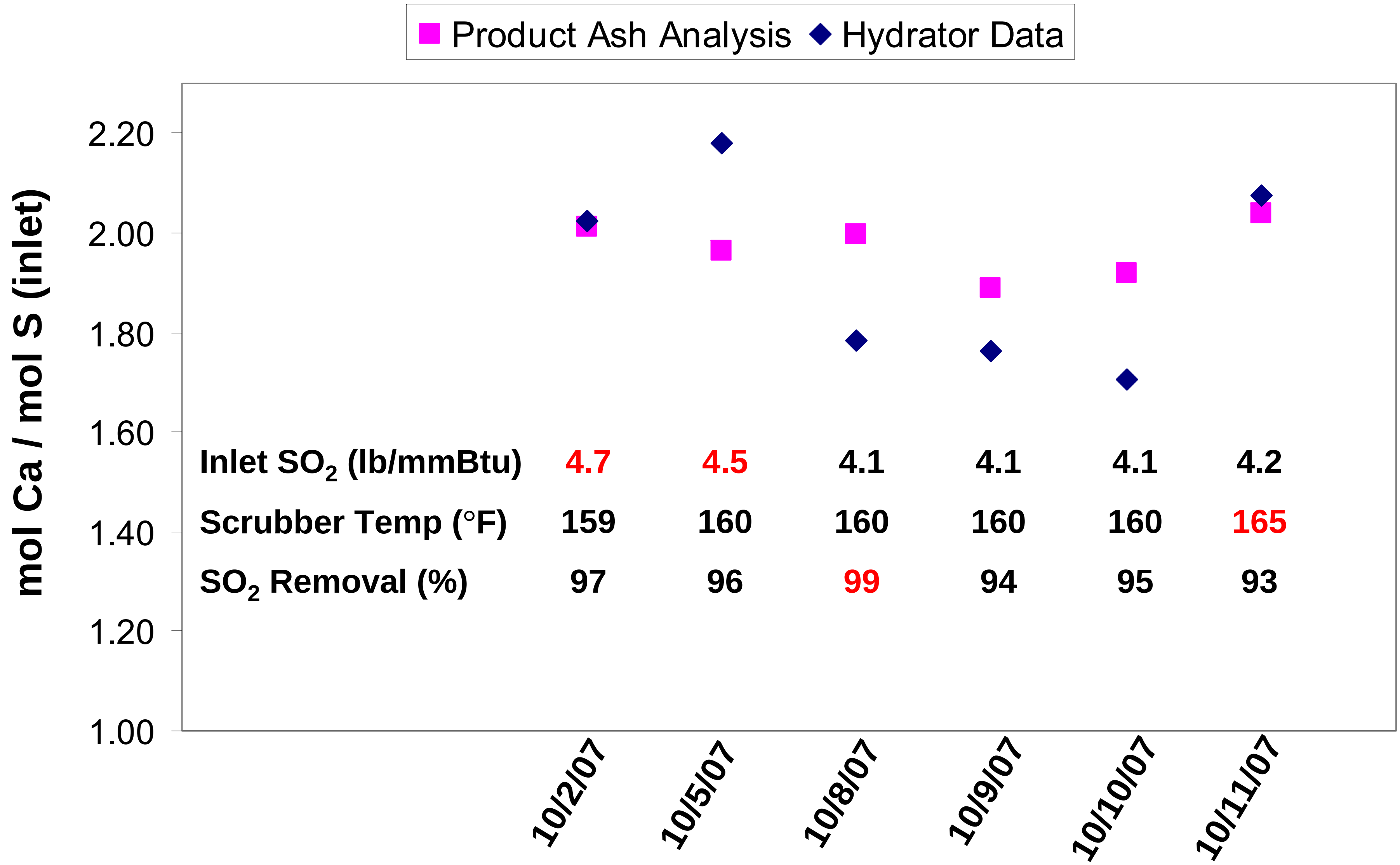
# $SO_2$ Removal Performance
## January 2008



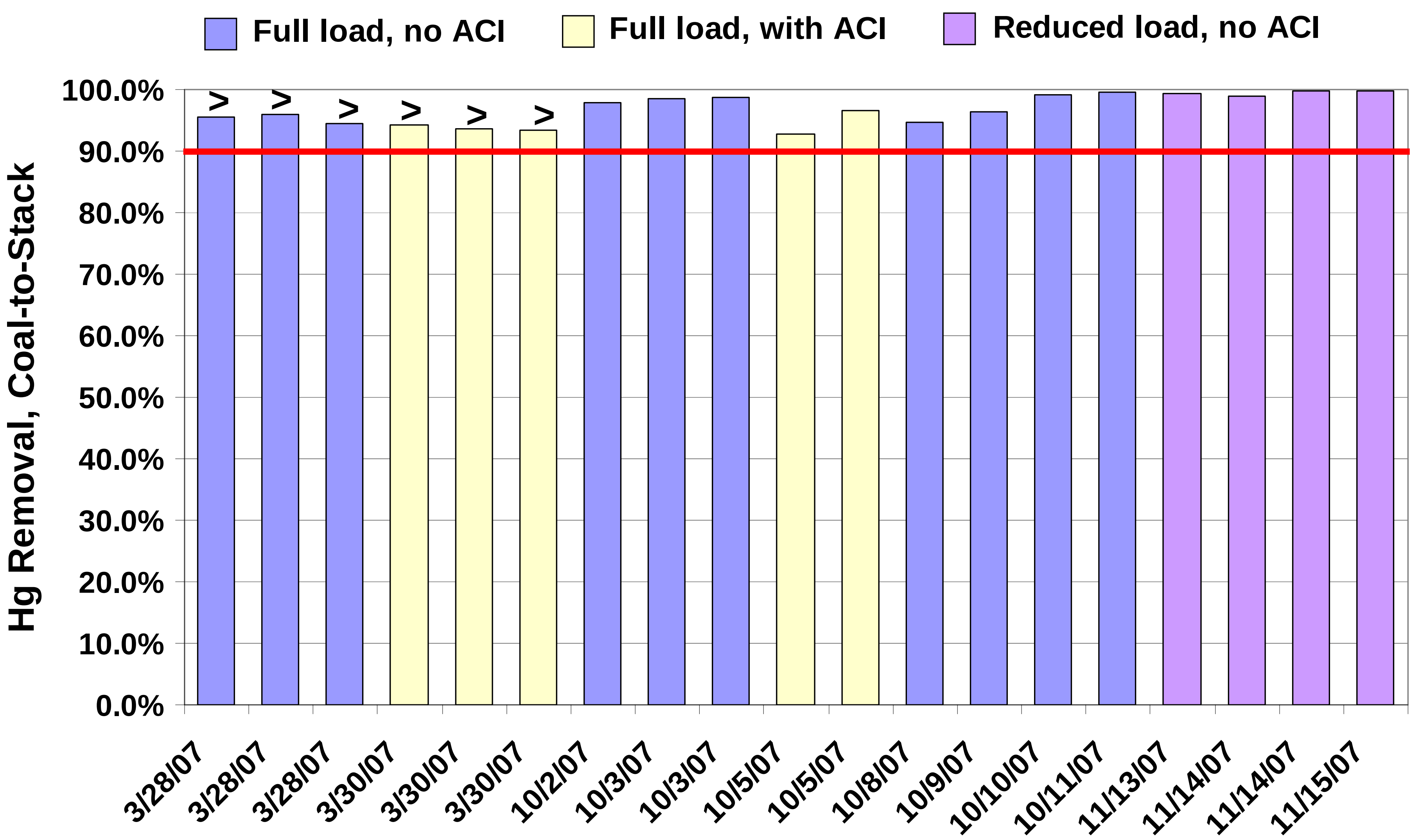
# Turbosorp® System
## Turndown



# Reagent Utilization
## October 2007 Testing



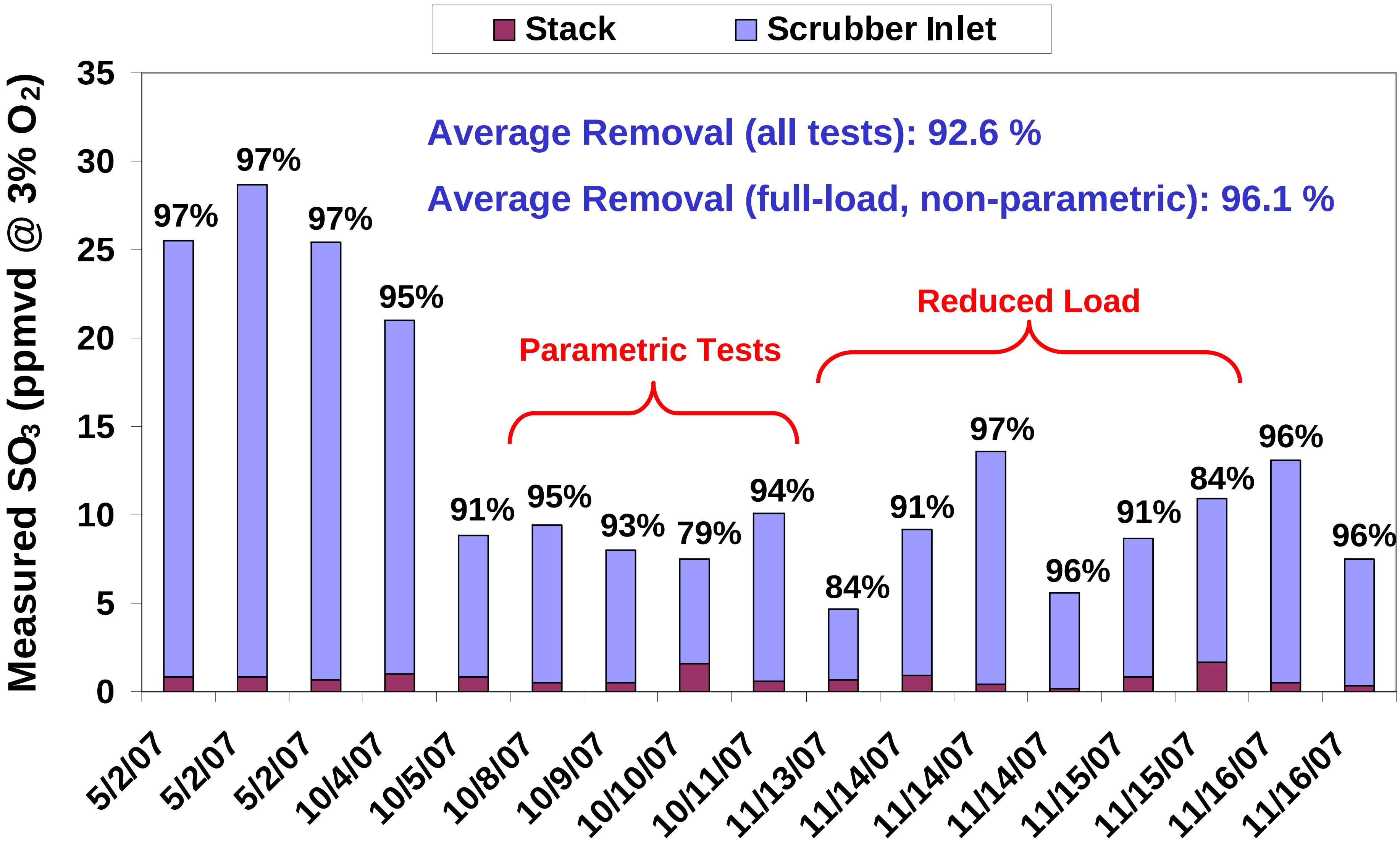
# Hg Testing Results
## Ontario Hydro Method



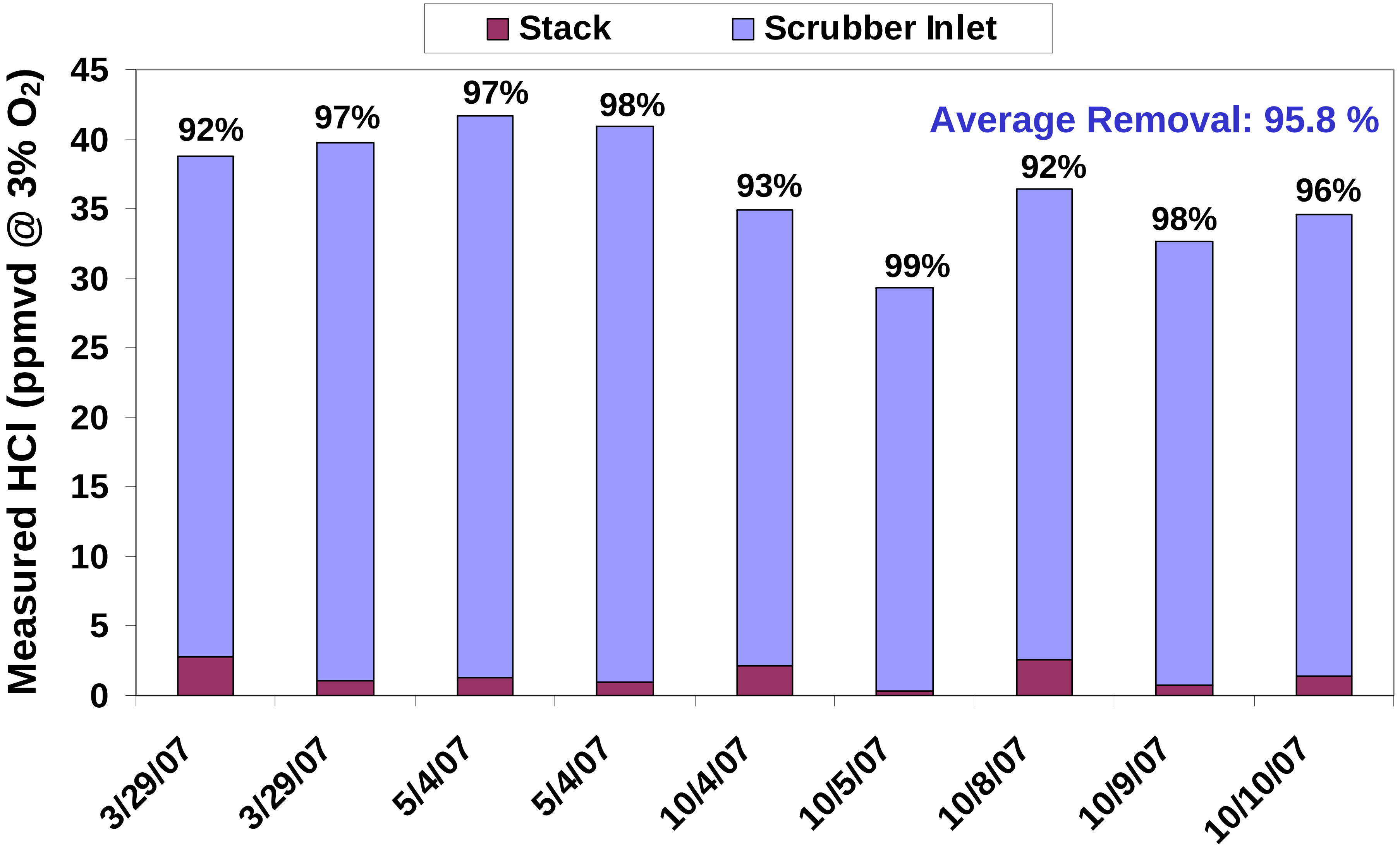
# Hg Testing
## Range of Process Conditions

| Parameter | Range |
|---|---|
| Coal Hg content (lb / TBtu) | 6.4 – 13.7 |
| Coal S content (lb $SO_2$ / mmBtu) | 3.7 – 4.9 |
| Coal Cl content (wt. %, dry) | 0.07 – 0.11 |
| Gross generation (MW) | 56.4 – 108.7 |
| Fly ash unburned carbon (%) | 9.2 – 25.3 |
| Activated carbon injection rate (lb / mmacf) | 0 - 3 |
| $SO_2$ removal efficiency (%) | 92.9 – 99.0 |
| Scrubber outlet temperature (°F) | 158.6 – 165.2 |

# $SO_3$ Testing Results
## Controlled Condensation Method

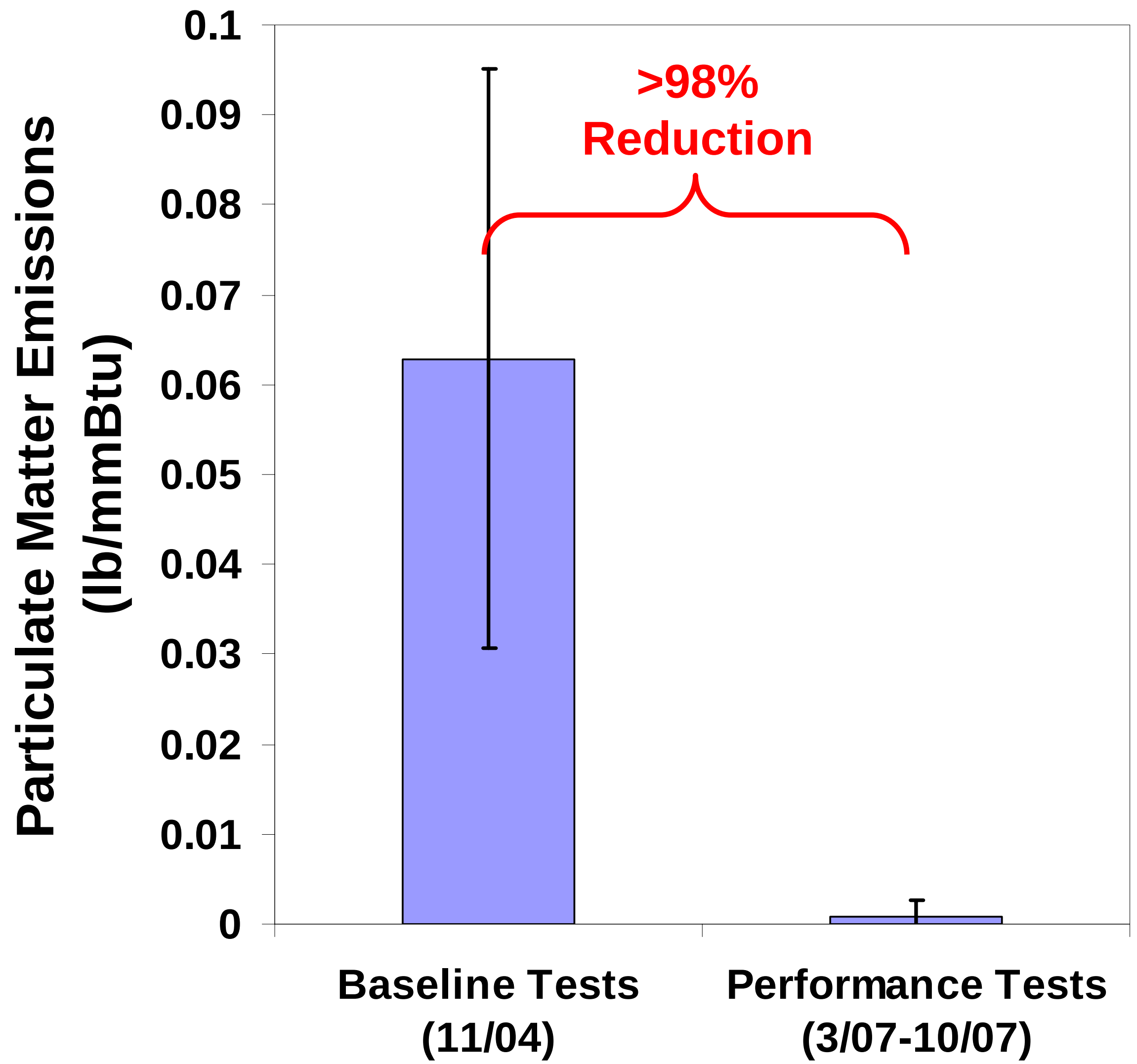


# HCl Testing Results
## EPA Method 26A



# Particulate Testing Results

## EPA Method 5/17, Full Load




**New baghouse significantly reduces particulate matter emissions relative to old ESP, in spite of increased particle loading from Turbosorp® scrubber**

Error bars represent ± 1 standard deviation

# Turbosorp® Product Ash

- Similar to spray dryer ash
- Dry powder (~1% moisture)
- Contains $CaSO_3$, $CaSO_4$, fly ash, $CaCO_3$, $Ca(OH)_2$, CaO, $CaCl_2$, $CaF_2$, inerts
- AES Greenidge sends to landfill (adjacent to plant site)
- Potential uses
  - Mine reclamation
  - Structural / flowable fill
  - Manufactured aggregate
- Leachable Hg (EPA Method 1312) is below detection limit
  - <1.2 % of total Hg in ash (3 samples)

# O&M Experience

- Lime hydration system
  - Most maintenance-intensive part of system
  - Can use delivered / stored hydrate to allow offline maintenance
  - Issues encountered to-date
    - Plugging in hydrated lime classifier
    - Water overfed to hydrator
    - Freezing of lines and valves
    - Balls escaped from ball mill
    - Failed bucket elevator shaft
  - Improvements
    - Adjusted classifier rotary feeder to reduce accumulation of fines
    - Modified logic for hydrator water feed
    - Increased onsite hydrate storage capacity

# O&M Experience
## (continued)

- Turbosorp® water injection lance
  - Changed about once per week
  - Retrofitted with high pressure quick disconnects
- Ash recycle and disposal system
  - Ash silo vents tend to plug
  - Some problems with freezing / clogging dosing valves

- Baghouse
  - Compressed air demand greater than expected
  - Temporary / permanent compressor capacity added
- No condensation issues encountered in absorber or baghouse

# Economics
## AES Greenidge Design Case

**Constant 2005 Dollars**

| | EPC Capital Cost ($/kW) | Fixed & Variable O&M Cost ($/MWh) | Total Levelized Cost |
|---|---|---|---|
| $SO_2$ Control | 229[a] | 6.14 | $567 / ton $SO_2$ |
| Hg Control - incremental | 6[b] | 0[c] | $1,567 / lb Hg[b] |

[a]Includes scrubber, process water system, lime storage and hydration system, baghouse, ash recirculation system, and booster fan

[b]Capital cost of activated carbon injection system, which has not been needed for 90% Hg capture

[c]Based on performance testing results to-date

Assumptions: Plant size = 107 MW net, Capacity factor = 80%, Coal sulfur = 4.0 lb $SO_2$/mmBtu, $SO_2$ removal = 95%, Hg removal = 90%, Ca/S = 1.65, Quicklime = $115/ton, Waste disposal = $17/ton, Internal COE = $40/MWh, Plant life = 20 years, Fixed charge factor = 13.05%, AFUDC = 2.35%, Other assumptions based on common cost estimating practices and market prices

# Economics
## AES Greenidge Design Case (continued)

| | $/MWh | $/ton $SO_2$ removed |
|---|---|---|
| Levelized Capital (TCR) | $4.54 | $241 |
| Fixed O&M | $0.88 | $47 |
| Variable O&M | $5.26 | $279 |
| Lime + Waste Disposal | $4.53 | $241 |
| Power/Water | $0.61 | $32 |
| Baghouse Bags/Cages | $0.12 | $6 |
| **Total Levelized Cost** | **$10.68** | **$567** |

- Improved dispatch economics relative to purchasing allowances
- Hg, acid gas, and improved primary particulate control for “free”

# Conclusions
## Turbosorp® System at AES Greenidge

- Well suited for 50-300 $MW_e$ coal-fired units
- Commendable emission reduction performance during 1st year
  - >95% $SO_2$ removal demonstrated for coals up to 4.9 lb $SO_2$/mmBtu
  - All tests to-date have shown >90% Hg capture with no activated carbon injection
  - Demonstrated >95% removal capability for $SO_3$ and HCl
- Footprint is < 0.5 acre
- EPC capital cost: $229/kW (2005)
- Total levelized cost: $567/ton $SO_2$ removed
- Improved dispatch economics
- O&M handled by existing plant staff
- Additional testing through summer of 2008

# Disclaimer

This presentation was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. 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 United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.