# Coal Gasification Technology for Coal-Fired Power Plants

## McIlvaine Hot Topic Hour

**By**

**CastleLight Energy Corp.**
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**See:** www.castle-light.com

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**DISCLAMER**

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- **Objective:**

  Re-engineer coal-fired power plants to reduce operating cost, and generate very competitive electricity with very low emissions.

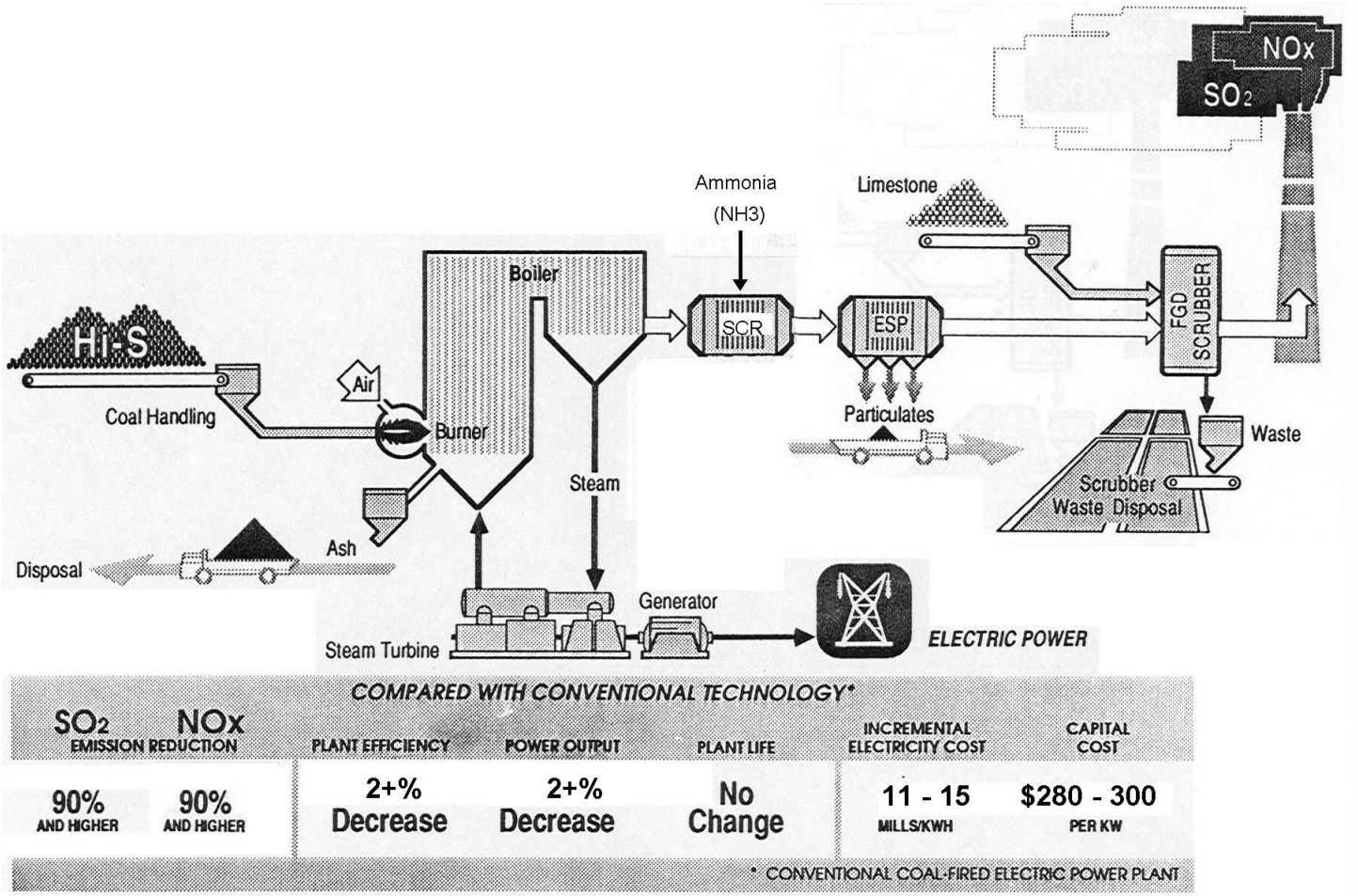
- **Approach:**

  Apply coal beneficiation and coal-gasification processes to existing coal-fired power plants

# Conventional Coal-Fired Power Plant

## with Back-End Emission Controls

## $SO_2$ = FGD+ Limestone; $NO_x$ = SCR + Ammonia; $SO_3$ = Trona ?, Hg = Activated Carbon ?

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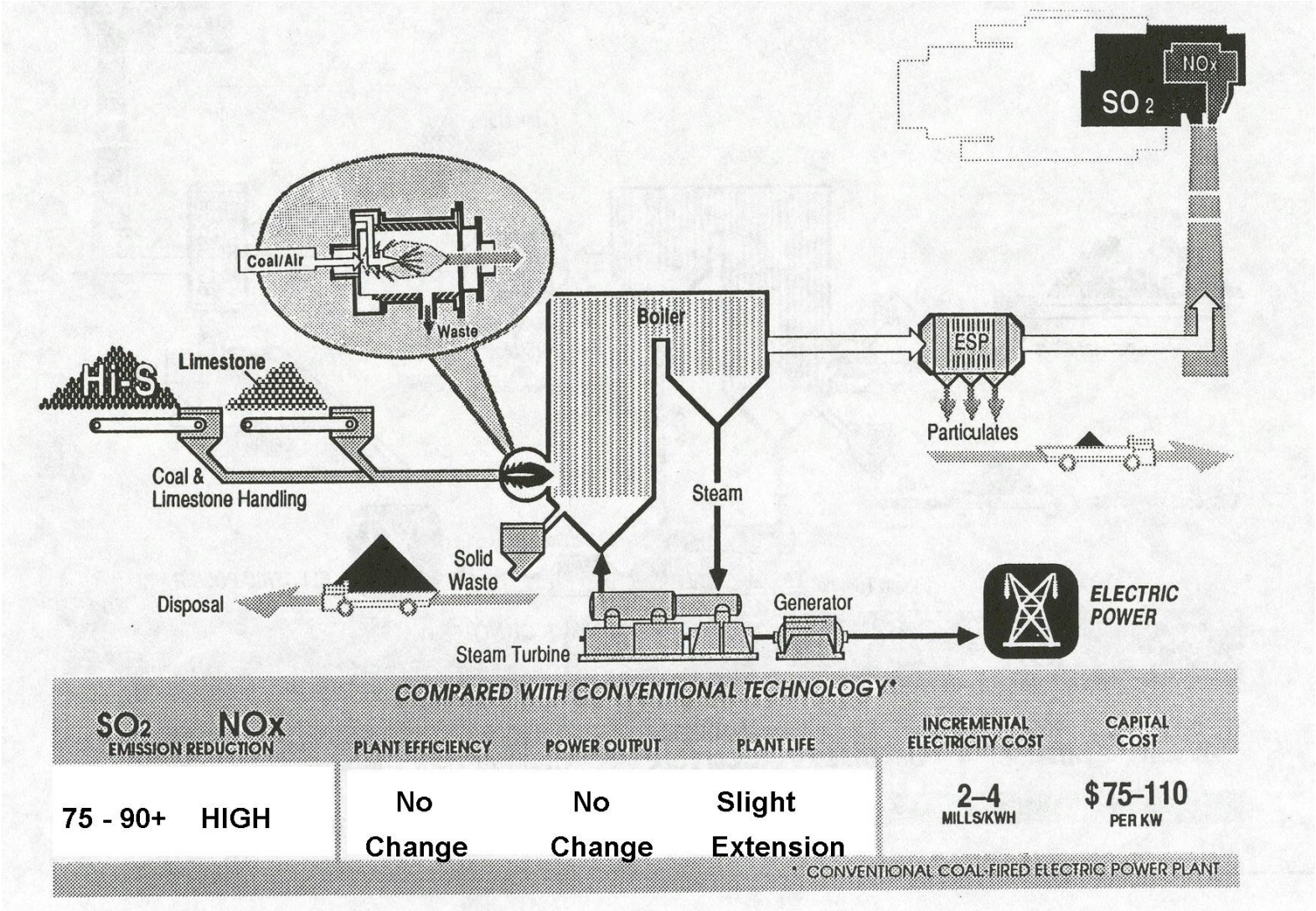
# Coal-Fired Power Plant

## Re-Engineered with Hybrid of Coal-Gasification

### $SO_2$ & $NO_x$ Controls Right in the Combustion Step




COMPARED WITH CONVENTIONAL TECHNOLOGY*

| $SO_2$ EMISSION REDUCTION | $NO_x$ EMISSION REDUCTION | PLANT EFFICIENCY | POWER OUTPUT | PLANT LIFE | INCREMENTAL ELECTRICITY COST | CAPITAL COST |
|---|---|---|---|---|---|---|
| 75 - 90+ | HIGH | No Change | No Change | Slight Extension | 2–4 MILLS/KWH | $75–110 PER KW |

* CONVENTIONAL COAL-FIRED ELECTRIC POWER PLANT

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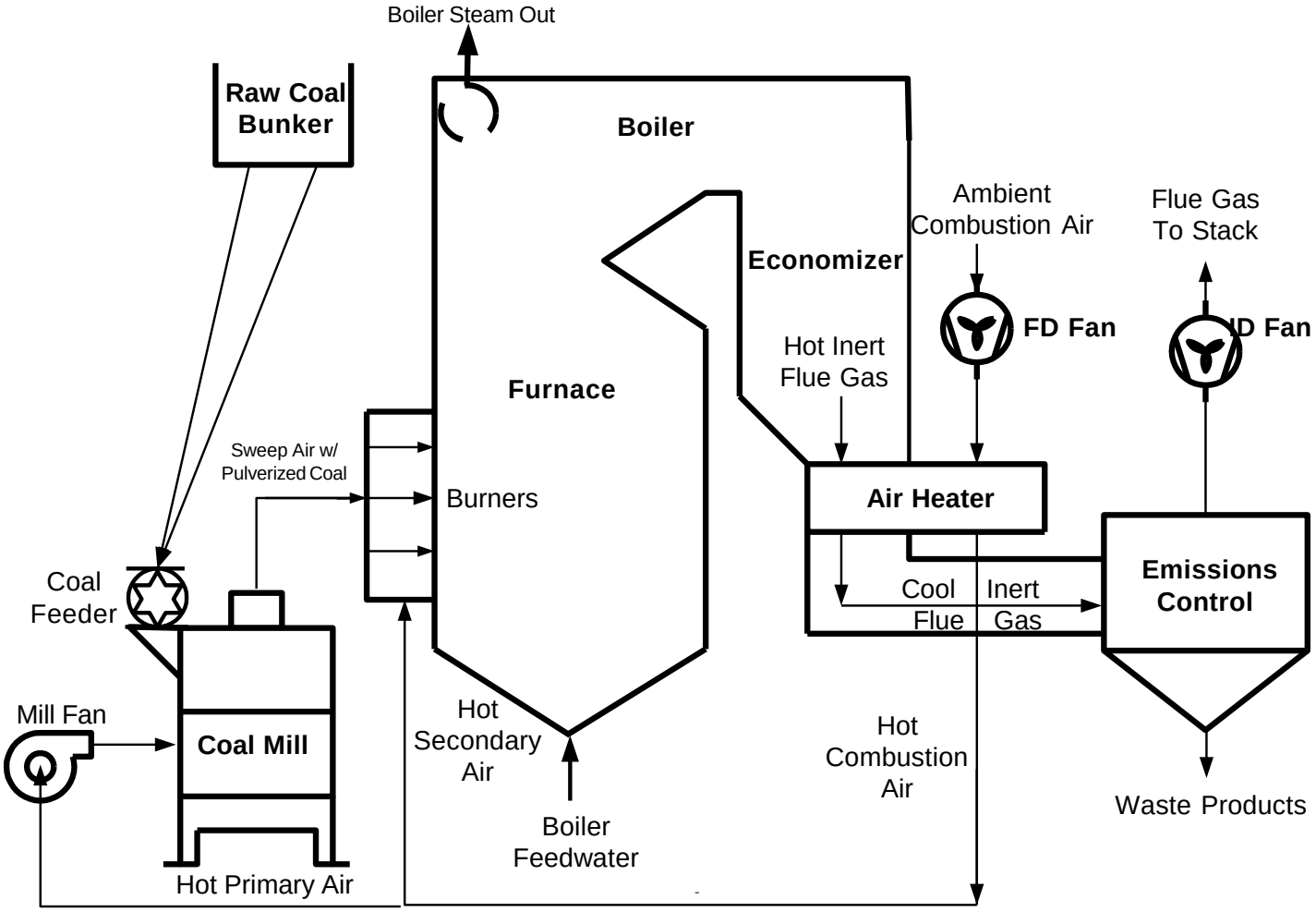
# Typical Pulverized Coal-Fired Power Plant

## 500 MW w/5 Mills – "Direct Fired" Pulverized Coal

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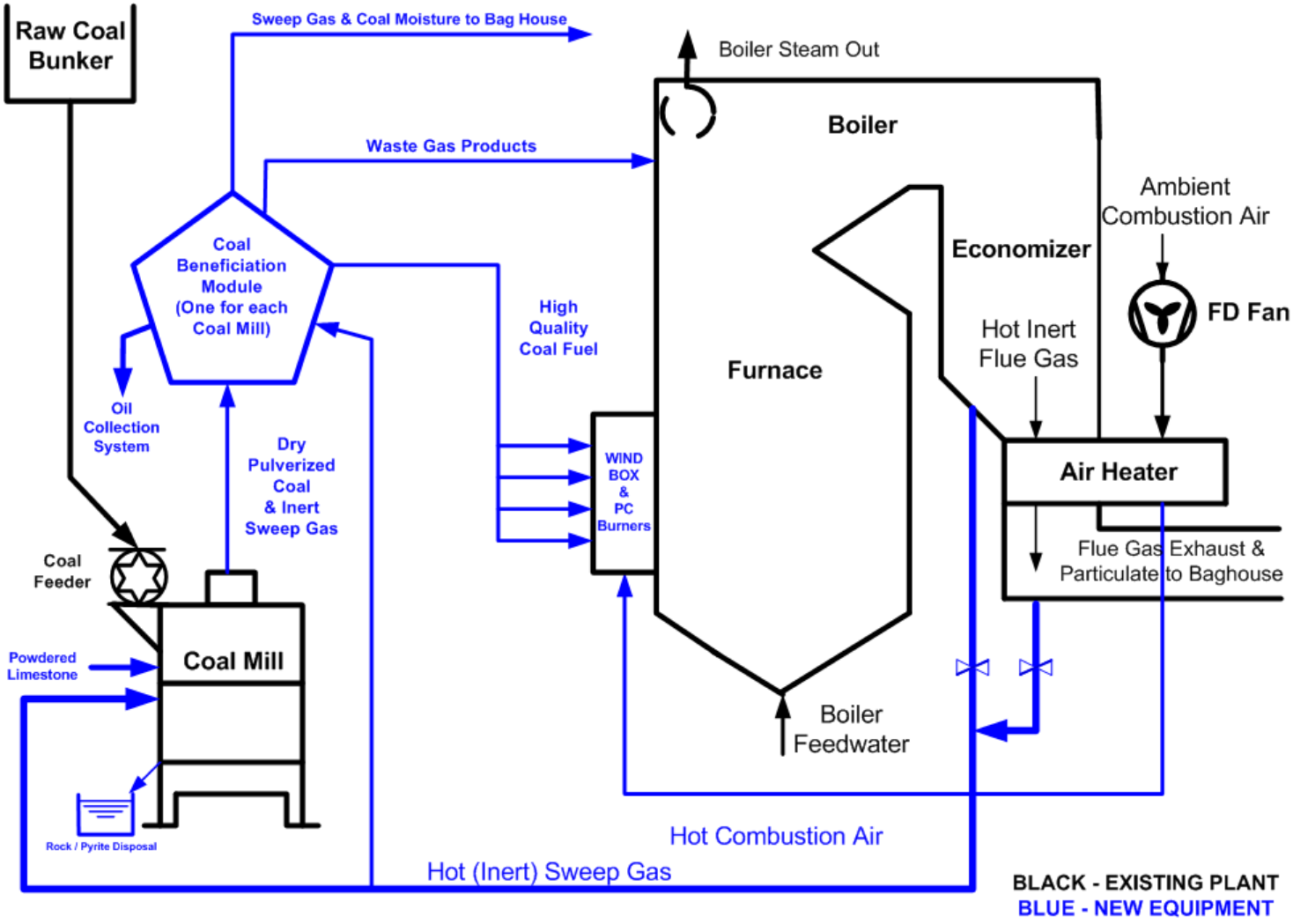
# Re-Engineered Power Plant

## "Indirect Fired" with Coal-Beneficiation Modifications

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# Re-Engineered Power Plant
## Coal-Beneficiation Modifications

- **<u>Add Coal-Beneficiation Modules – One for each coal mill</u>**

1. Re-route coal mill sweep gas:
   - Use the hot inert (low $O_2$) boiler exhaust vs. hot air
   - Improve safety - eliminate mill fires & puffs
   - Dry the coal (from >20% to <10% moisture)
2. Separate the powdered coal from sweep gas with bag house:
   - Direct wet sweep gas to boiler stack
   - Process powdered coal to extract volatile hydrocarbon oil
3. Separate carbon particles from oil vapor with cyclone:
   - Meter coal carbon with limestone added to furnace
   - Condense and collect oil from each mill

**<<<< Sell the oil and pay for the coal! >>>>**

# Coal Beneficiation Process

## Powder River Basin (PRB) Low Rank Coals

- **Coal Characteristics - PRB** :

| | |
|---|---|
| - Low in Btu | ~ 8300 Btu/Lb. |
| - High in Moisture | 20 – 30% |
| - High in Ash | 10 – 15% |
| - High in Mercury | 130 to 150 ppb |

- **Coal Beneficiation Target - PRB Coals** :

| | | |
|---|---|---|
| - Increase Btu | ~ 10,000 Btu/Lb. | (+20%) |
| - Reduce Moisture | 10 – 12% | (- 50%) |
| - Reduce Ash | 7 – 10%% | (- 50%) |
| - Compliance Mercury | ~36 ppb | (- 75%) |

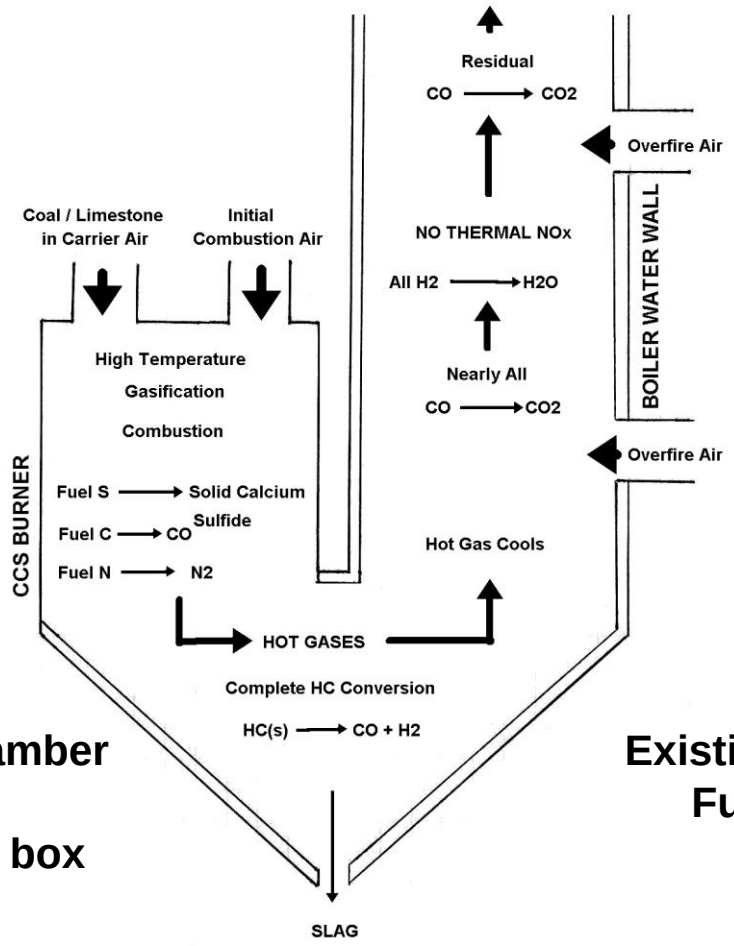
- **EPA CAMR – Compliance Mercury (Hg)** :
  - Existing Plants = 4.0 lb./Trillion Btu or ~ 36 Parts / Billion

- **Oil Production Example**:
  **500 MW Electric Generation**: Fires 12,000 T/day PRB; cost =$360,000/day;
  **Oil Product**: ~ 5000 barrel/day crude oil @ $72/BBL = $360,000/day income
  **Coal By Product**: 10,000 T/day high quality coal-fuel for power plant
  May show as a **Carbon-Neutral Process** (No $CO_2$ increase!)

**“An Oil Well in the Coal Pile”**

# The Clean Combustion System (CCS)

## Hybrid of Coal-Gasification & Combustion Schematic




**CCS Gasification Chamber replaces coal burners & wind box**

**Existing Boiler Furnace**

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# CCS Process Steps

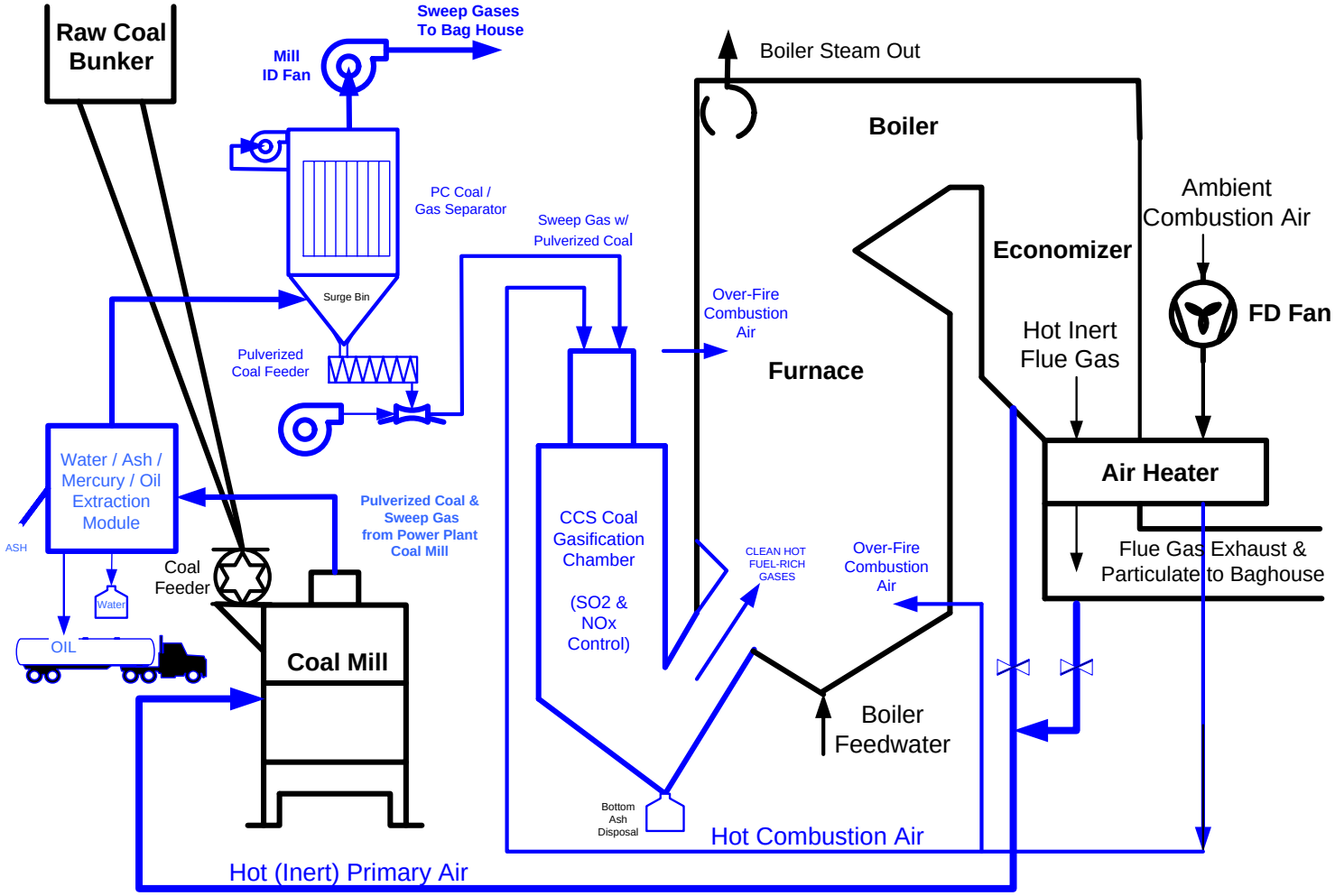
## $SO_2$ & $NO_x$ emissions control right in the combustion step

- An entrained-flow gasification of powdered coal; Creates a hot, fuel-rich gas, and frees the sulfur from the coal,
- Limestone - provides calcium, captures the sulfur in the coal,
- Forms calcium sulfide (CaS) - a solid particle,
- High temperatures melt the coal ash (alumina & silica) and encapsulate the CaS; forms liquid slag – drains as bottom ash,
- At these conditions, nitrogen is molecular $N_2$ ($NO_x$< 50 ppm),
- Clean hot gases – CO, $H_2$ and $N_2$ enter boiler & cool,
- Staged over-fire air completes combustion to $CO_2$ & $H_2O$ in boiler (<2300$^o$F, where $NO_x$ formation is frozen).

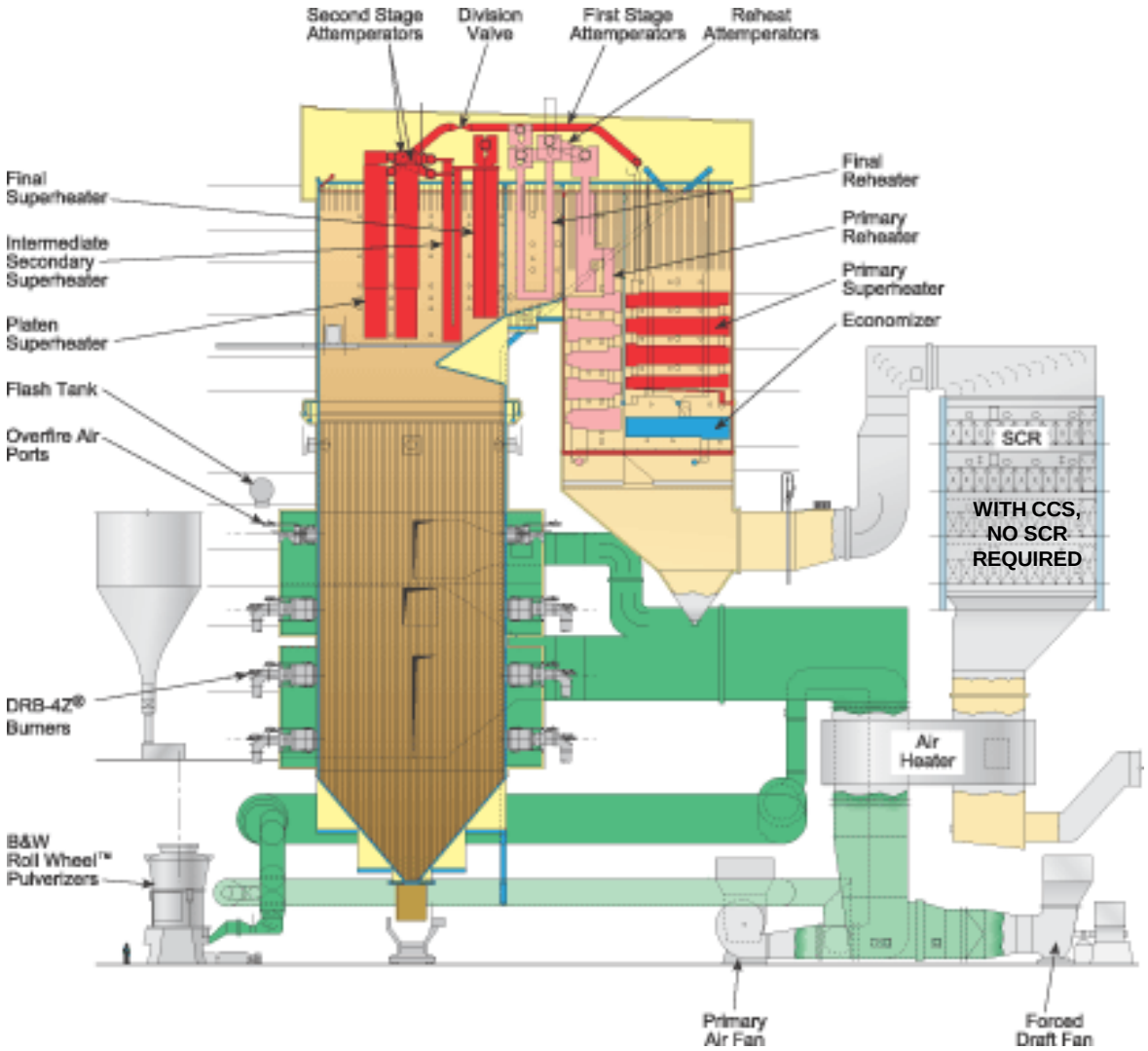
# Re-Engineered Power Plant

## Indirect Fired with Coal-Beneficiation & Coal-Gasification Modifications



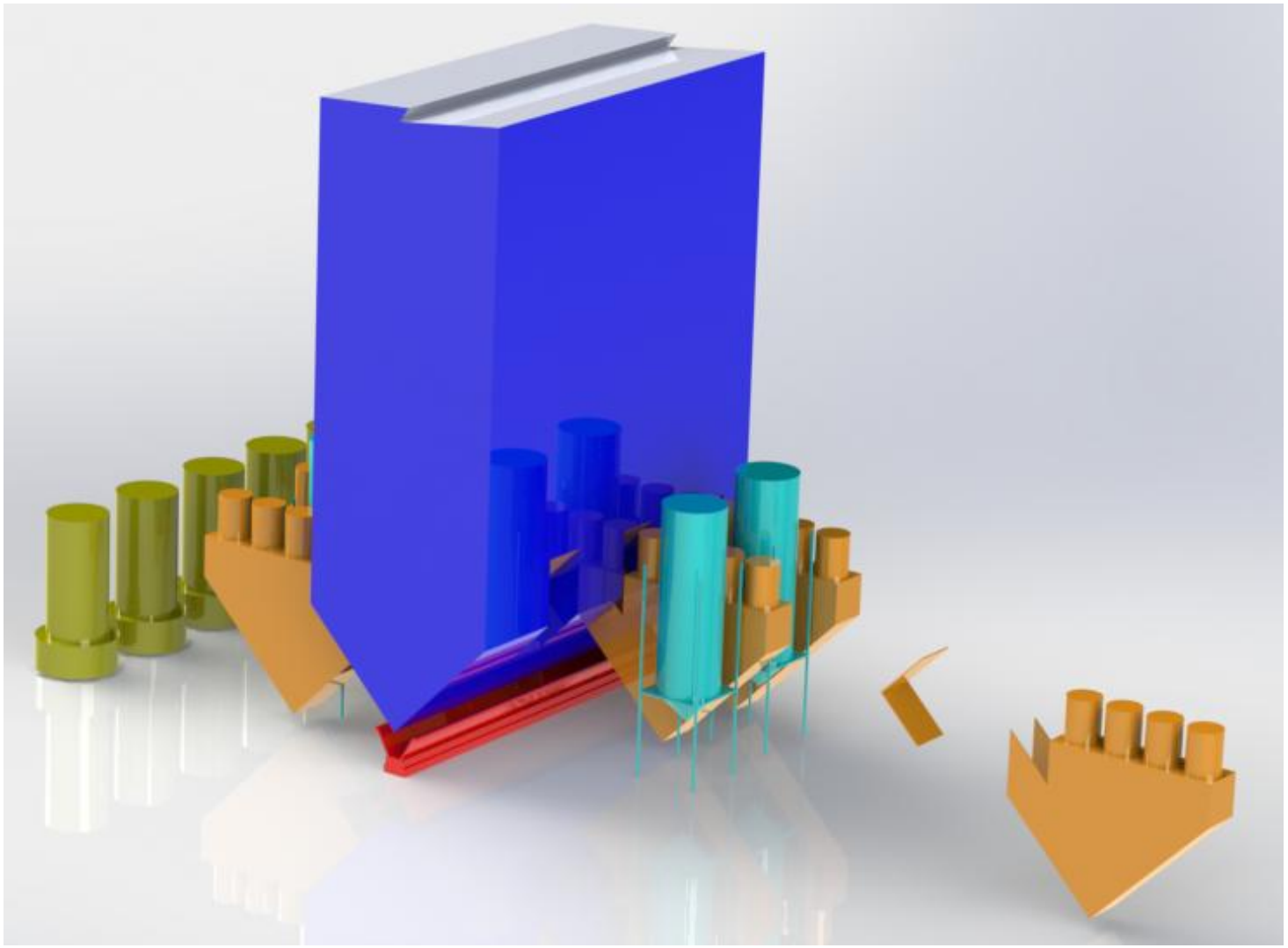
# Opposed-Wall Fired Boiler

## 500 MW – 24 Wall-Fired PC Burners



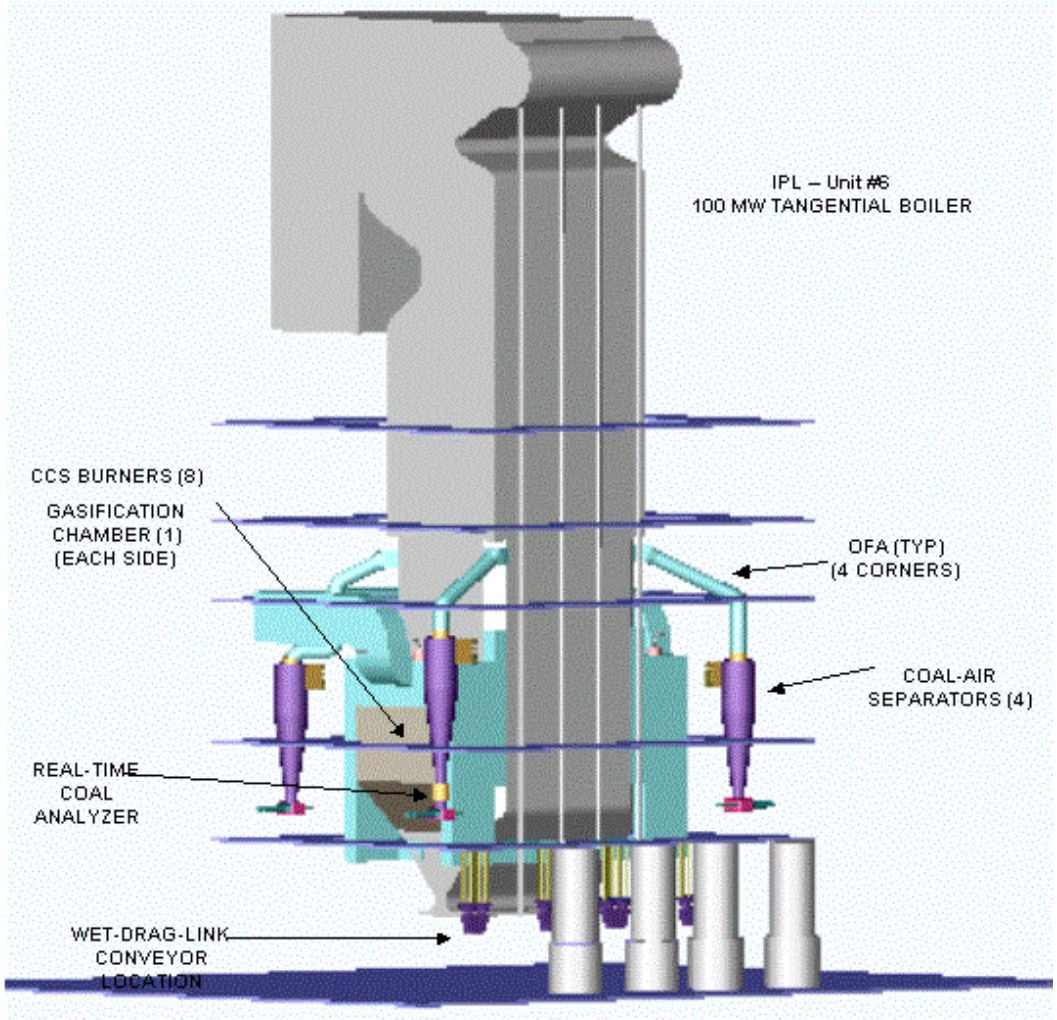
# CCS Re-Engineered Wall-Fired Boiler

## Replace Burners with 24 new CCS Burners & 6 GC's



# CCS-Tangential™ Boiler Retrofit

## 100 to 300 MW

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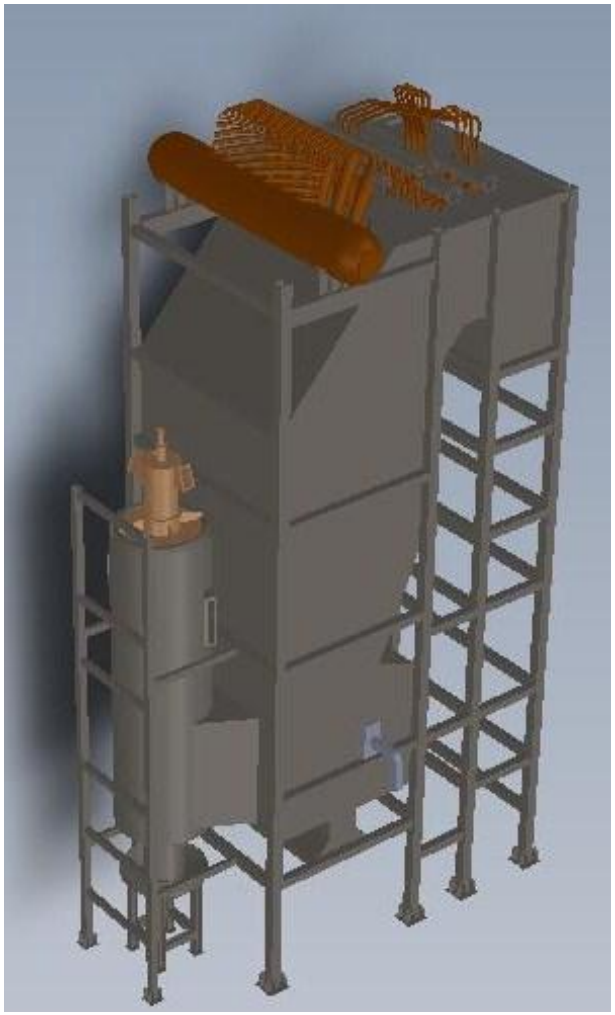
# CCS-Cyclone® Industrial Steam Supply



**Design Capacity (MCR):**
**165,300 lb./h Steam (74 $T_M$/h )**

**Features:**

- **Smallest Boiler Foot print per $MW_T$**
- **· Largest Steam Output per Ton of Steel**
- **· Internal $SO_2$ & $NO_x$ Emissions Control**
- **· Near Zero $SO_3$ emissions**
- **· High Combustion Efficiency (Reduced $CO_2$—Near Zero LOI)**
- **· Fires most all coal types**
- **· PC Coal-fired w/Limestone added**
- **· Slag Screen Fly Ash Removal**
- **· Wet bottom slagging operation**
- **· Clean Furnace Walls**
- **· Bottom Ash / Fly Ash is saleable**
- **· No waste water disposal**
- **· Affordable & Rapid Delivery**

# Re-Engineered Power Plant with CCS & Coal Beneficiation Processes

## Stack Emissions Estimate* firing PRB coals (1.2 lb. $SO_2$/mm Btu Coal)

- $SO_2$ = < 0.2 lb./mmBtu (< 105 ppm)
  ~80% $SO_2$ reduction
- $NO_x$ = < 0.10 lb./mmBtu (< 75 ppm)
- CO = < 300 ppm
- LOI = < 1% (high efficiency combustion)
- $SO_3$ = < 0.1 ppm (condensable particulate)
- Mercury = < 40 ppb
- Particulate = < 0.03 lb./mmBtu (bag house)
- Boiler Efficiency = 2 – 10% increase

* Preliminary estimates of performance, measured after bag house – no guarantees

# Rockwell International

## 25 x $10^6$ Btu/hr (1 ton/hr) Test Facility (1990)

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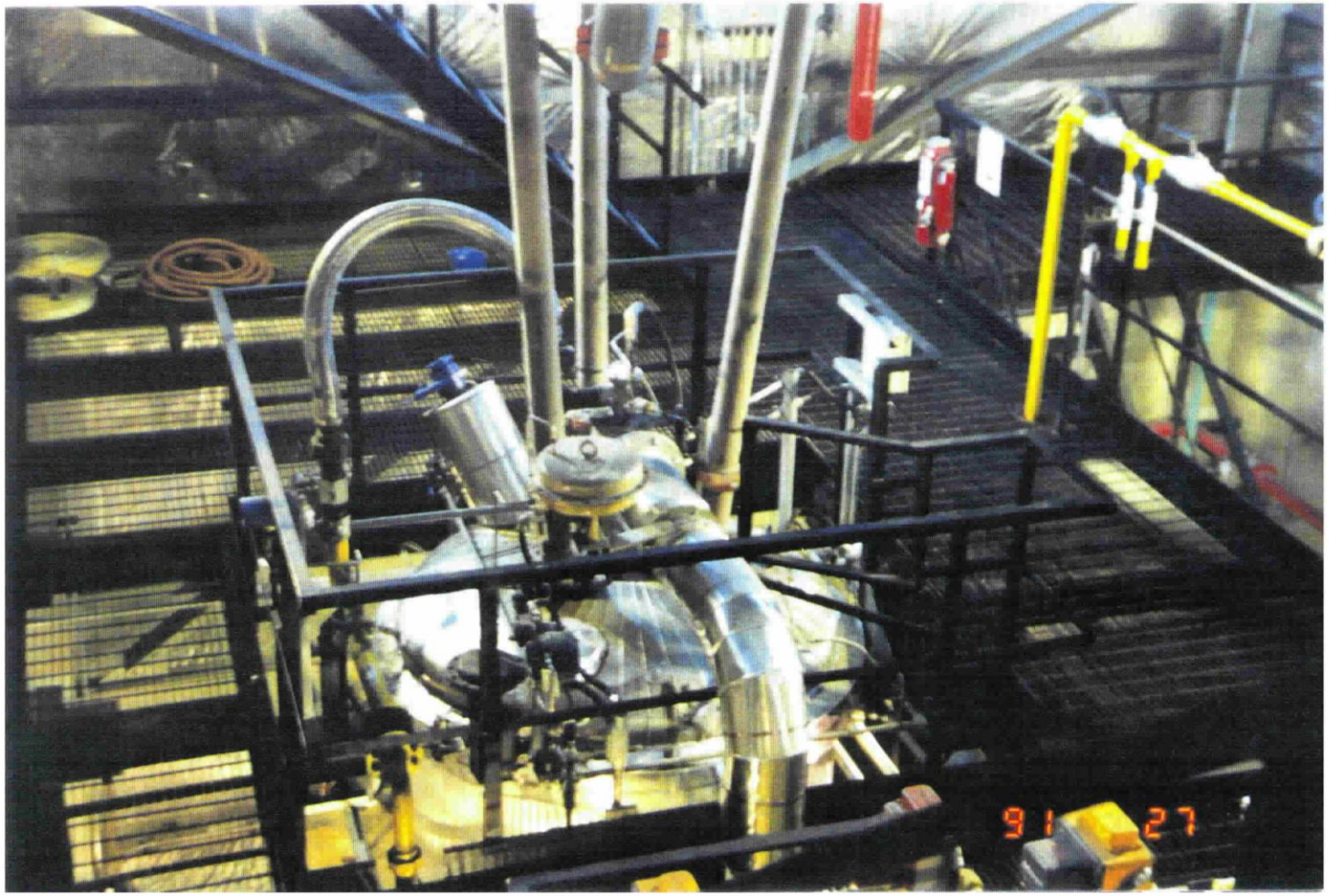
# LNS-CAP Facility

## ESSO Site, Cold Lake, Alberta Canada
## 50 mmBtu/hr – 3T/hr PRB Coal

# LNS-CAP

## Top of LNS Burner



# LNS-CAP

## Gasification Chamber Inspection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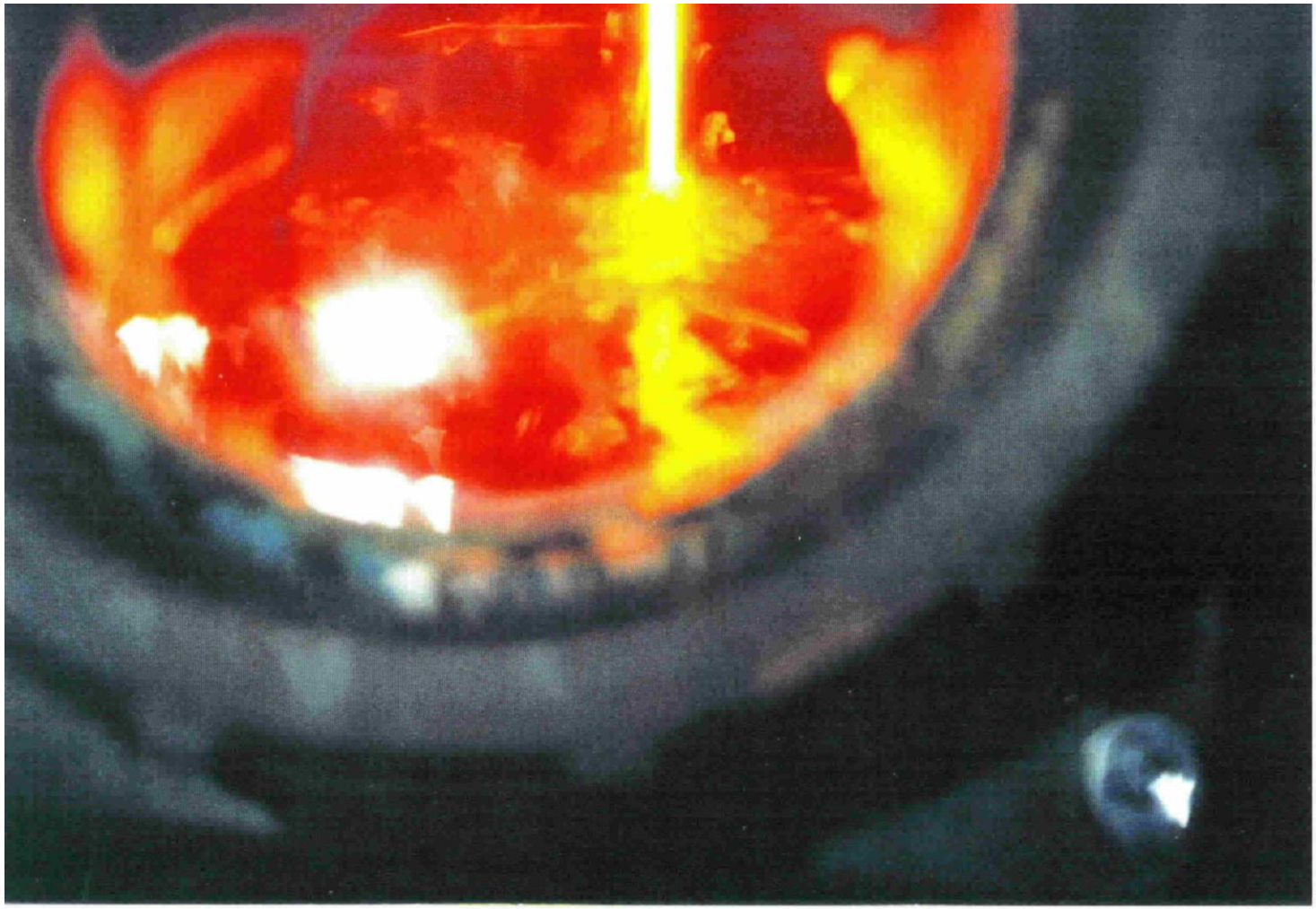
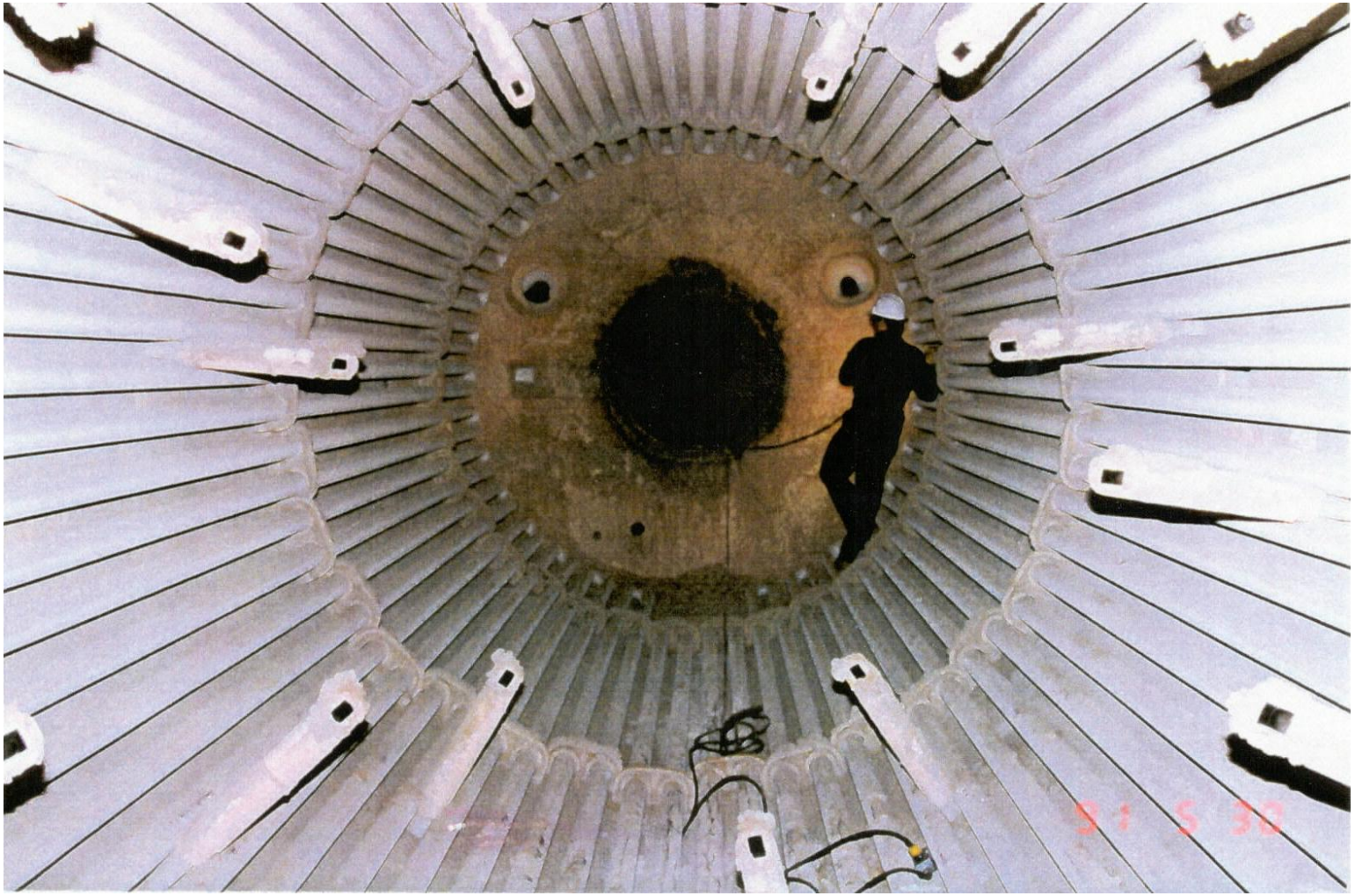
# LNS-CAP

## Slag to Water Trough



# Boiler Radiant Section

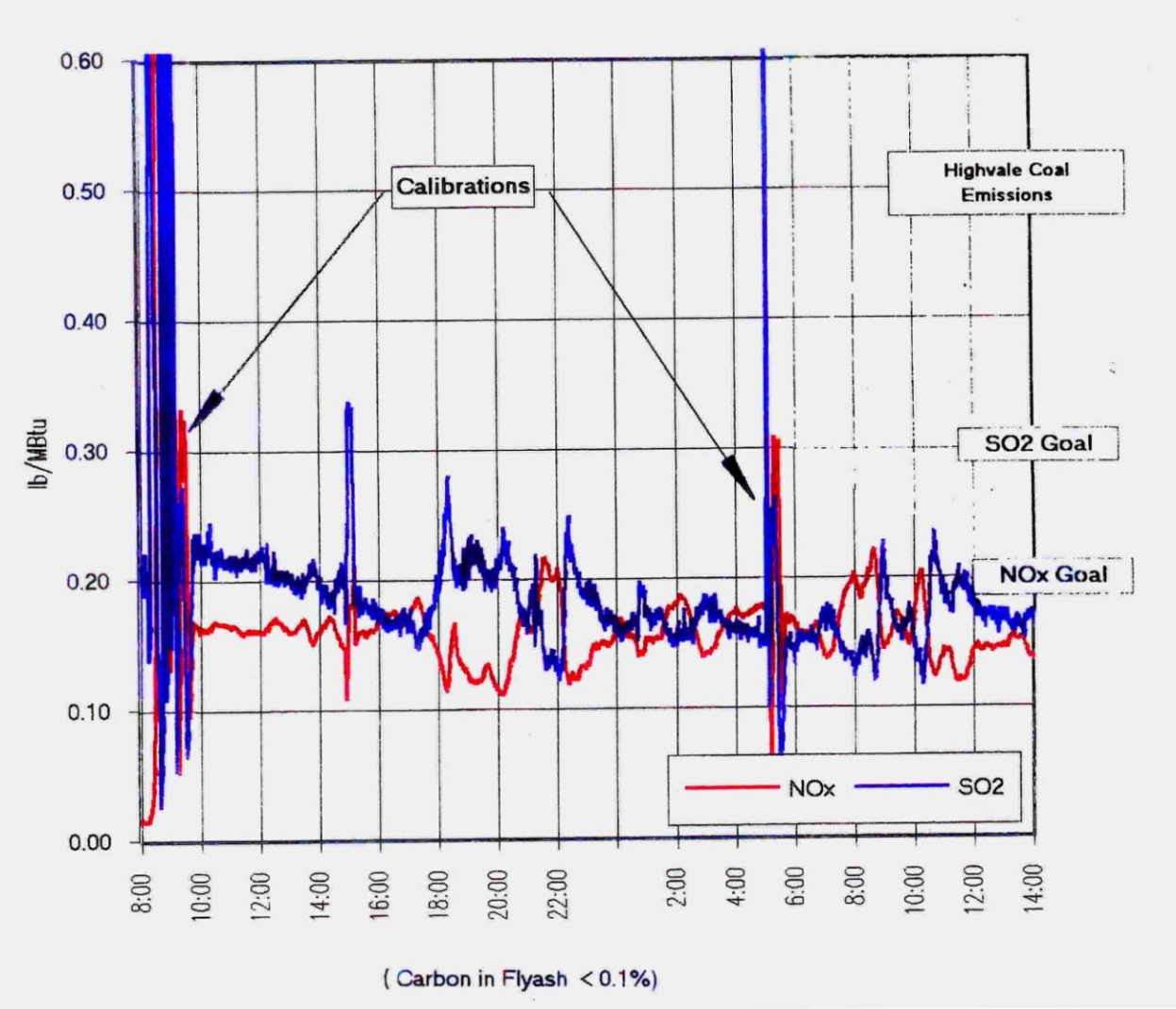
## View Forward to Burner



# Demonstrated Emissions

## $SO_2$ - 0.2 lb./mmBtu & $NO_x$ - 0.15 lb./mmBtu

**ESSO LNS-CAP Facility, Cold Lake, Alberta, Canada**

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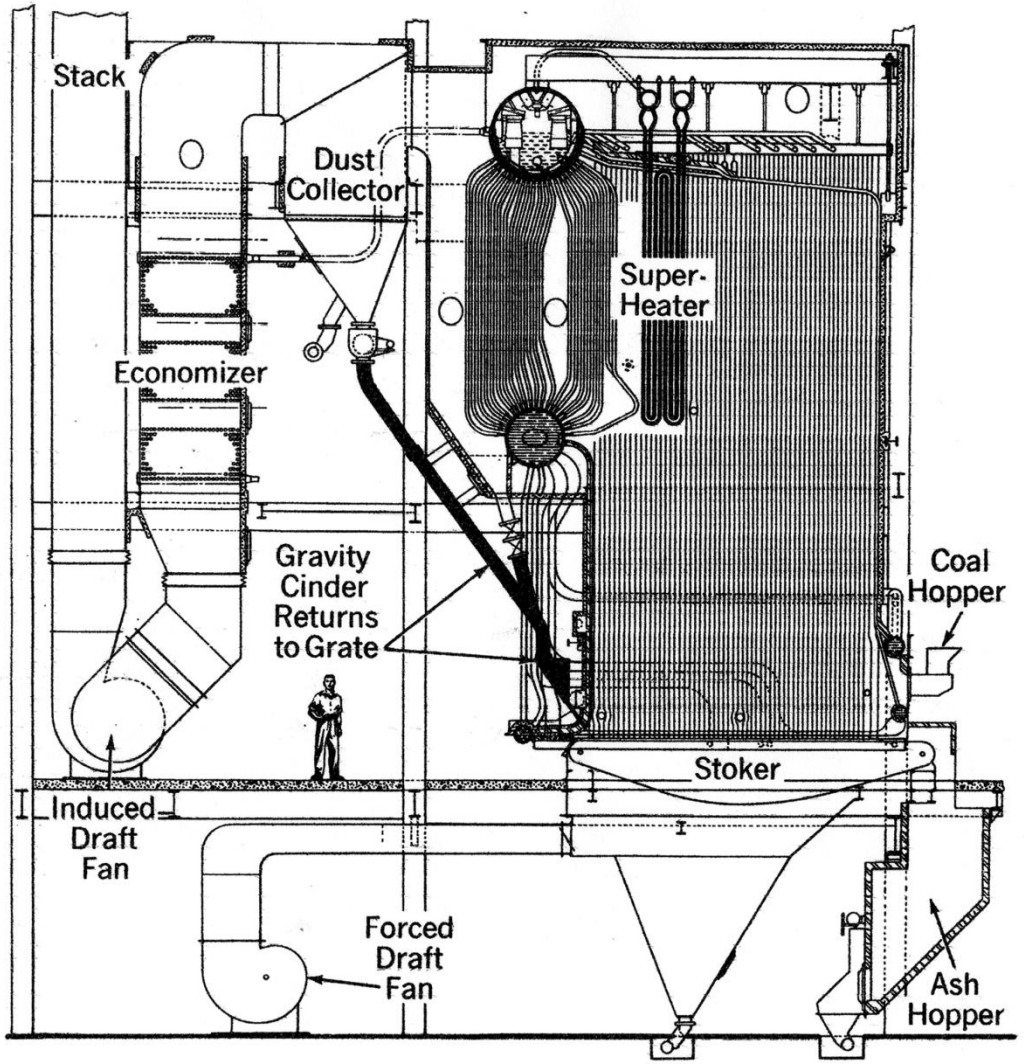
# CCS-Stoker® Project

- **Objective**:
  - Reduce operating cost by half
    (switch to low-cost high-sulfur Illinois coal – 2.5 lb. $SO_2$/mmBtu)
  - Construction Permit w/ waiver NSPS, PSD; no NSR
  - Emissions Warrantee: <0.9 lb. $SO_2$ /mmBtu, <0.25 lb. $NO_x$ /mmBtu
- **Project Initiated**: Oct 2005,
  **Commissioning**: Jan 2007
- **CEC Scope** : Process Design & Engineering;
  - Supply all equipment, hardware, electrical, instrumentation / controls
  - Provide Commercial Warrantee & License
- **Client Scope**: Site Construction Management;
  - Equipment Installation, as directed by CLPRC
  - Commissioning & Start-up
- **Project Support**: In part, by the Illinois Department of Commerce and Economic Opportunity through the Illinois Clean Coal Institute and the Office of Coal Development.

# Coal-Fired Stoker Boiler
## (typical)




### CCS Retrofit Modifications

**Remove:**

Stoker Feeders,
Ash Hopper,
Brick over stoker grate
Control Panel

**New Equipment:**

CCS Burner,
Gasification Chamber,
Combustion Air Heater
Boiler Instruments,
Coal Mill, Bag house, FD fan, BM & Combustion Sys,
HMI & PLC Controls
New MCC

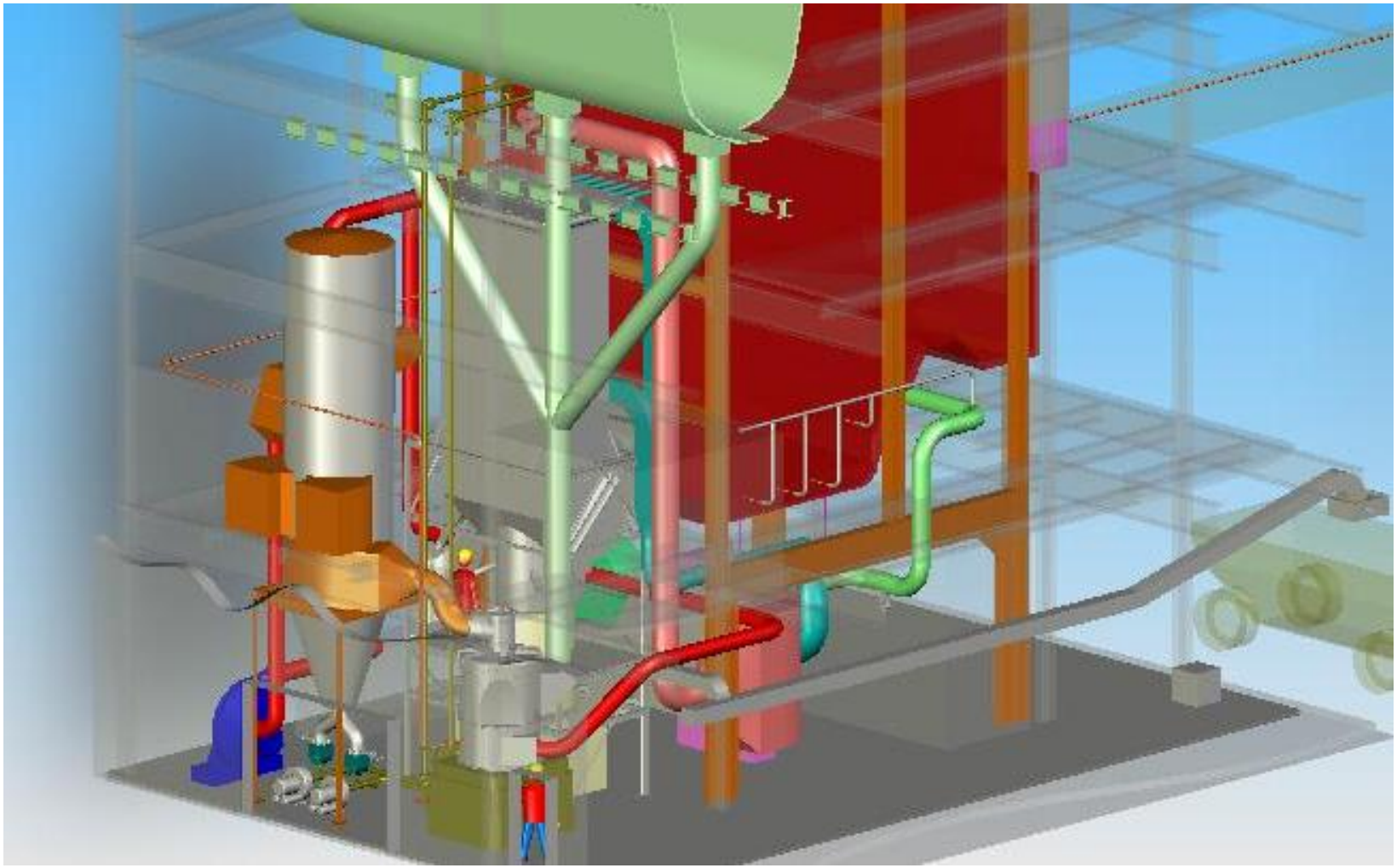
**Operators (one/shift)**:

Was all manual operation;
Now with HMI - from cold start to automatic full load operation in 5 hrs.

# CCS-Stoker® Retrofit

## 30 MW (Thermal) - 125 mmBtu/hr – 5 T/hr Coal



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# CCS-Stoker® Gasification Chamber

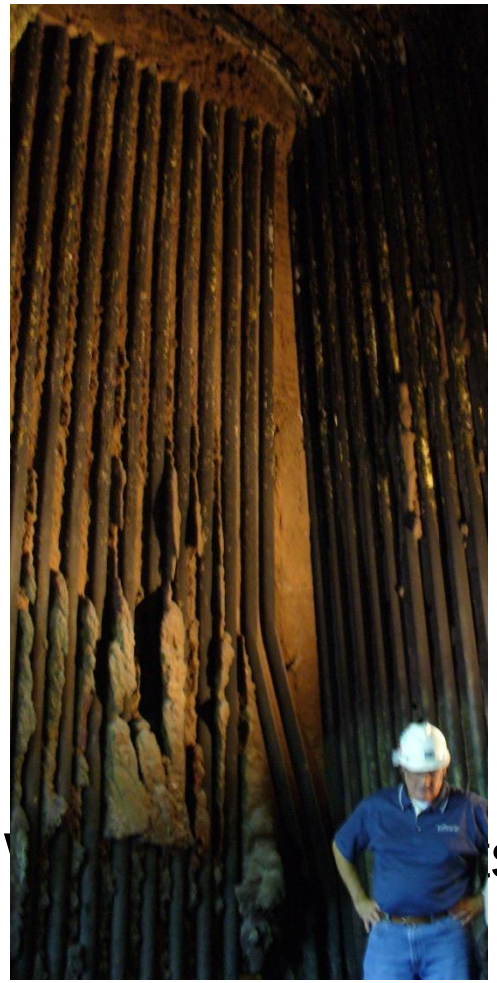
 

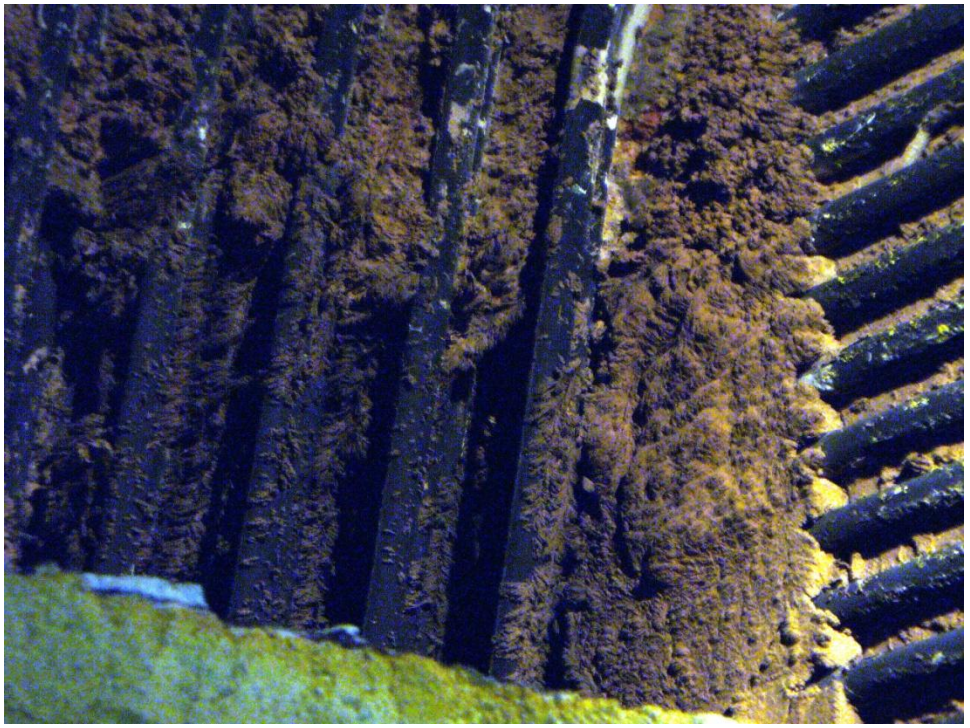
# CCS-Stoker® Gasification Chamber Installation

- McBurney Corp designed and supplied the GC
- Connected to the boiler drums for natural circulation water cooling
- Shop fabricated membrane wall studded and refractory lined.

# Stoker Boiler Furnace Deposits

## Typical Examples





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# Operation Observations
## CCS-Stoker® Furnace Ash Deposits

 

# CCS-Stoker® Operation @ MCR

## Steam Overboard

# CCS-Stoker® Retrofit Performance

## Preliminary Results – Full Load Operation

| Item | Stoker Base Line Test | Preliminary CCS Performance | % Change from Base Line |
|---|---|---|---|
| $SO_2$ Stack Emissions (lb/MMBtu) | 1.80 | 0.72 | - 67.0 % |
| NOx Stack Emissions (lb/MMBtu) | 0.50 | 0.14 (88 ppm) | - 72.0 % |
| Boiler Efficiency | 77.0 | 86.9 | + 12.8 % |
| $CO_2$ Emissions - Ton/yr GW credits (% Reduction) | 94,019 | 73,720 | 20,300T/y (- 21.6 %) |
| Project Cost Recovery (from firing lower cost coal) | | ~ 3 years | |

 

# CCS Features

## Improved Operability, Availability & Reliability

- All equipment off-the-shelf & familiar to the operators
  - Safe, stable burner operation,
  - Same startup, shutdown and turndown as the PC plant
- Bottom Ash (slag) removed before furnace
  - low particulate/ash load; clean furnace, less soot blowing
- Sulfur removed from furnace gases - near-zero $SO_3$:
  - Allows for lower furnace exit temperatures
  - Minimize water-wall wastage & corrosion,
  - Can use hot boiler exhaust for pulverizer sweep air:
    - Dry the coal – reject moisture
    - Improves coal pulverizer safety from fire & puffs (low $O_2$)
- Improved Boiler Efficiency (2 to +10%)
  - Reduce $CO_2$ emissions
  - High combustion efficiency (LOI < 1%)
- Limestone is only "chemical" required
- No waste water for disposal

# CCS Summary
## (Key Strategic Issues)

- From Fundamental Combustion Theory to Commercial Operation
- Fire lower cost coals - reduce plant operating cost
- Meets EPA's new stringent regulations for $SO_2$ & $NO_x$
- Allow power plant upgrade with waiver of NSPS & PSD - No NSR
- Low Retrofit Cost; maintains older, smaller plants competitive
- Improve plants capacity factor & dispatch
- Fits within plant & boiler site footprint
- Ash products have value (sell bottom ash & fly ash)
- No hazardous or toxic chemicals required

**It's ADVANCED COAL GASIFICATION TECHNOLOGY!**

 

# Strategic Business Opportunity?

## Acquire Abandoned Coal-fired Power Plants

- **Re engineer and Update PC Electric Generation Plant with CCS;**
  - Provides $SO_2$ & $NO_x$ emissions control,
  - Waiver of NSPS, PSD, & no NSR
- **Integrate a CBM on each coal Mill**
- **Improved power plant performance**
  - improves boiler heat rate/efficiency - less fuel fired
- Very competitive dispatch;
  - "**paid for**" fuel = low cost electricity
- Meet EPA "CAMR" goals (+90% mercury reduction)
- Can show carbon neutral process = No $CO_2$ increase!

 

# CastleLight Energy Corp.
# Re Engineering Programs


**Please Contact CastleLight Energy Corp.**

**Keith Moore - President**

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**See Web Site: www.Castle-Light.com**


## For Technical Presentations / Plant Surveys and Reports:

- **"Re-Engineering Coal-Fired Power Plants for Low Emissions and Competitive Electricity Dispatch"**

- **"Operating Experience of a Coal-Fired Boiler Retrofit with an Advanced Hybrid of Coal Gasification For $SO_2$ & $NO_X$ Emissions Control and Reduced Operating Cost"**

- **Proposal: - "Re-Engineering Coal-Fired Power Plants with the Clean Combustion System"**

 