Re-Engineering Coal-Fired Electric Generating Plants with Coal Gasification

By

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DISCLAMER

Information herein is best estimates of the presenters and subject to change.
No guarantees or warrantees implied or given.

CastleLight Energy Corp.

- Technology evolved from coal combustion research at **Rockwell International** with further development by **TransAlta Utilities**.
- **Hybrid of Coal Gasification** with strong SO_2 and NO_x emissions control ……
- Coupled with a fast **Coal Beneficiation** process ……
- Some $60 million in Utility peer reviewed development and field demonstrations & commercial programs
- Patented Technology
- **CastleLight Energy Corp. provides :**

  - Overall Technology Management
  - System Engineering, Design, CFD & PEPSE Analysis
  - All Hardware, Equipment, Instrumentation, and Controls including supervision of installation by customer
  - Commercial Warrantee & Technology License

TECHNOLOGY LEAP FROGS!

When was the last time you:

Dialed a Phone?

Typed a Letter?

Flew in a Piston Engine Airplane?

Observe…… these technologies are obsolete!

Technology LEAP FROGS! …. It does not evolve.

Existing U.S. Coal-fired Plants

Must meet stringent EPA emission regulations

Some 600 older, smaller (100 to 400MW) coal-fired plants are subject to being mothballed, abandoned or demolished because of the following EPA regulations. They can not afford the cost for modifications!

- **Cross-State Air Pollution Rule:** SO_2 & NO_x
- **MACT Rule:** Mercury, HCl , & CO
- **Clean Power Plan**: CO_2 reduction
- **Coal Combustion Waste:**
- **Wastewater Discharge:**

Re-Engineered Plant Performance Targets

Estimated: firing PRB coals * (1.2 lb. SO_2/mm Btu Coal)

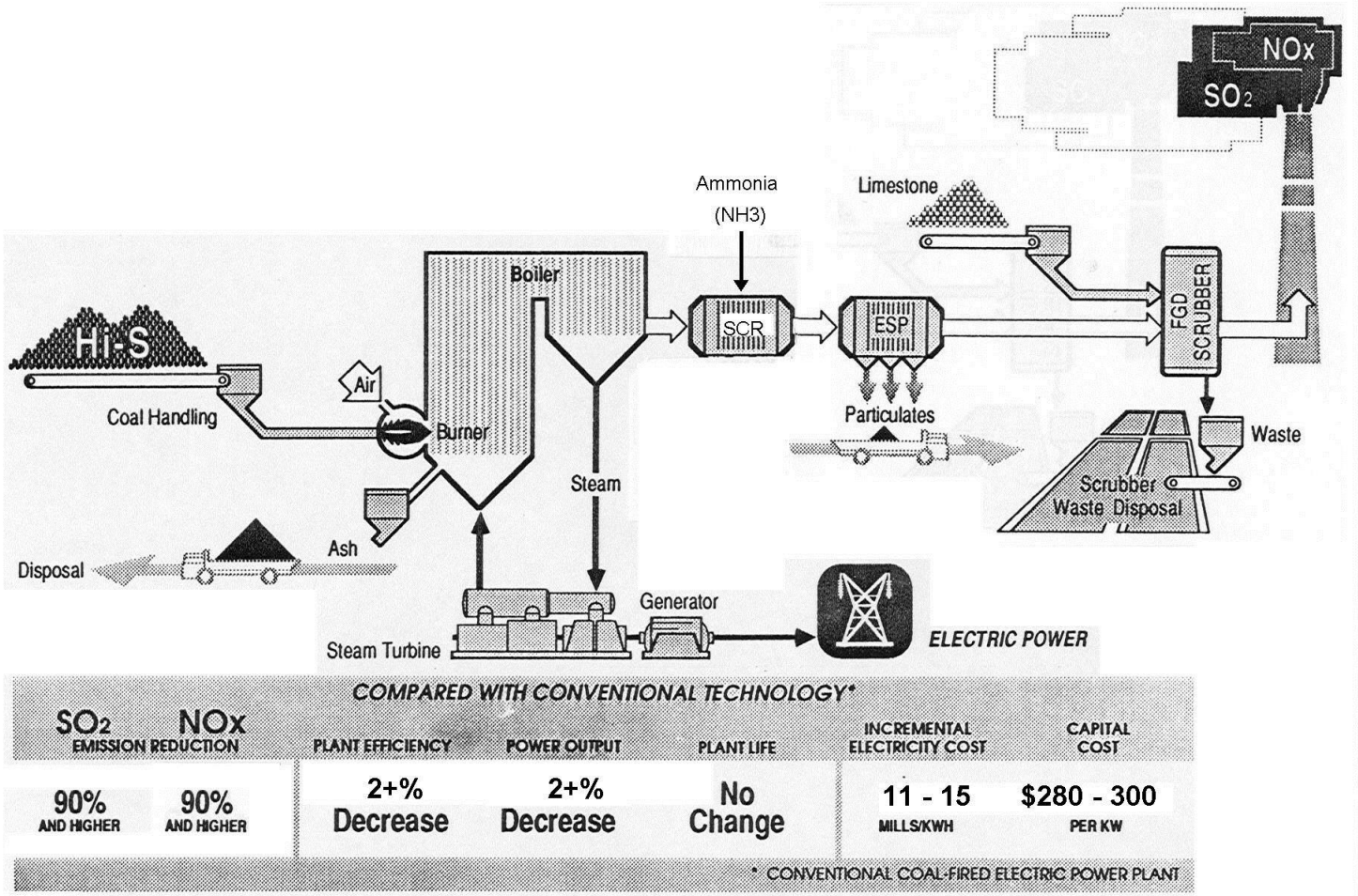
- **SO_2 :** < 0.2 lb./mmBtu (~ 105 ppm) ~80% SO_2 reduction
- **NO_x :** < 0.10 lb./mmBtu (~ 80 ppm)
- **CO :** < 320 ppm
- **SO_3 :** Near Zero (condensable acid particulate)
- **HCl:** < 0.022 lb./mmBtu
- **Hg:** < 5.7 lb./Tbtu, (~ 40 ppb)
- **Particulates:** < 0.03 lb./mmBtu (bag house)
- **Bottom Ash & Fly Ash:** sailable product
- **Waste Water:** Reduce or eliminate
- **Plant Efficiency:** > 6% increase (= 6% CO_2 reduction)
  - Remove water from coal
  - High Temperature, high efficiency combustion (LOI < 1%)
  - Provide clean furnace wall & back pass surfaces
  - Reduce flue gas exit temperatures
  - Address / reduce parasitic loads (add variable speed drives)
  - Possible Steam Turbine Upgrade

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

Typical Coal-Fired Power Plant

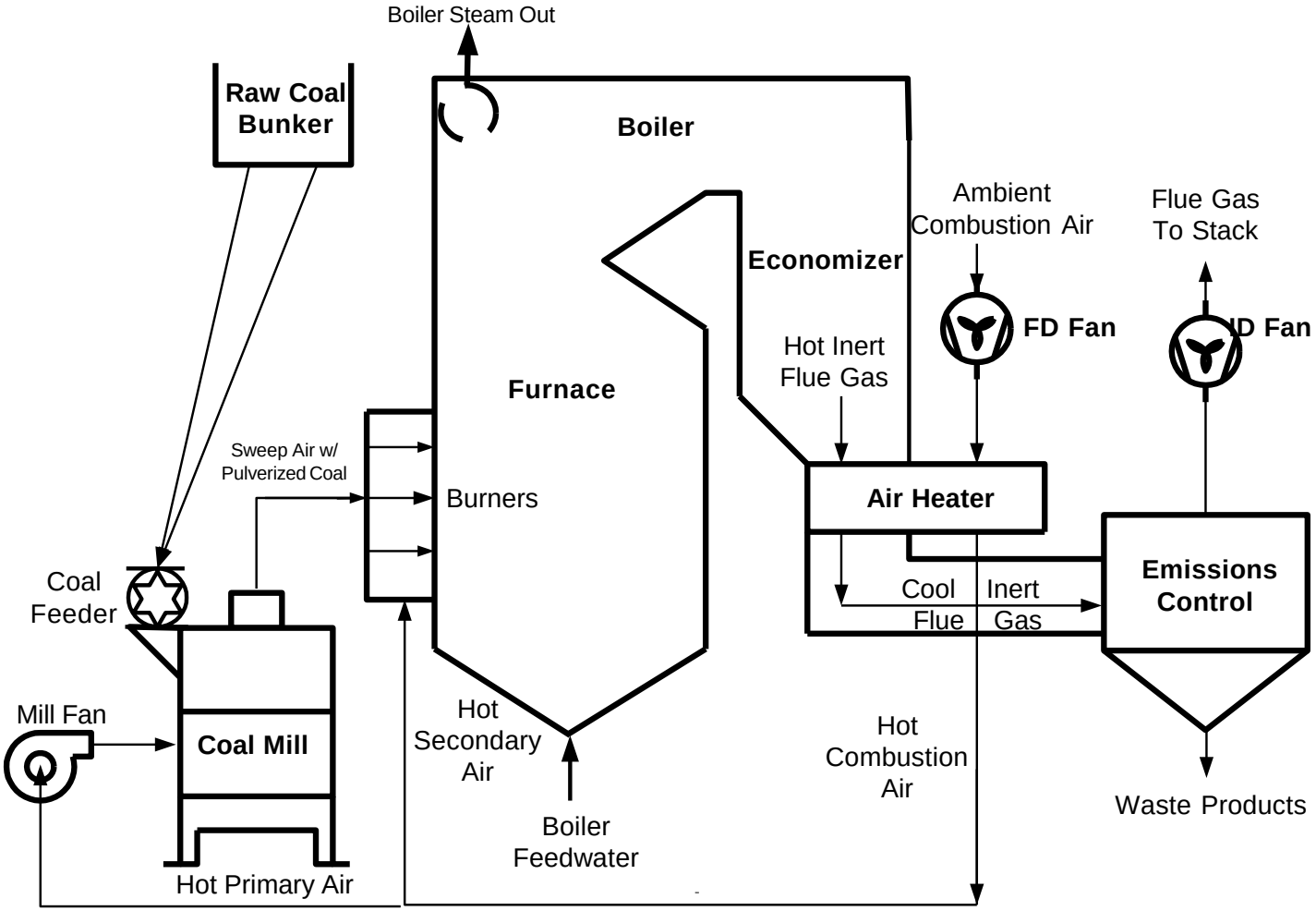
with Back-End Emission Controls

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



Typical Pulverized Coal-Fired Power Plant

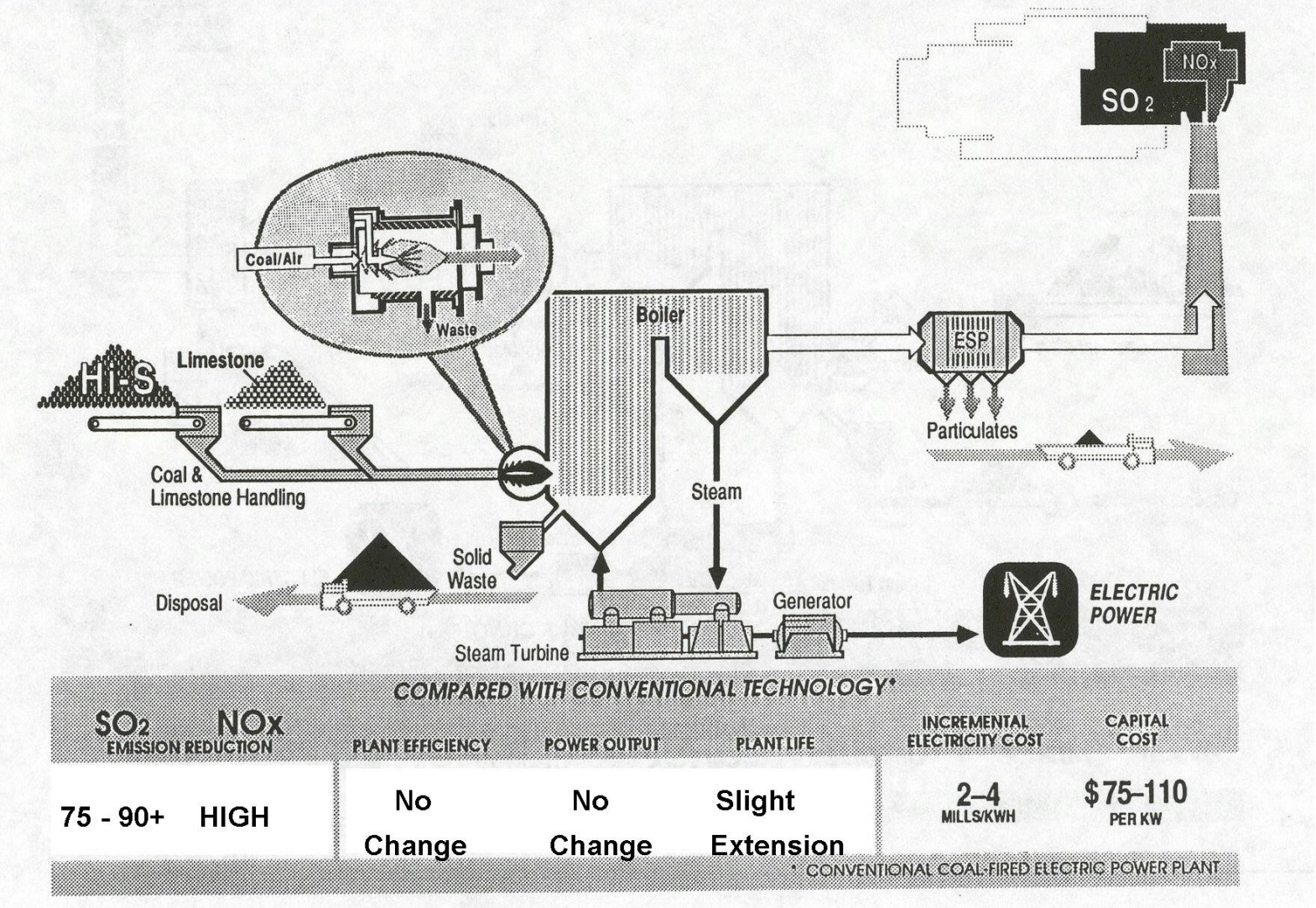
"Direct Fired" Pulverized Coal - 500 MW w/5 Mills –



Re-Engineered Coal-Fired Power Plant

with Coal Benefication & Hybrid of Coal-Gasification

(SO_2 & NO_x Control Right in the Combustion Step)



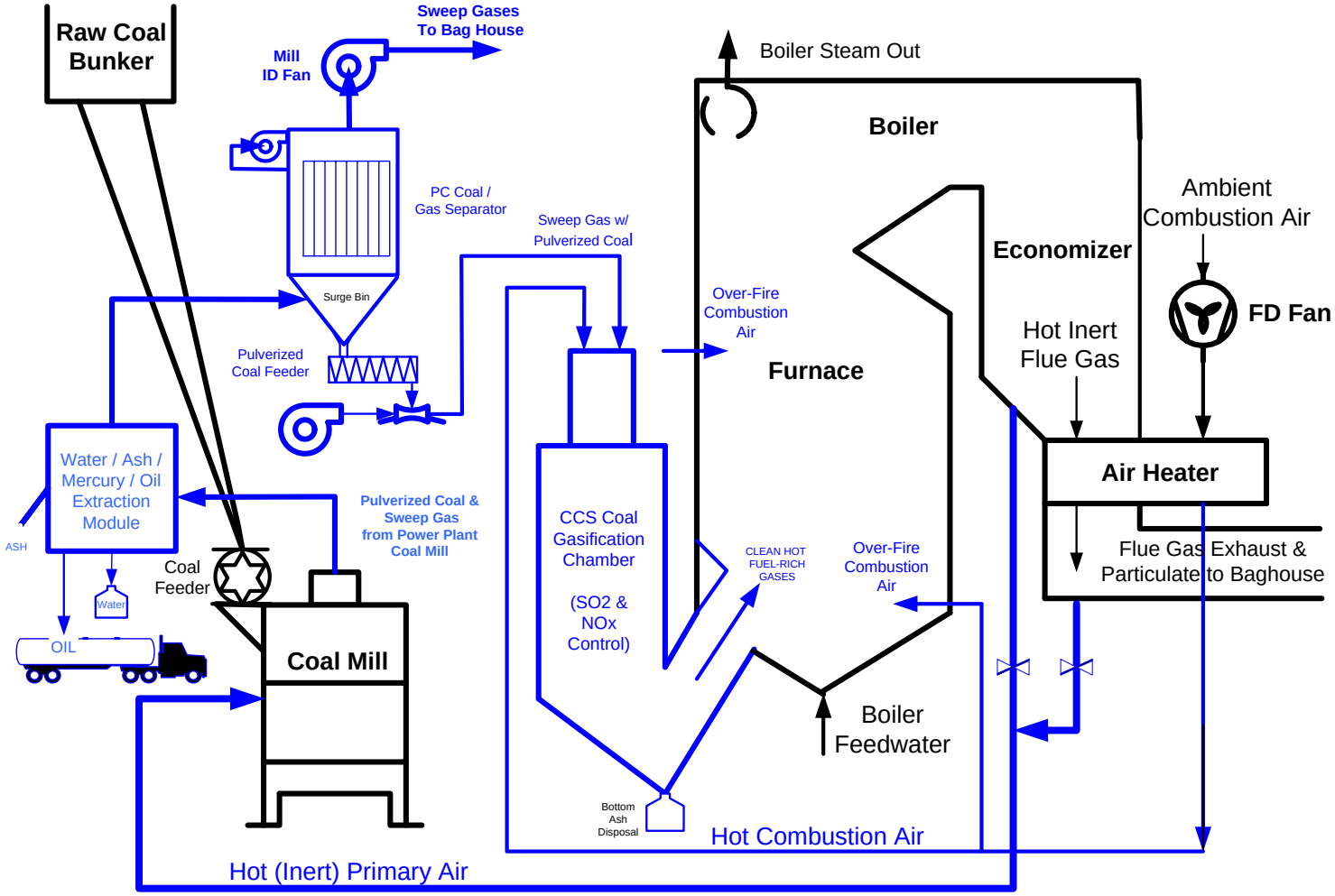
COMPARED WITH CONVENTIONAL TECHNOLOGY*

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

Re-Engineered Power Plant

"Indirect Fired" - Coal-Beneficiation & Coal-Gasification / Combustion



Re-Engineered Power Plant
Coal-Beneficiation Process

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

  1.) Replace the hot primary air to the coal mill:

  - With hot inert boiler flue gas ((low O_2 and near zero SO_3)

  Improves operation safety - eliminate mill fires & puffs

  - Dries the pulverized coal (to <10% moisture)

  2. Re-direct the powdered coal and wet sweep gas from the mill to a small bag house:

  - Separate the wet sweep gas from the dry coal.

  - Dispose the wet sweep gas around the boiler to plant stack. (removed water improves boiler efficiency)

  - Collect the dry powdered coal in the bag house hopper

  3.) Meter the dry powdered coal to new Gasification Burners

  Must process the coal as fast as it is pulverized ……
  (~one cubic foot coal / second)

Coal Beneficiation Target

Powder River Basin (PRB) Low Rank Coals

- **Coal Characteristics - PRB** :

- Low in Btu	~ 8300 Btu/Lb.
- High in Moisture	25 – 35%
- High in Ash	10 – 15%
- High in Mercury	130 to 150 ppb

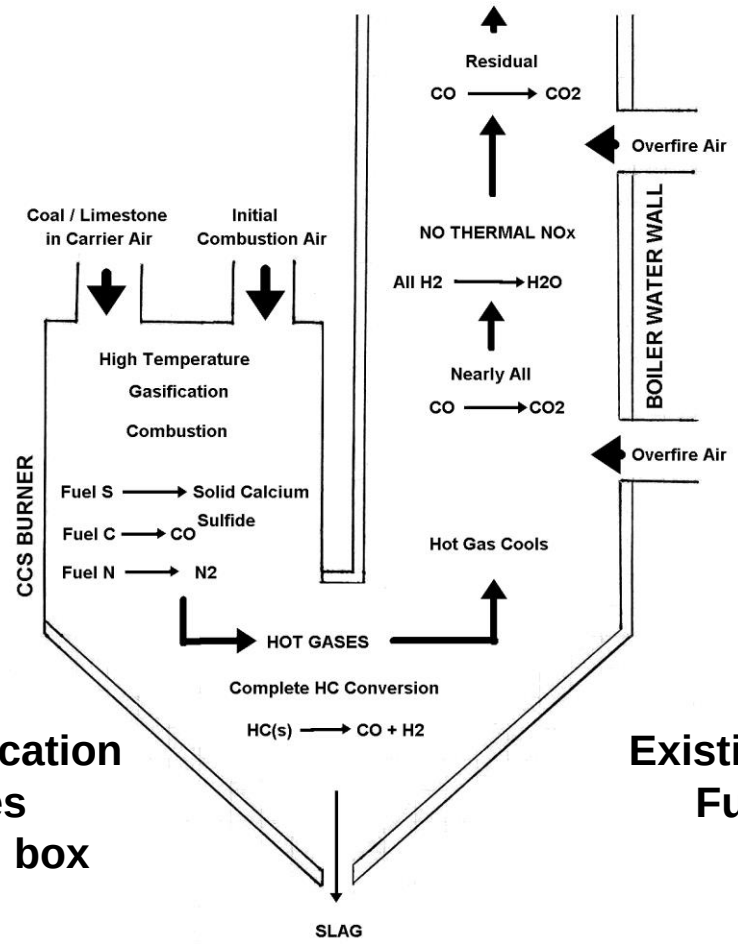
- **Coal Beneficiation Target - PRB Coals** :

- Increase Btu	~ 10,000 + Btu/Lb.	(+20%)
- Reduce Moisture	10 – 12%	(- 50%)
- Reduce Ash	7 – 10%%	(- 50%)
- Mercury Compliance	~40 ppb	(- 75%)

- **EPA MACT – Mercury (Hg) Compliance**:
  - Existing Plants = 5.7 lb./Trillion Btu or ~ 40 Parts / Billion

Schematic

Hybrid of Coal-Gasification & Combustion



New Burners & Gasification Chamber replaces coal burners & wind box

Existing Boiler Furnace

Coal-Gasification & Combustion Process

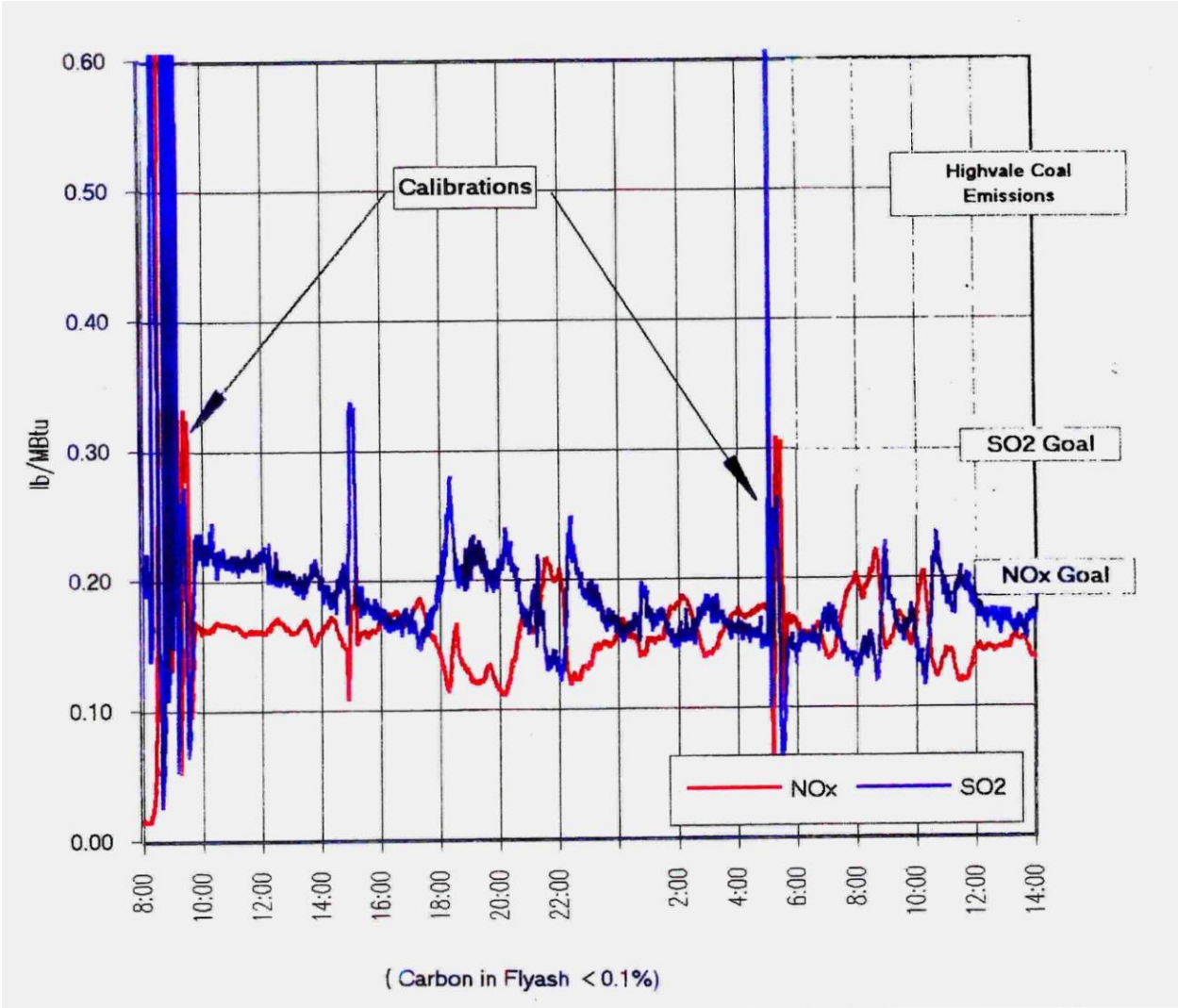
SO_2 & NO_x emissions control right in the combustion step

- 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).

Demonstrated Emissions

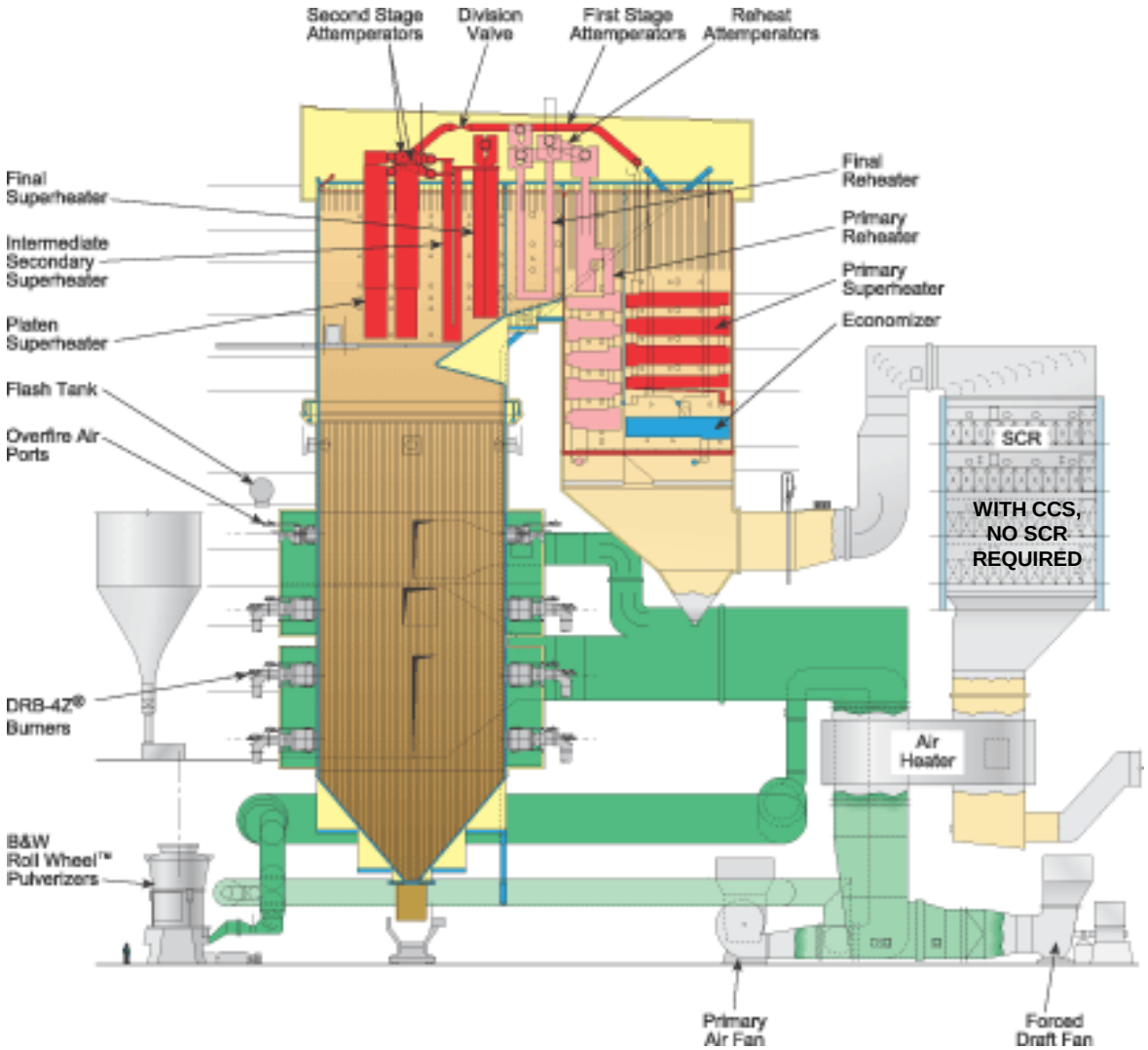
SO_2 - 0.2 lb./mmBtu & NO_x - 0.15 lb./mmBtu

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



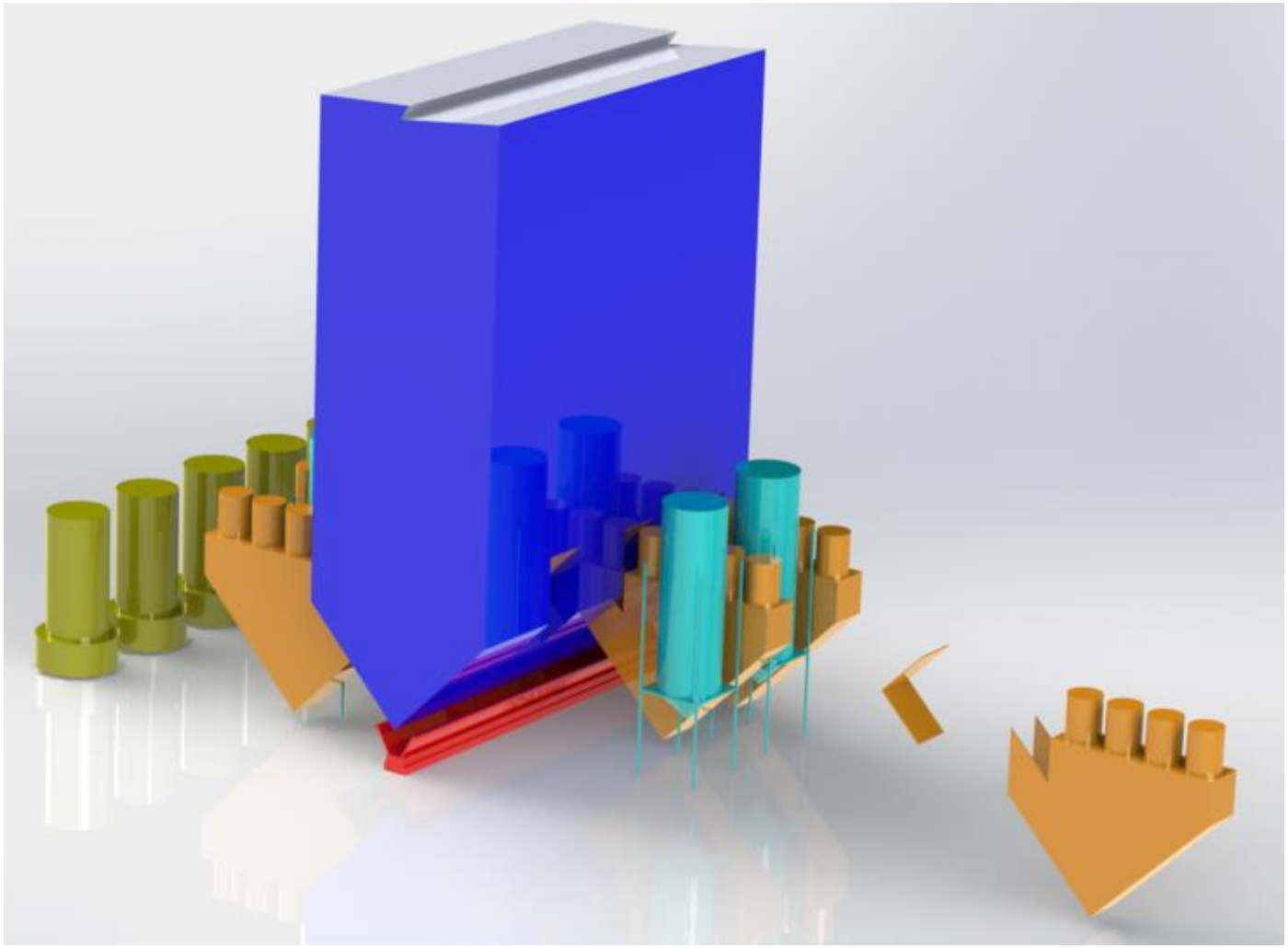
Example: Opposed-Wall Fired Boiler

500 MW – 5 Mills & 24 PC Burners (Remove Burners & Wind box)



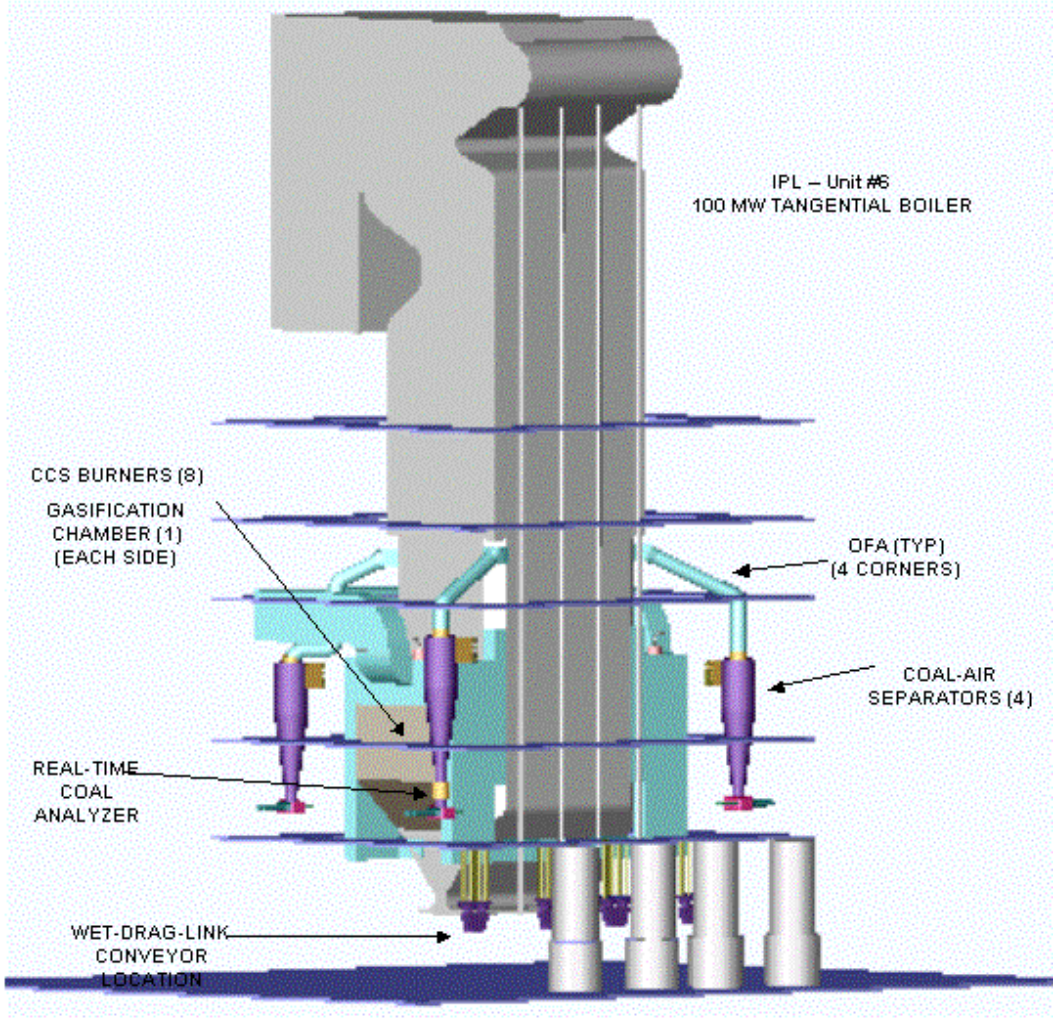
Re-Engineered Wall-Fired Boiler

Install 6 Gasification Chambers & OFA, 24 Burners, 6 Bag houses



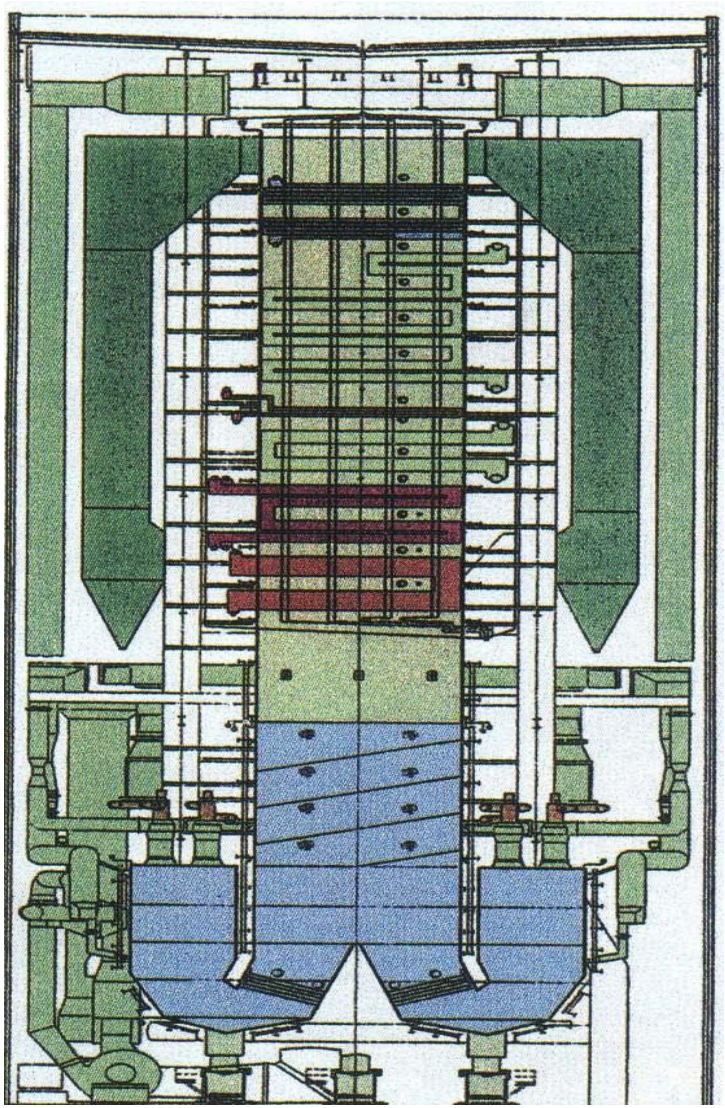
Re-Engineered Tangential™ Boiler

Example: 100 MW



New Steam Generator Design

With SO_2 & NO_x Emissions Control



Features:

- Affordable Boiler Design
- Smallest Boiler Foot print per MW_T
- Largest Steam Output per Ton of Steel
- 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 for Fly Ash Removal
- Wet bottom slagging operation
- Clean Furnace Walls
- Bottom Ash / Fly Ash is saleable
- No waste water disposal

Rockwell International

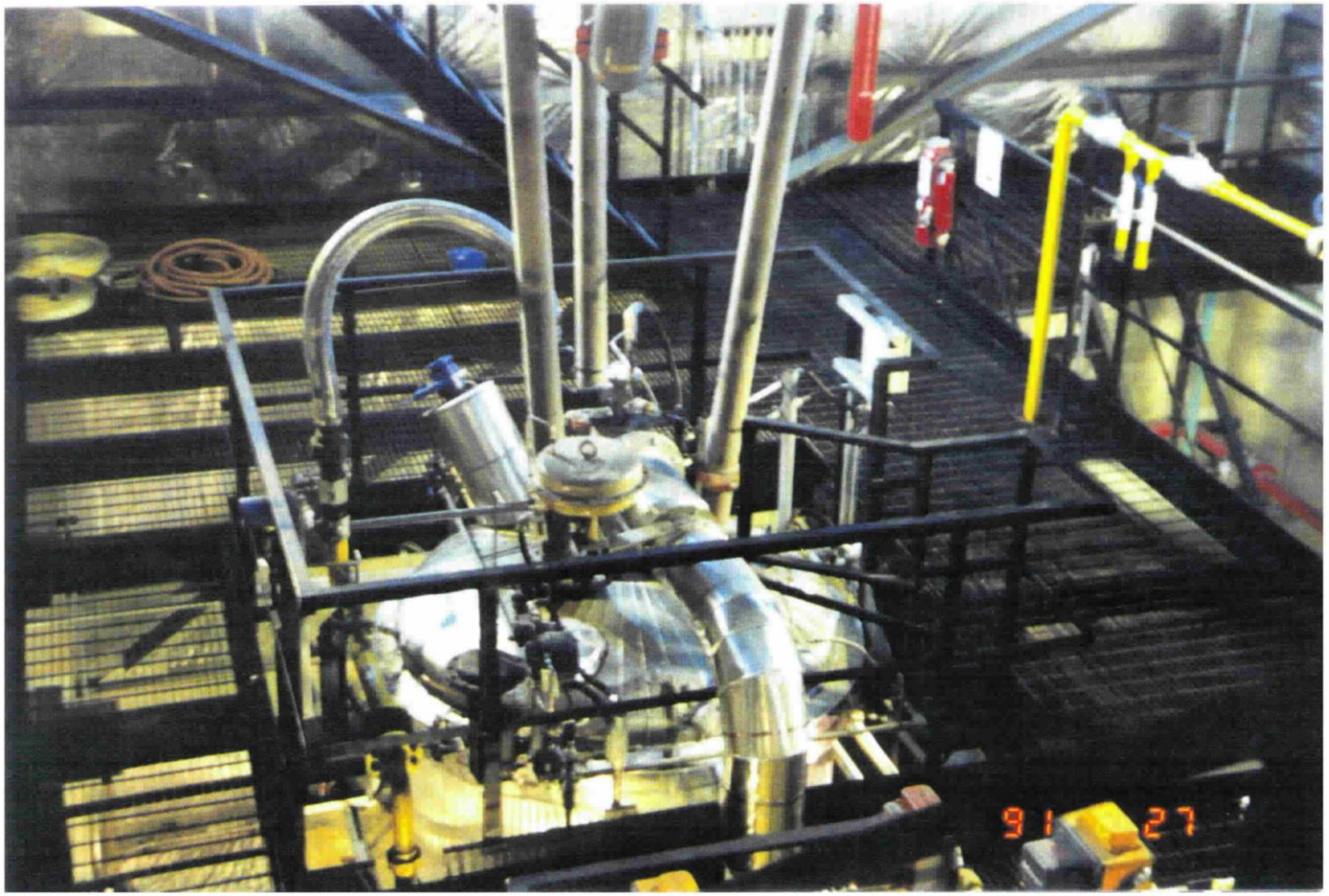
25 x 10^6 Btu/hr (1 ton/hr) Test Facility (1990)

LNS-CAP Facility

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

LNS-CAP

Top of LNS Burner

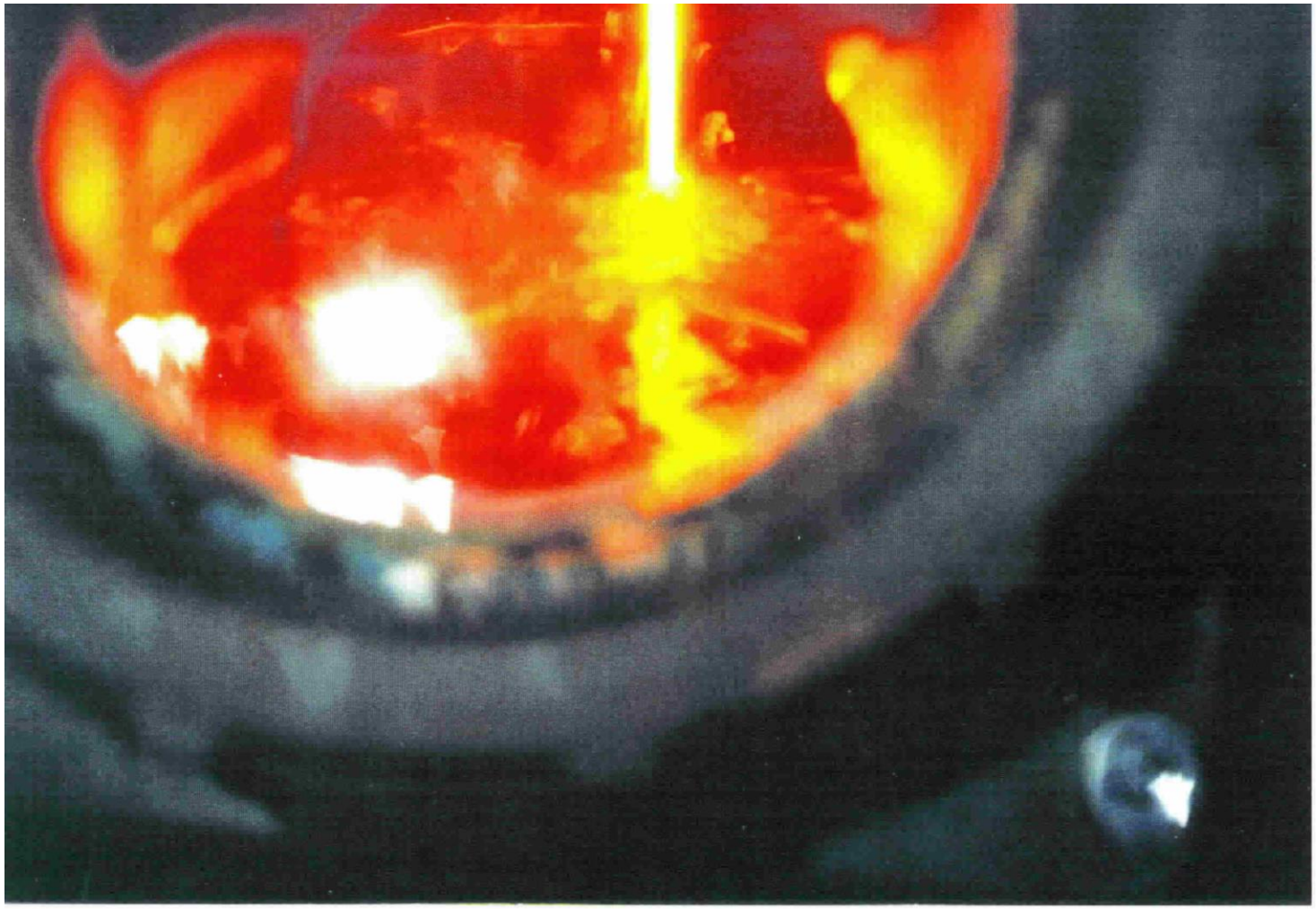


LNS-CAP

Gasification Chamber Inspection

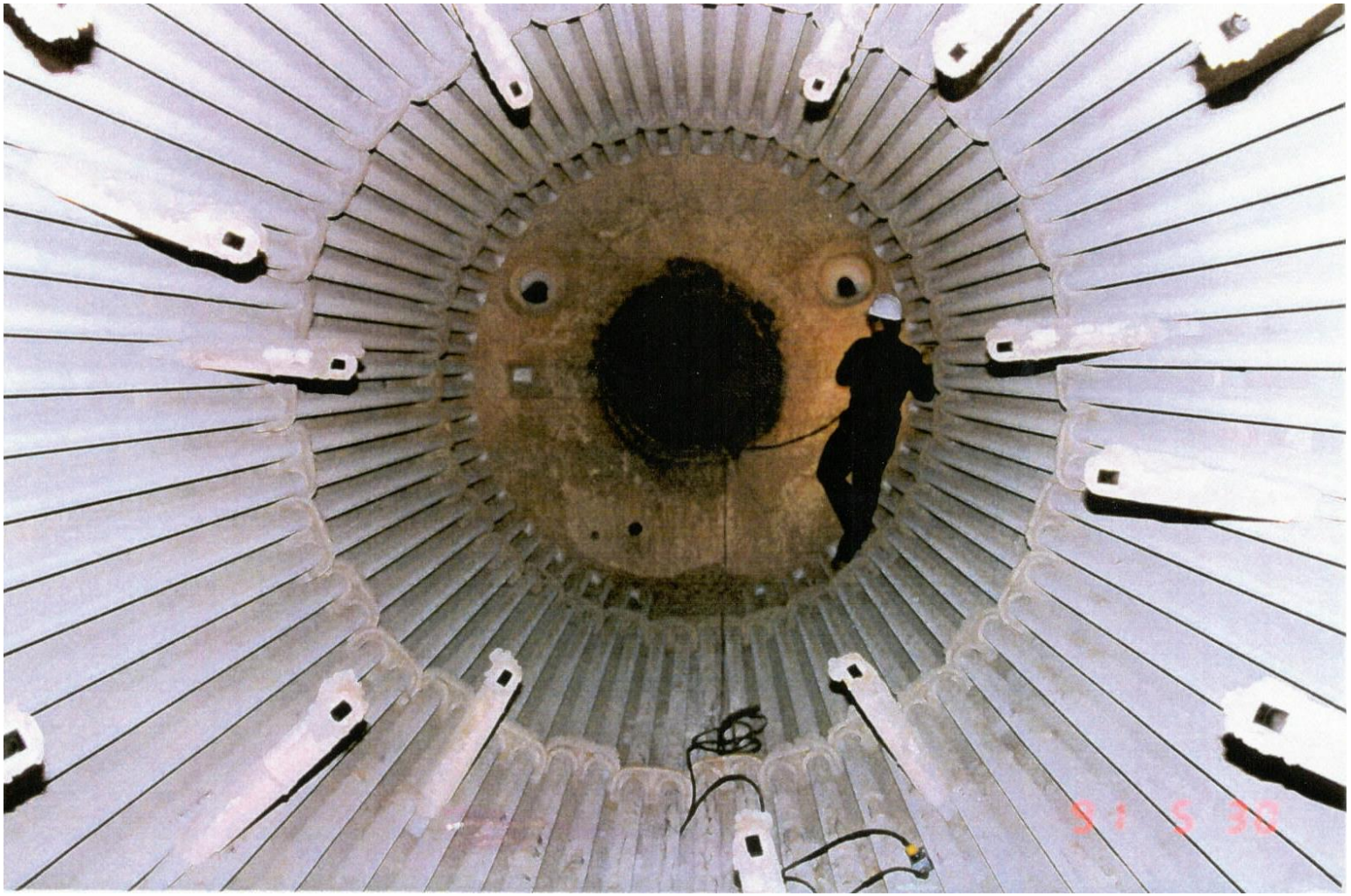
LNS-CAP

Slag to Water Trough



Boiler Radiant Section

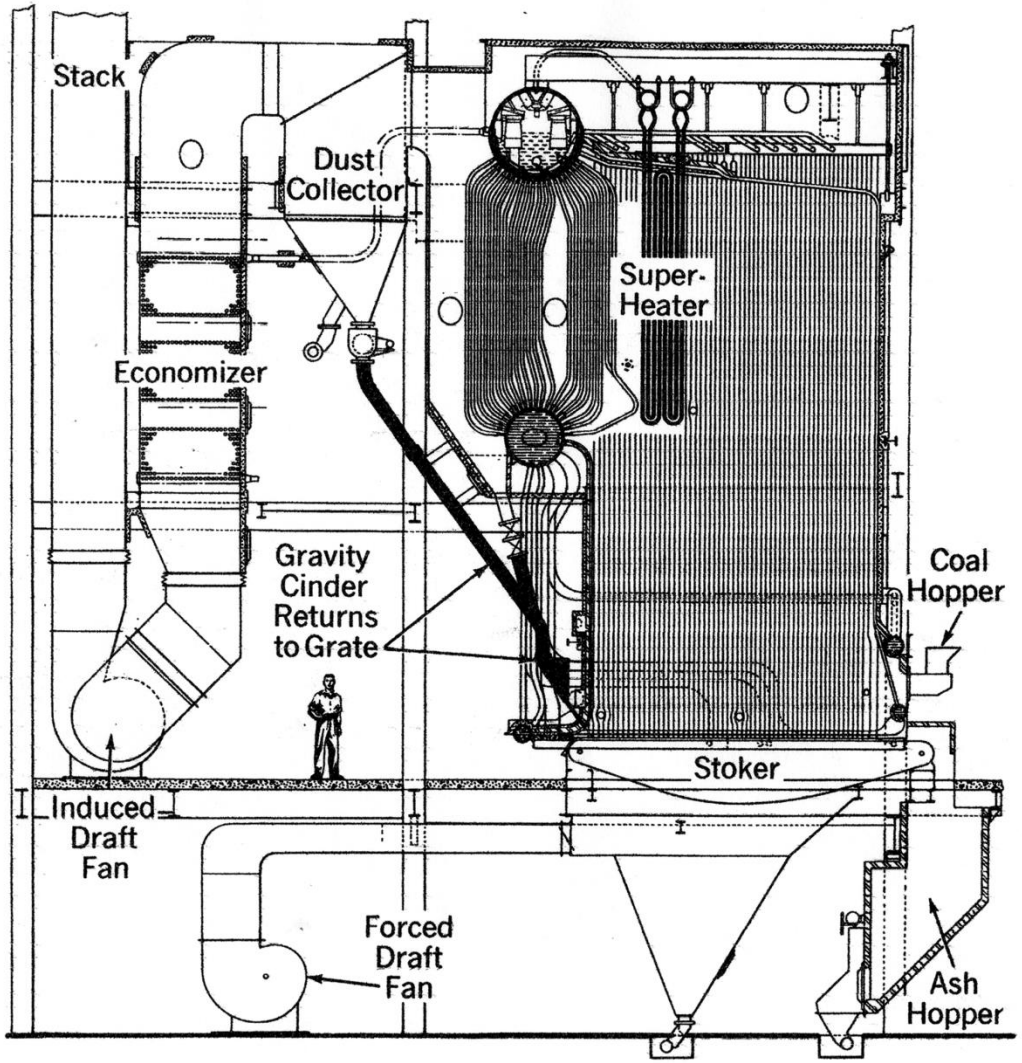
View Forward to Burner



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:

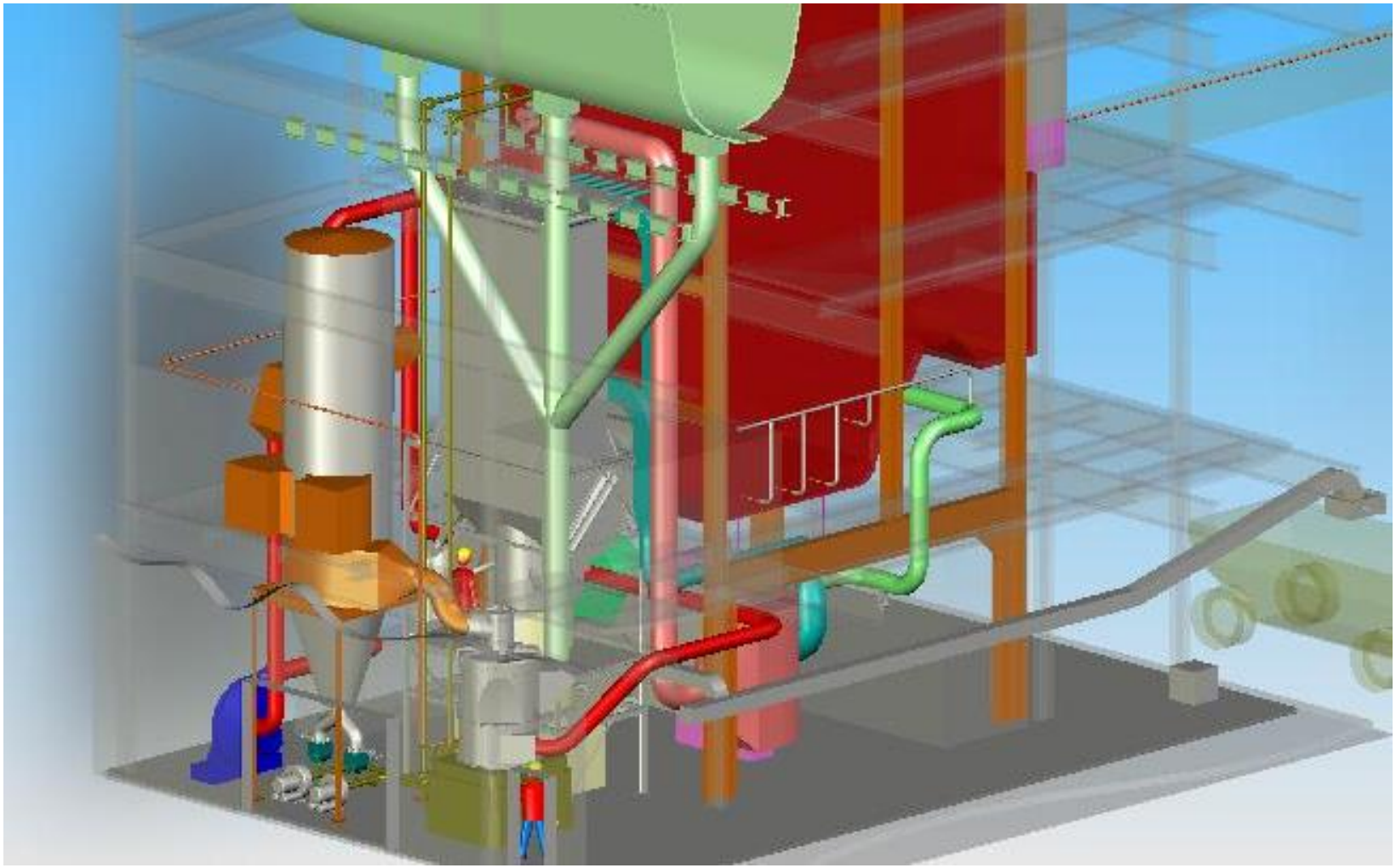
CCS Burner,
Gasification Chamber,
Combustion Air Heater
Boiler Instruments,
Coal Mill, Bag house, FD fan, BM & Combustion Sys,
HMI & PLC Controls
New MCC

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



CCS-Stoker® Gasification Chamber

CCS-Stoker® Gasification Chamber Installation

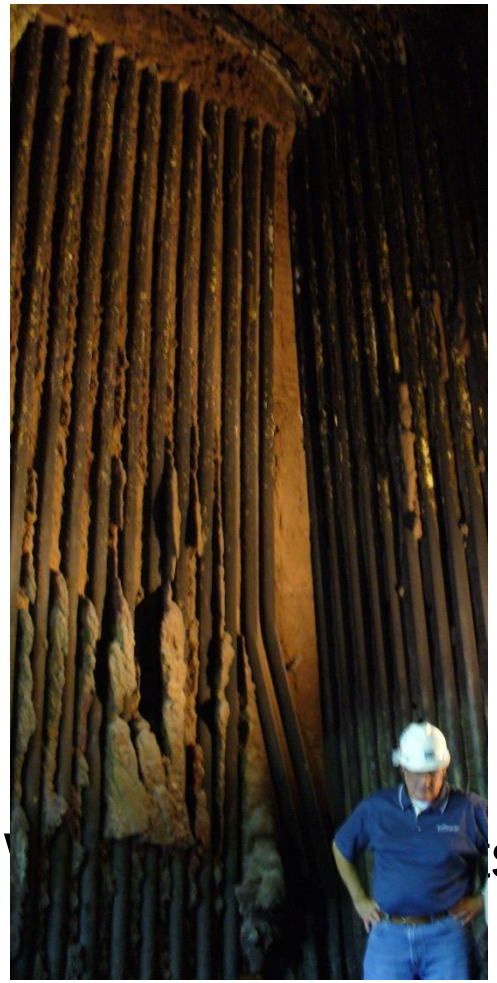
- McBurney Corp designed and supplied the GC
- Connected to the boiler drums for natural circulation water cooling
- Shop fabricated membrane wall studded and refractory lined.

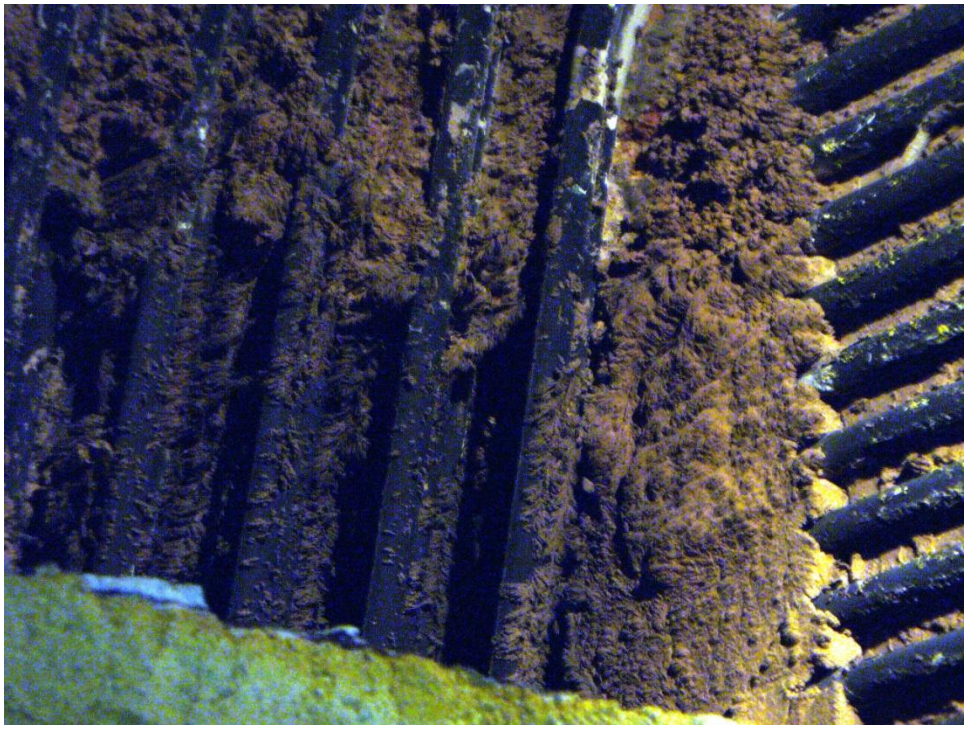
Coal - Sweep Gas Separator

- Separates powdered coal from mill sweep gas
- Inert gas used for bag cleaning (No O_2)
- Hopper w/ level switches maintains ~15 min. coal supply
- Gate & spouts to rotary feeders - meters PC to Gasification Burners

Stoker Boiler Furnace Deposits

Typical Examples





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
- Construction permit with waiver of NSPS & PSD
  – No New Source Review (NSR) Trigger!

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;**
  - 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 "CSPR & MACT goals

CastleLight Energy Corp.
Re Engineering Program

For Technical Presentations and Plant Surveys :

Contact CastleLight Energy Corp.

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See Web Site: www.Castle-Light.com

- **"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"**