Fundamentals of NO_x Control for Coal-Fired Power Plants

CastleLight Energy Corp

Re-Engineering Coal-Fired Power Boilers for Improved Efficiency, Low Pollutant Emissions and Reduced Operating Cost

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DISCLAMER
Information herein is best estimates of the presenters and subject to change.
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CastleLight Energy Corp.

A Technology Management Company

- Couples a fast, low cost **Coal Beneficiation** process ……
- With a **Hybrid of Coal Gasification** for strong SO_2 and NO_x emissions control and high efficiency for coal-fired power plants.
- Technology evolved from coal combustion research at **Rockwell International**.
- Some $60 million in Utility peer reviewed R&D, field demonstrations & commercial programs
- Patented Technology
- **CastleLight Energy provides Power Plant Re-Engineering:**
  - Overall Technology Management
  - System Engineering, Design, CFD & PEPSE Analysis
  - All Hardware, Equipment, Instrumentation, and Controls including supervision of customer installation.
  - Commercial Warrantee & Technology License

OBSERVATION

Technology does not evolve…….it

“LEAP FROGS”

When was the last time you flew
on a commercial piston engine airplane?

Objective

- **McIlvian** seeks NO_x control technologies for **Pacific Corp's** coal-fired tangential boilers at Hunter and Huntington stations.
- NO_x emissions target: 0.07 lb/MMBTU (~50 ppm)
- It is problematic that these low NO_x emission levels can be met with conventional technology.
- Estimates for an SCR/ammonia system: ~$215/kW
- **CastleLight Energy** suggest a review of the fundamentals of NO_x formation and its destruction.

NO_x Formation Fundamentals

- In coal combustion, the nitrogen in the coal (~ 1%) is the major source of NO_x (~85%).
- In the late 70's, Dr. Axworthy at Rocketdyne showed that the nitrogen in the coal forms NO_x, or the precursors of NO_x - such as ammonia (NH_3), and cyanide (HCN), at the same time and place as the carbon is oxidized.
- Further, he showed that there is no way that that this fuel-NO_x can be avoided;
  - such as low temperature combustion, as used when firing natural gas to avoid thermal NO_x formation.
- However, observations of Fluid Bed Combustion (FBC) showed that something was effectively reducing the fuel-NO_x levels in the bed.
- A theory evolved - look for a NO_x destruct catalysis in the combustion step.

NO_x Destruction

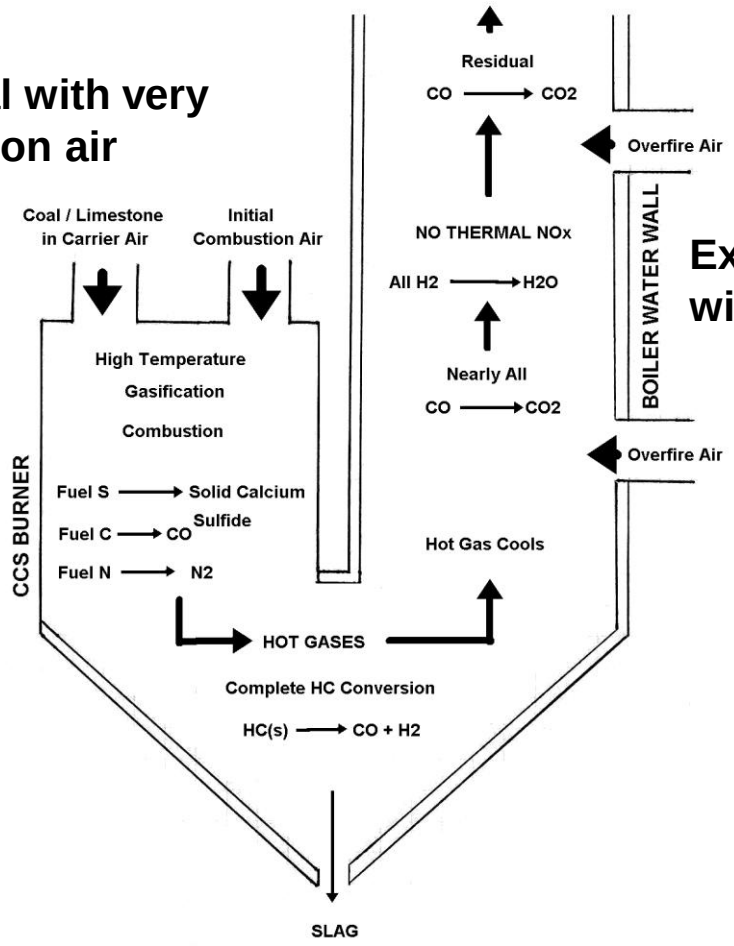
- A lab furnace was set up to duplicate the FBC combustion bed conditions .
- The minerals and compounds found in in coal were exposed to NO_x under combustion conditions and any change in NO_x inlet / outlet levels were noted.
- It was determined that **calcium sulfide** (CaS) is a gang buster NO_x destruct catalysis, especially under the fuel-rich, high-temperature conditions such as found in an FBC bed.
- This was a remarkable discovery, as Rockwell was developing a new coal-fired burner for SO_2 control; fuel-rich combustion featuring **sulfur capture with calcium** (limestone - $CaCO_3$) .
- Calcium sulfide is a very reactive compound; it quickly oxidizes to H_2S in air, so it must be created when needed.
- In fuel-rich combustion (no oxygen) sulfur reacts with calcium to form CaS. – a solid particle even at high temperatures.
- We observed that the CaS destroyed fuel-NOx to “single digit ppm levels” right in the initial combustion step - 20 to 30 inches from the burner face.
- Rockwell now had a new coal-fired burner concept with **SO_2 and synergistic NO_x control .**
- We now describe it as the **CLEAN COMBUSTION SYSTEM.**

Schematic

Hybrid of Coal-Gasification & OFA Combustion

(SO_2 and NO_x control)

Meter ALL the coal with very little hot combustion air



Existing Boiler Furnace with new OFA Ports

New Coal Burners & refractory lined Gasification Chamber replaces original wind box & coal burners

CCS Process Steps

SO_2 & NO_x emissions control right in the combustion step

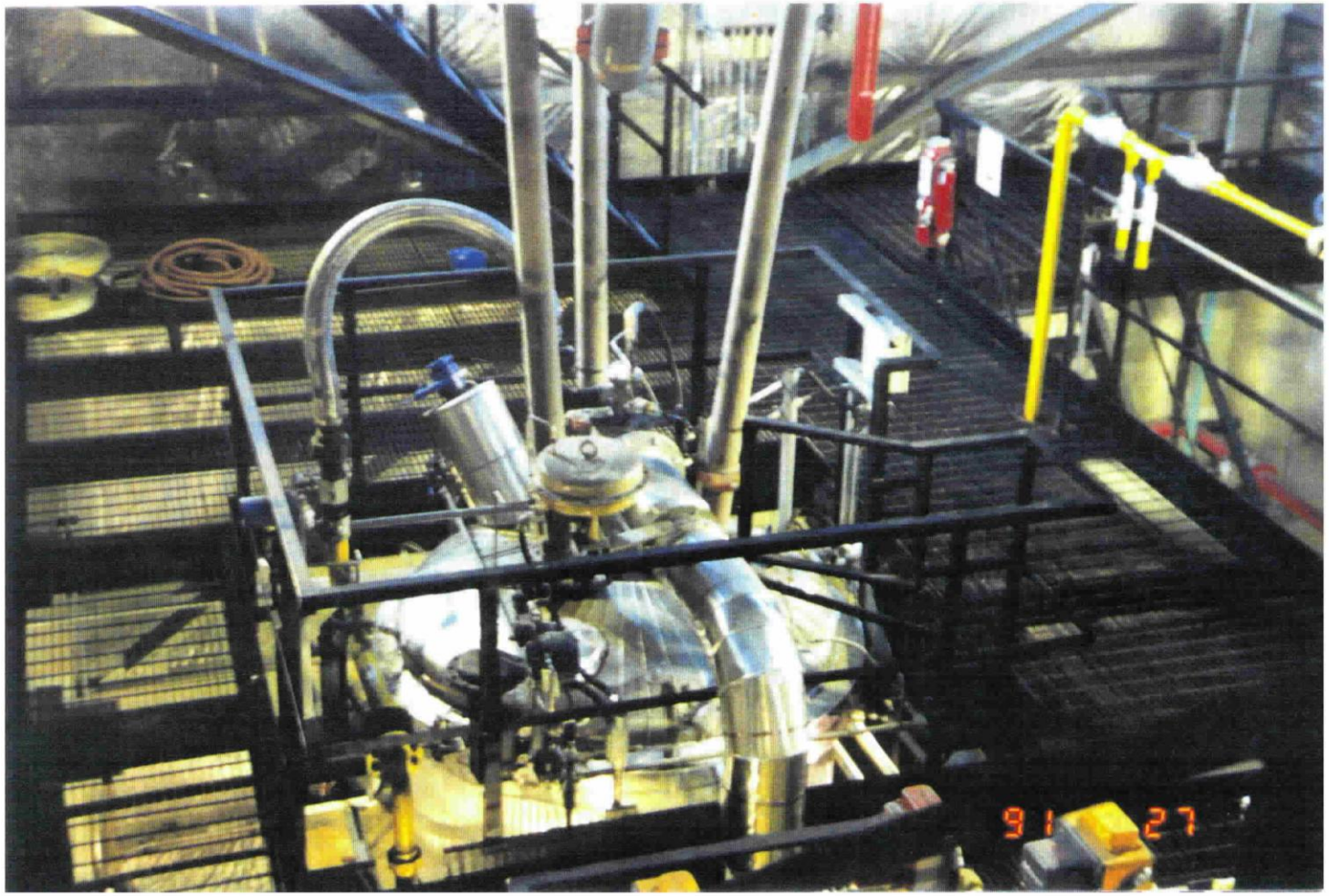
- Coal is fired with very limited hot air in an entrained-flow gasifier
- In the initial combustion step, the carbon consumes all the oxygen and creates a hot, fuel-rich gas and frees the sulfur from the coal,
- Limestone ($CaCO_3$) provides calcium as CaO
- Sulfur reacts with CaO to form calcium sulfide (CaS) - a solid particle at these temperatures,
- CaS destroys the NO_x (NO_x< 10 ppm) to form elemental nitrogen (N_2)
- At the high temperatures, coal ash (alumina & silica) mix with the CaS and melts to form a slag product; the sulfur is thereby encapsulated in the slag
- About half the slag drains from the chamber to a water quench slag tank.
- Clean red-hot gases enter the furnace & cool to < 2300 F, where thermal NO_x formation is frozen. Any slag particles solidify to a fine fly ash
- Staged over-fire air is then carefully added to complete combustion in the furnace to CO_2 & H_2O and to avoid any thermal NO_x formation.
- The hot exhaust gases exit the furnace to the back pass at the original design conditions.

LNS-CAP Facility

ESSO Site, Cold Lake, Alberta Canada
50 mmBtu/hr – 3T/hr PRB Coal; 1992

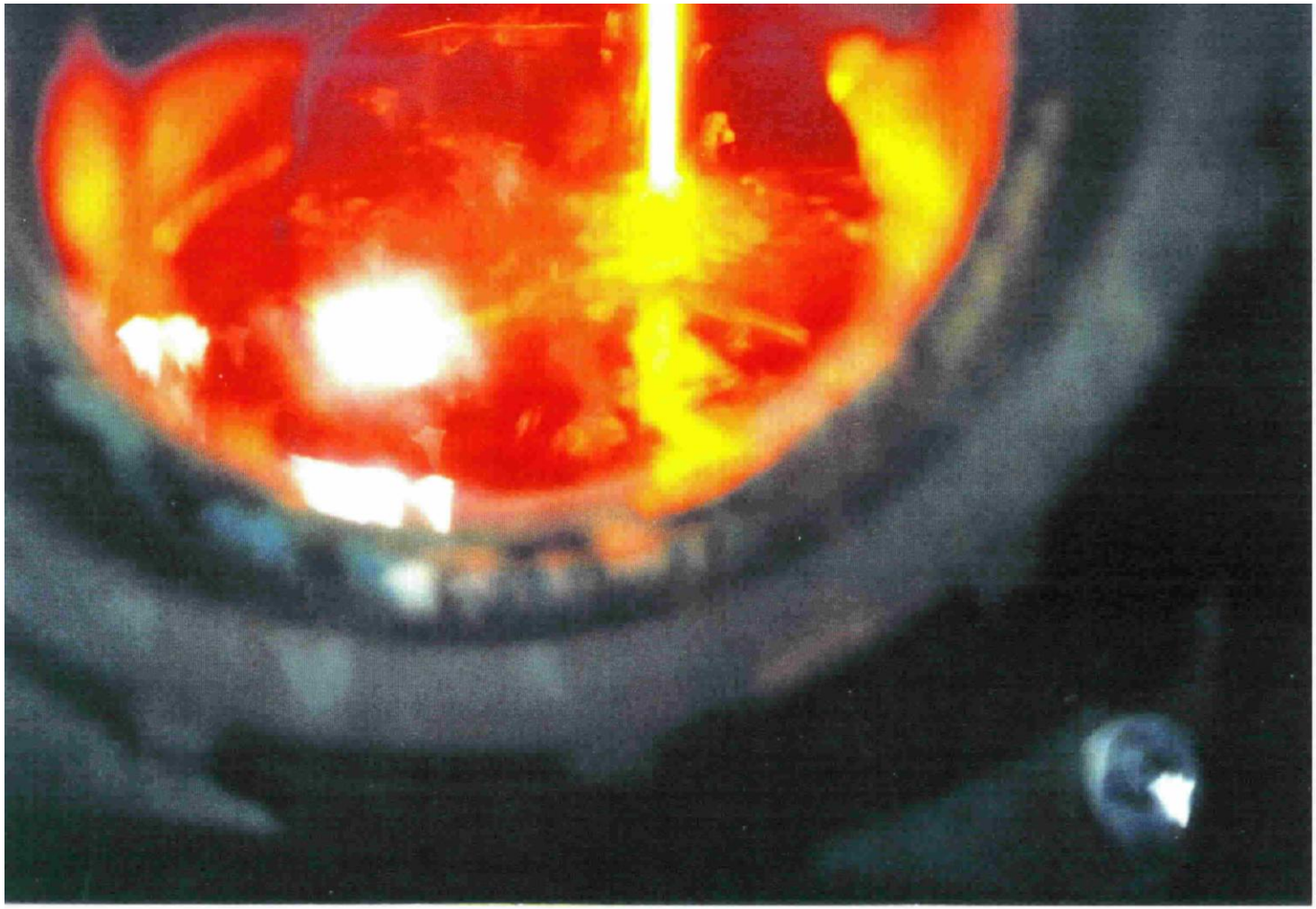
LNS-CAP

Top of LNS Burner



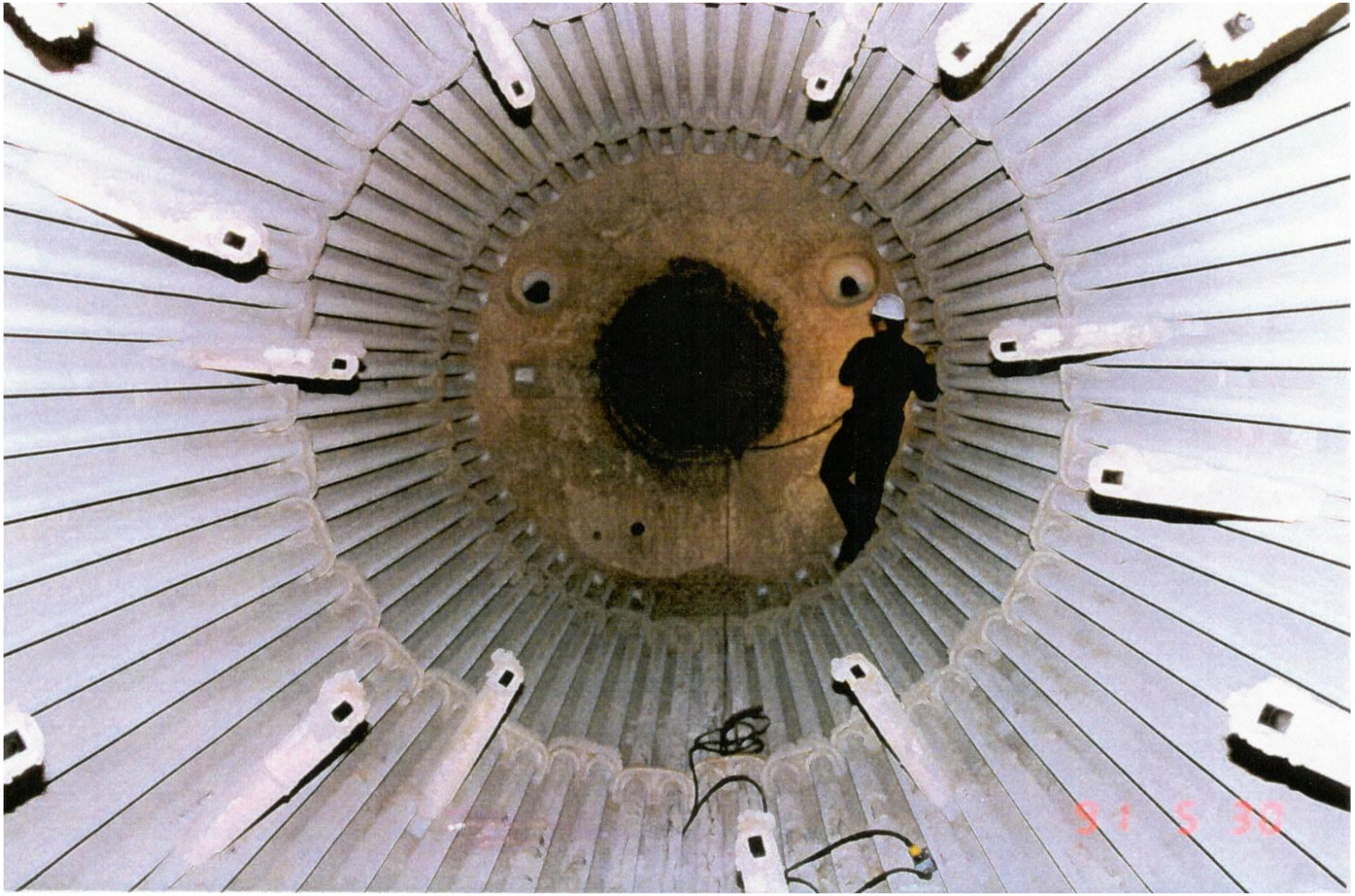
LNS-CAP

Slag to Water Trough



Boiler Radiant Section

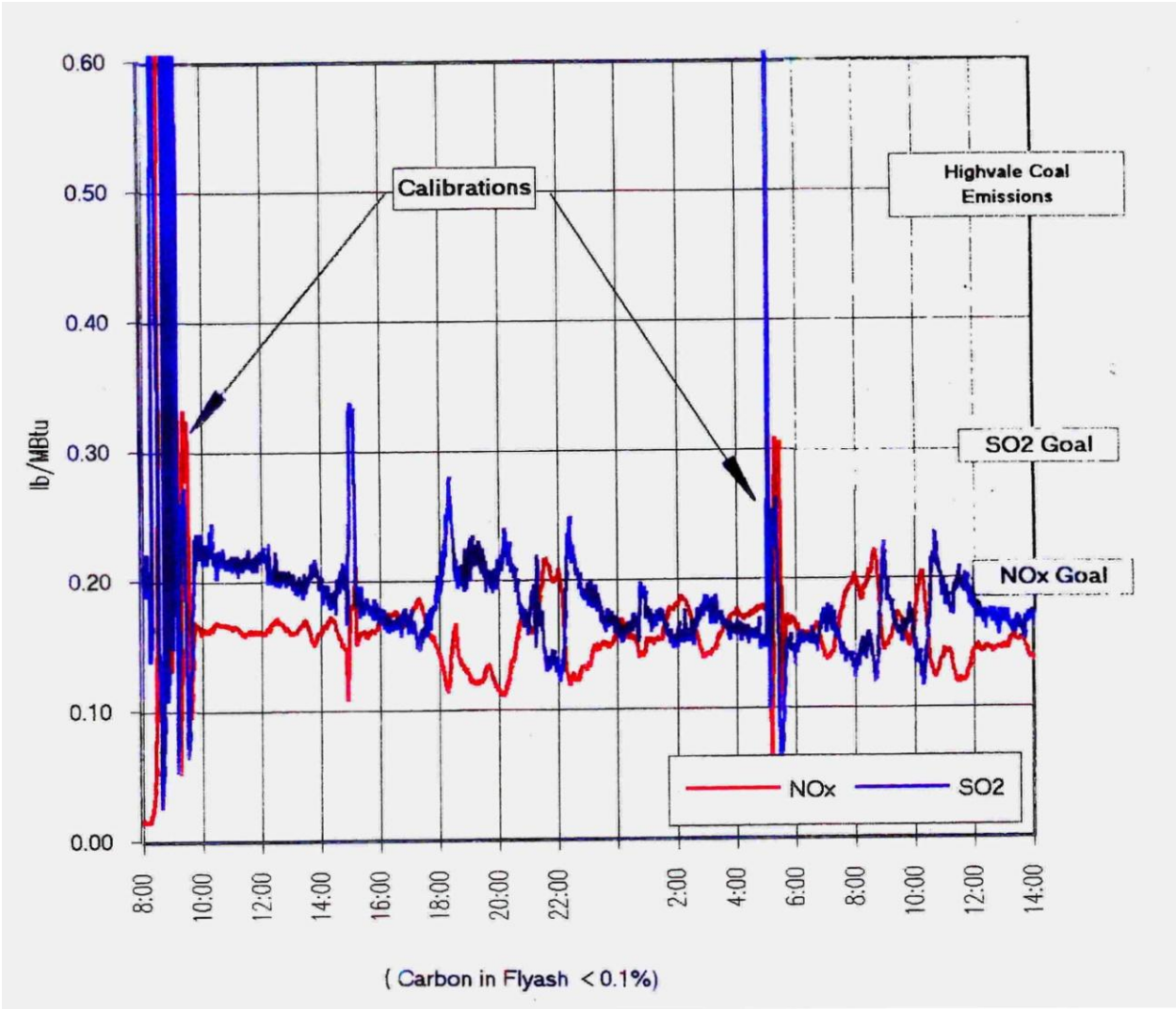
View Forward: OFA Pipes and Burner (note the white ash)



Demonstrated Emissions

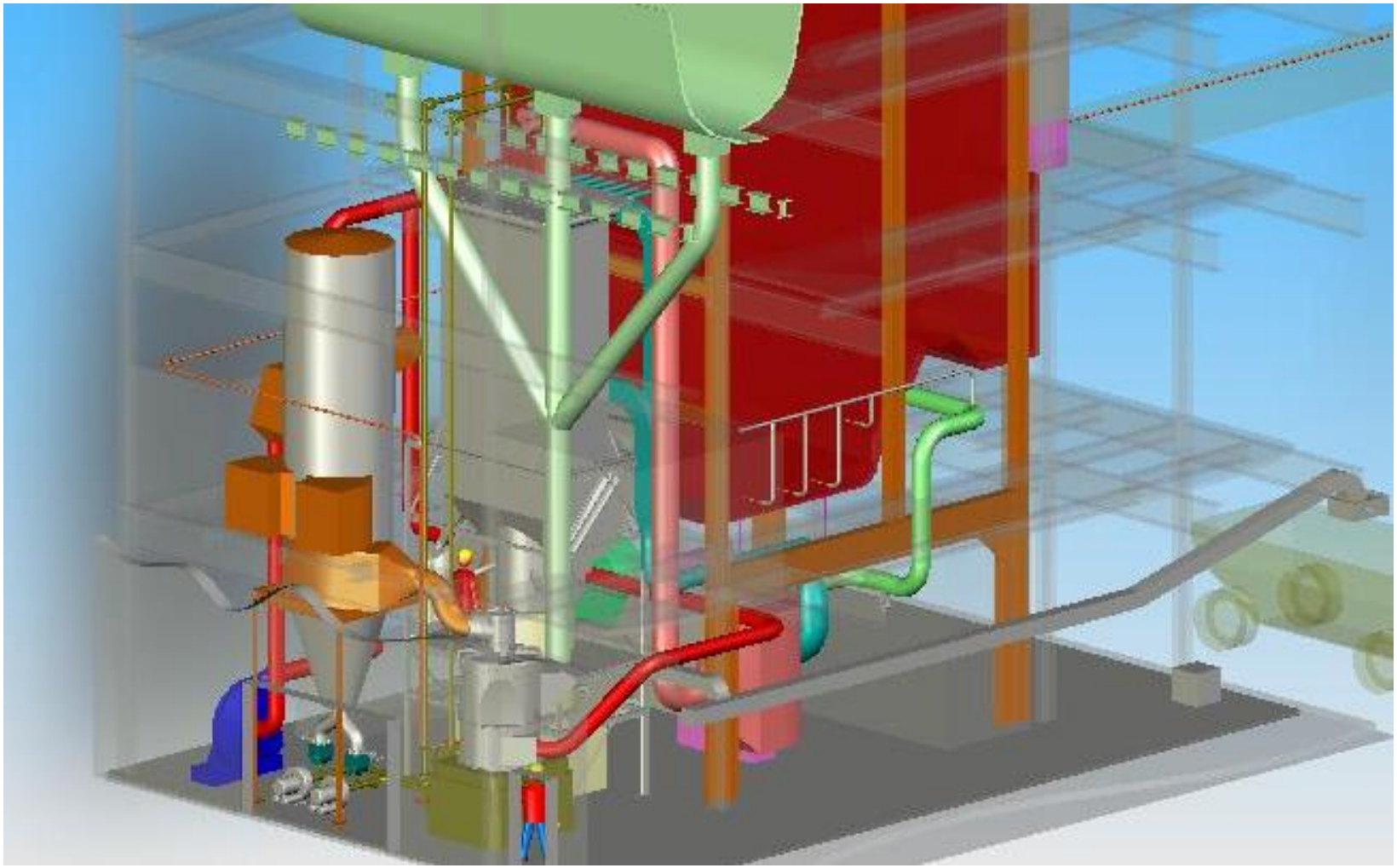
SO_2 ~ 0.2 lb./mmBtu & NO_x ~ 0.15 lb./mmBtu (110 ppm)

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



CCS-Stoker® Retrofit

30 MW (Thermal) - 125 mmBtu/hr – 5 T/hr Coal ;2008



Gasification Chamber Installation

Hybrid Coal Gasifier
Chamber Installation on Boiler

- Shop fabricated membrane wall, studded and refractory lined for coal gasification.
- Natural circulation water cooling connection to the boiler drums

CCS-Stoker® Operation Observations

Operation @ MCR – NO_x < 88 ppm

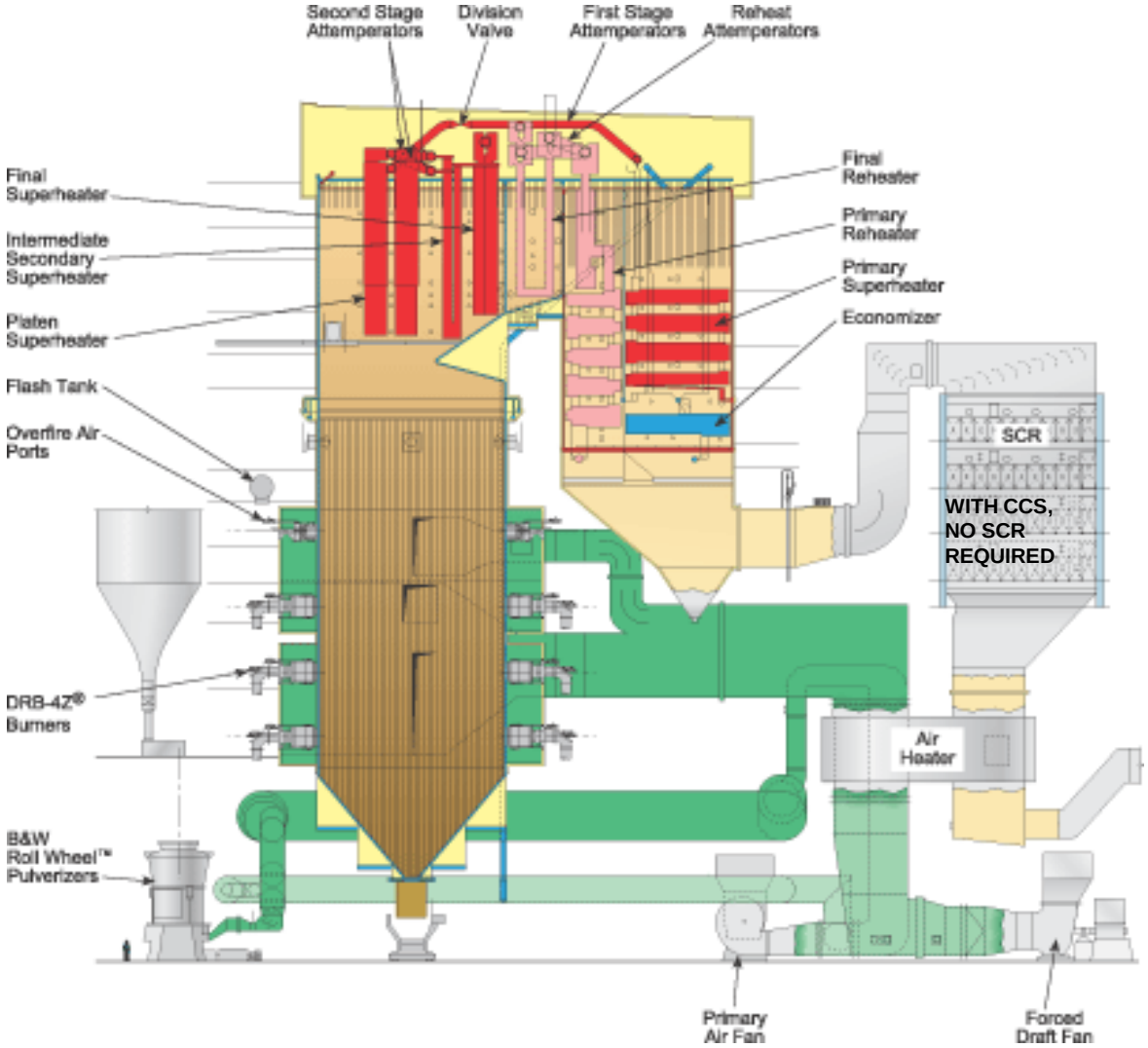
CCS-Stoker® Retrofit Performance

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	

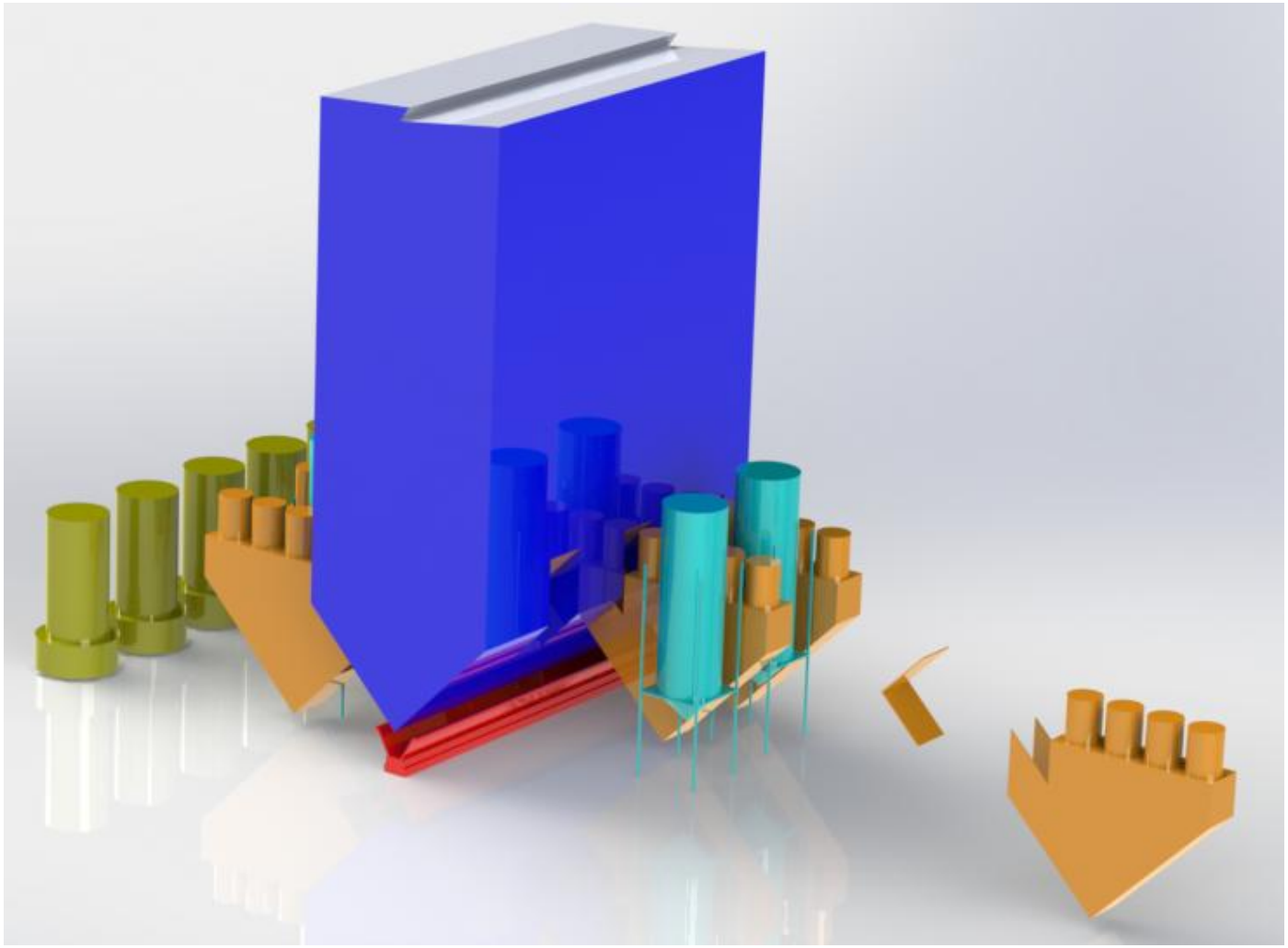
Example: Opposed-Wall Fired Boiler

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



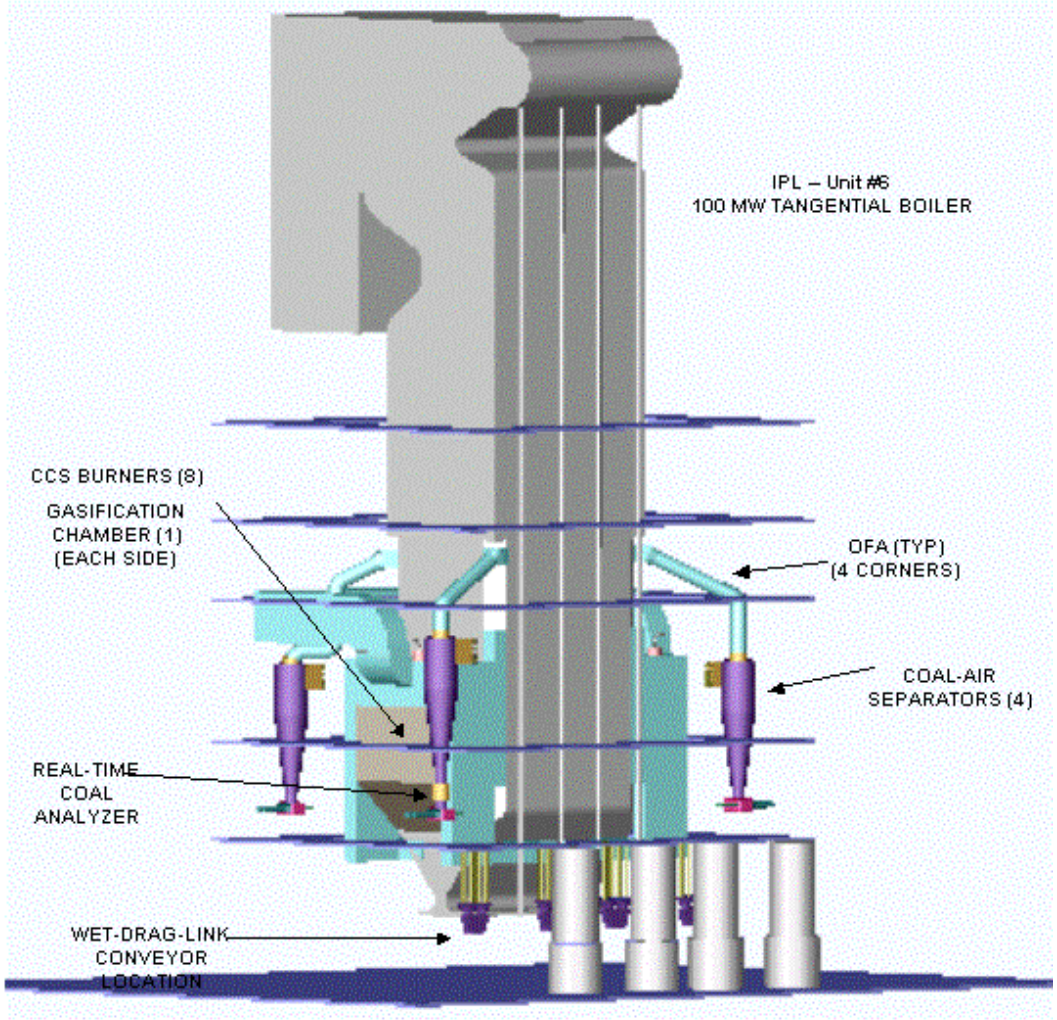
Re-Engineered Wall-Fired Boiler

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



Re-Engineered Tangential™ Boiler

Example: 100 MW



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
- Meets EPA's new stringent regulations for SO_2, NO_x & now CO_2
- Allow power plant upgrade with waiver of NSPS & PSD - No NSR
- Low Retrofit Cost; maintains older, smaller plants competitive
- Lower coal consumption - reduce plant operating cost
- 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!

CastleLight Energy Corp.
Power Plant Re Engineering Program

For Technical Presentations and Plant Surveys :

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