OEC for NOx Control on PC Boilers

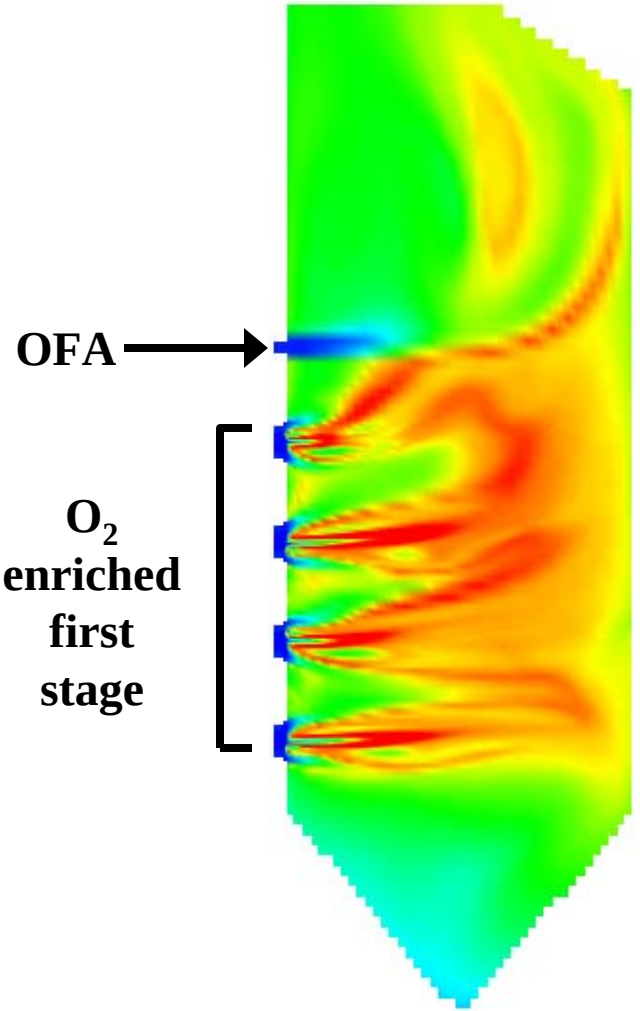
Larry Bool
Sho Kobayashi
KT Wu

Discussion Points

- **Introduce concept of Oxygen-enhanced combustion for fuel NOx control**
- **Industry- DoE - University collaboration to develop O_2-enhanced NOx control technology for coal fired boilers**
- **Laboratory efforts**
- **Commercial implementation**
- **Summary**

Concept for Using O_2 for NOx Reduction

- **O_2 anchors coal flame**
- **O_2 enhances volatile yields and makes gas phase more fuel rich**
- **O_2 increases first stage temperature and residence time and convert Fuel N to N_2**
- **O_2 reduces char yields and reduces UBC in ash**



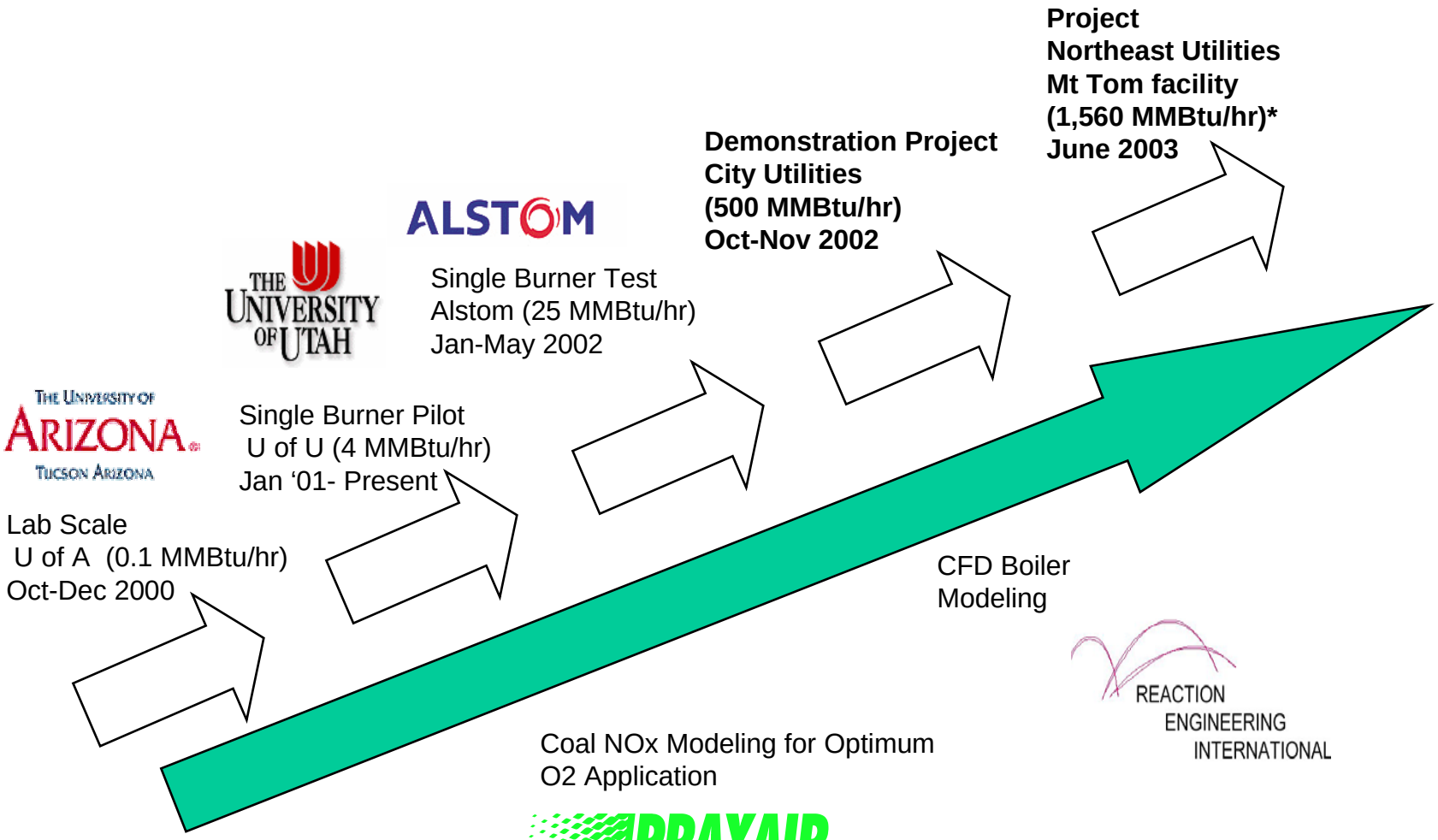
Technology Development Approach

The approach was to use a combination of theoretical and experimental work to transform the novel concept of oxygen-enhanced combustion for NOx control into a technology that is both theoretically sound and commercially practical.

Goal

Less than 0.15 lb/MMBtu NOx for bituminous coals

Technology Development History

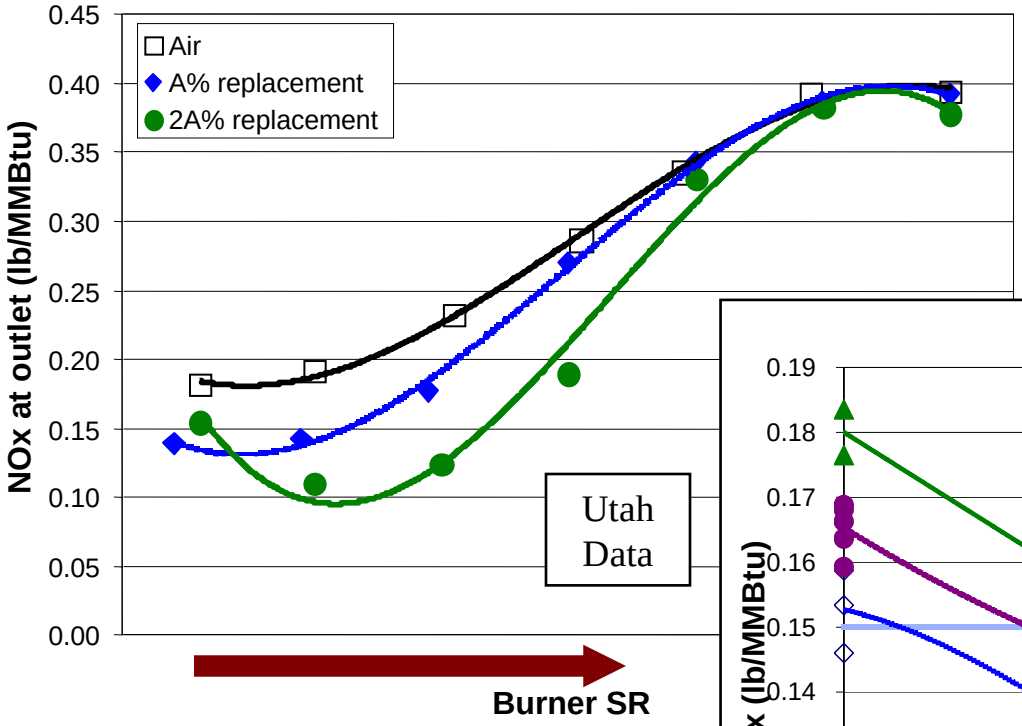


*Heat Input at maximum output

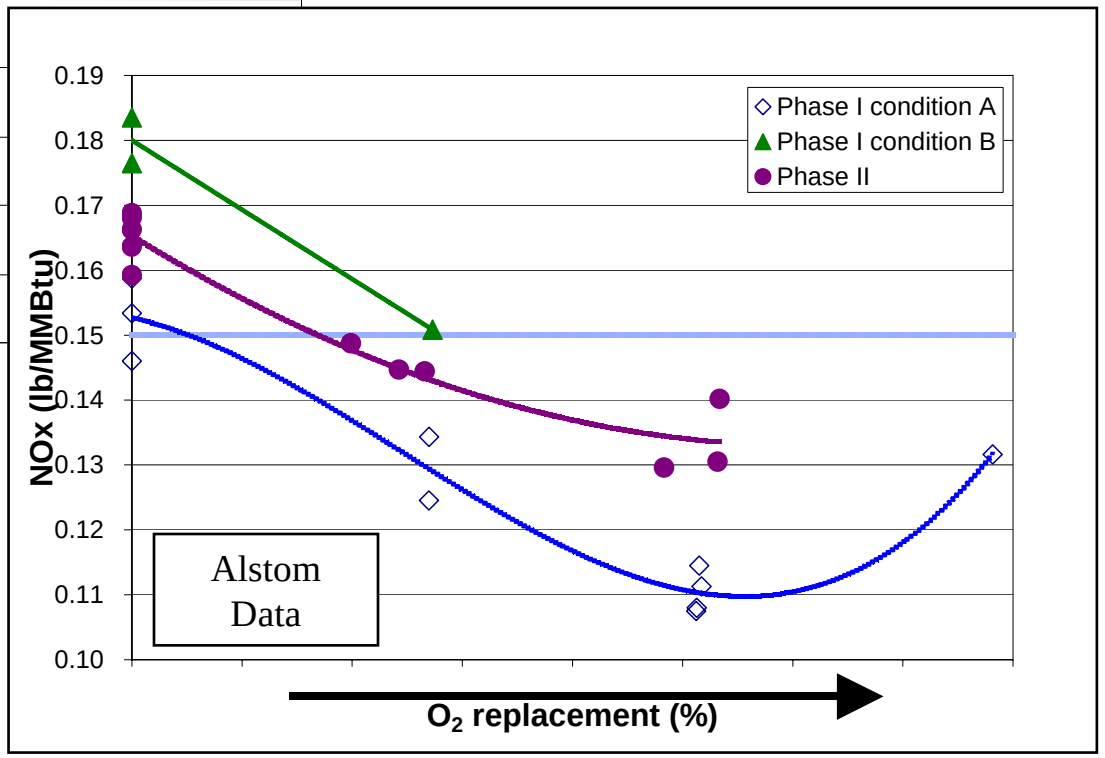
Key Points from Laboratory Work

- **Key findings from the earlier work are important for NOx results at commercial installations**
  - **effect of staging and O_2 replacement**
  - **effect of residence time**
  - **effect of temperature**
  - **effect of SR_{prime} on O_2 effectiveness**
- **Effect of oxygen on flame stability and LOI also important**

Effect of Staging and O_2 Replacement

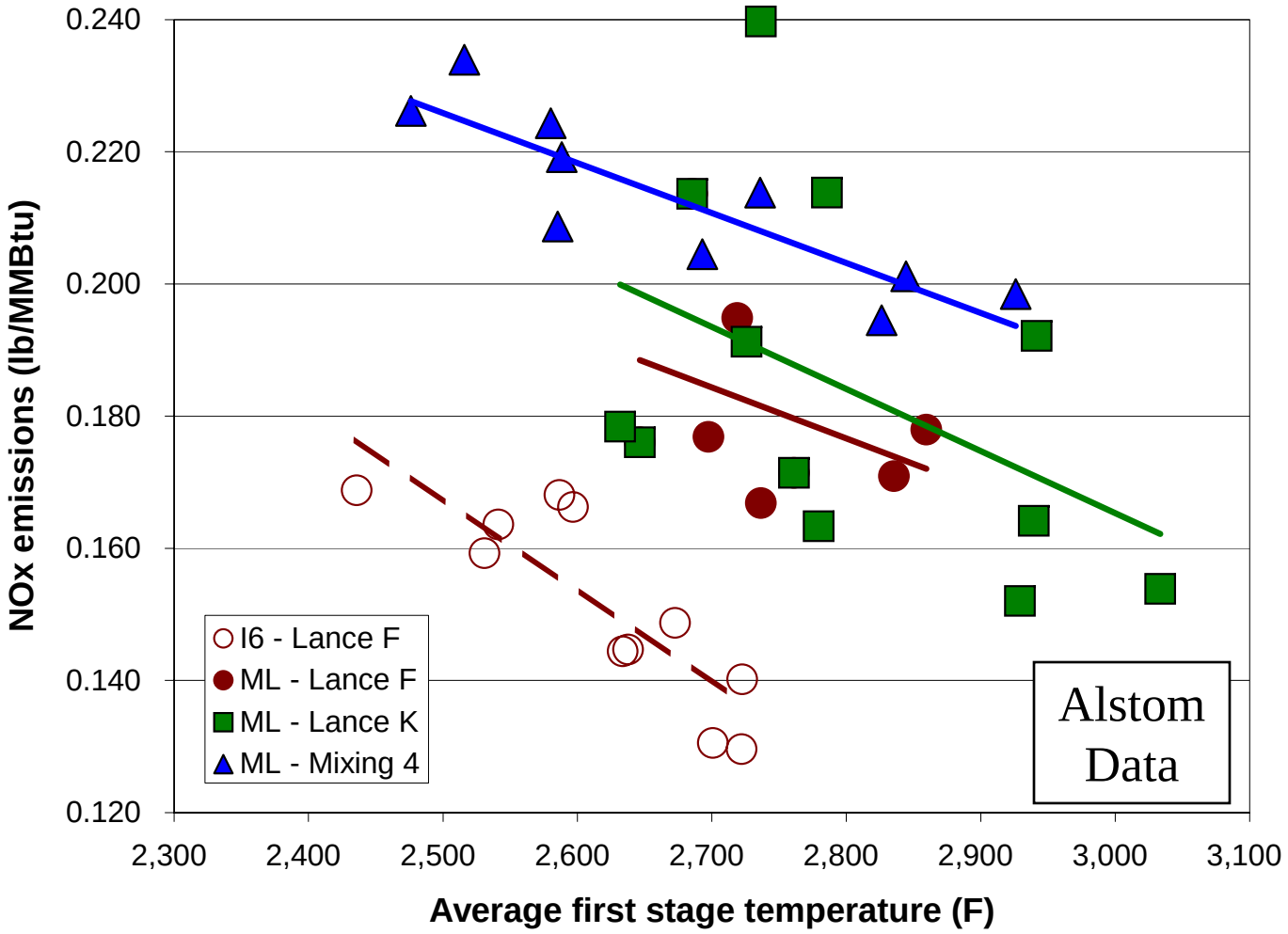


- **O_2 reduces NOx under deep staging**



- **NOx reduction w/ O_2 under mildly staged conditions at full-scale**

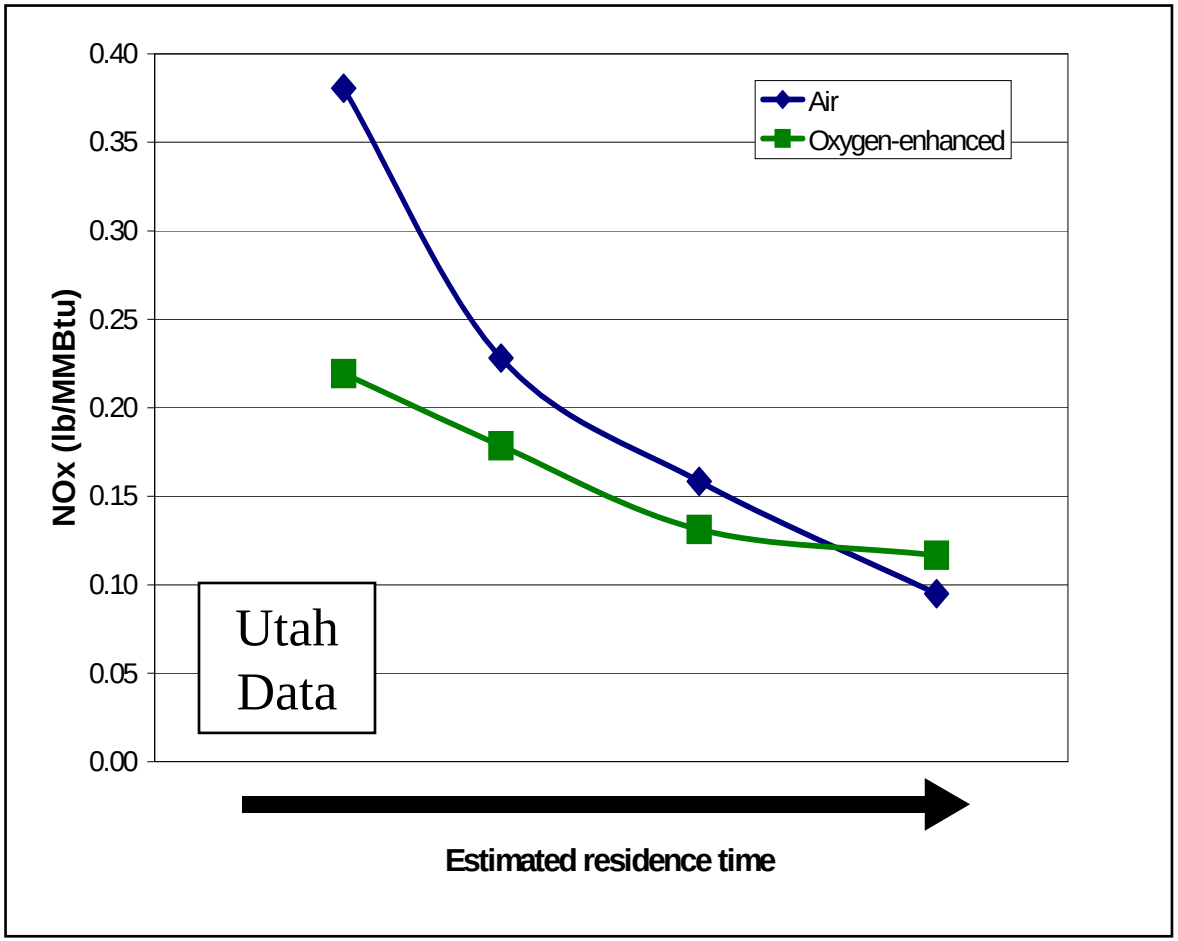
Effect of First Stage Temperature



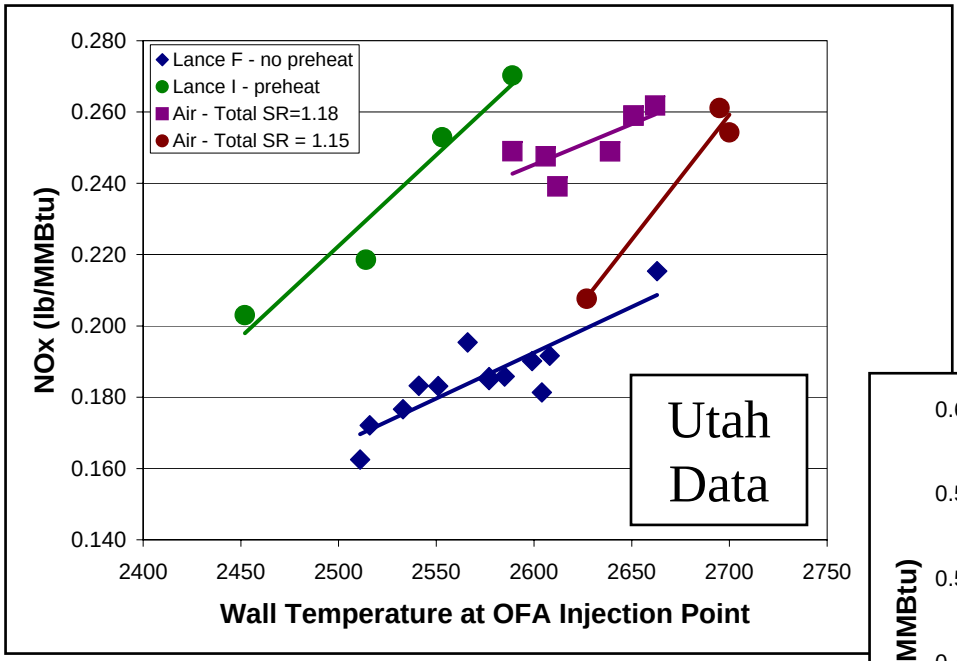
- **Increasing flame temp in fuel rich zone reduces NOx**
- **O_2 increases temp w/o changing SR**

Effect of Residence Time

- **Staging effectiveness increases with residence time**
- **O_2 most effective at short residence time**
  - **overcomes kinetic limitations**
- **Short second stage residence time leads to LOI and CO burnout problems**

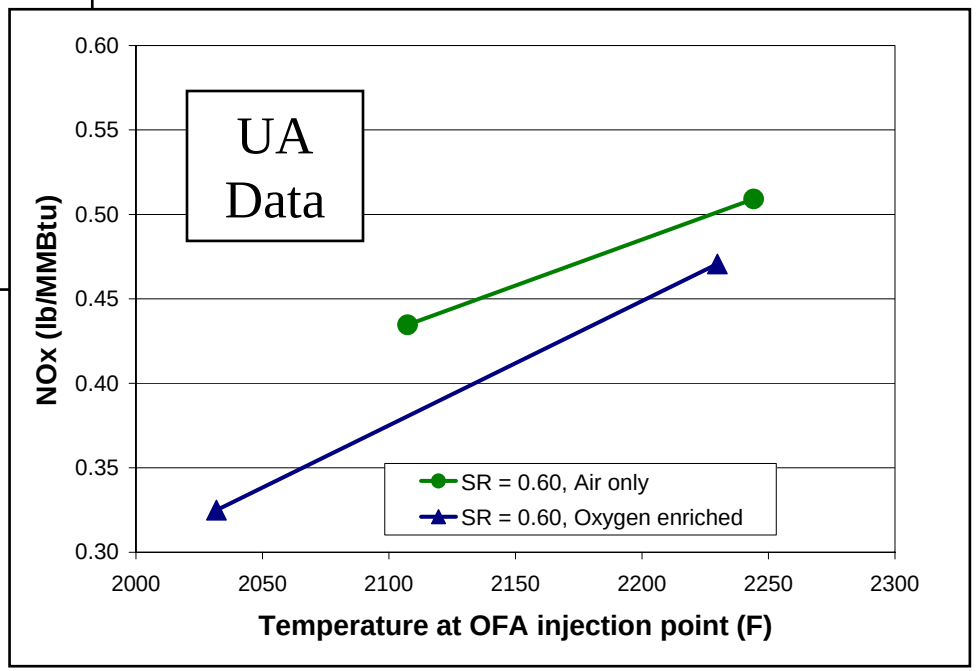


Effect of Second Stage Temperature



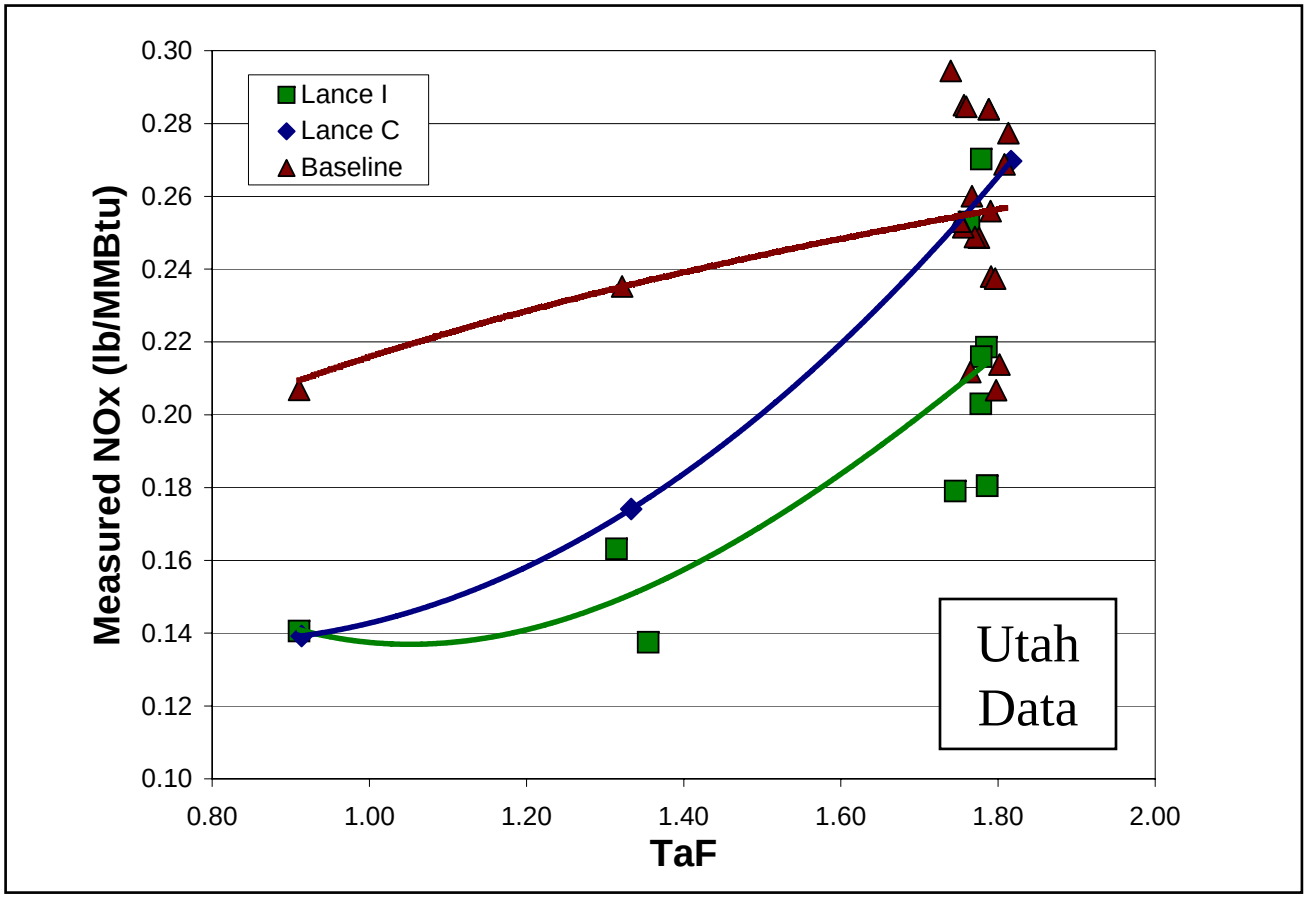
- **Increasing second stage temperature increases final NOx emissions**

- **Becomes important when comparing different boilers and determining optimum staging at a given boiler**



Effect of Primary SR

- **Transport air to fuel ratio changes SR of fuel rich flame core**
- **O_2 and staging effectiveness reduced with increasing SR_{prime}**
  - **less local staging**
  - **more transport air dilutes oxygen effect**



Flame Stability and LOI

- **Oxygen significantly improved flame stability at Alstom and Utah**
  - **reduced NOx even under fuel lean conditions**
  - **allowed deeper staging without blowout concern**
- **Oxygen shown to improve LOI compared to air-alone staging**
  - **some cases LOI lower or comparable to baseline case**

Making the Transition to Commercial Units

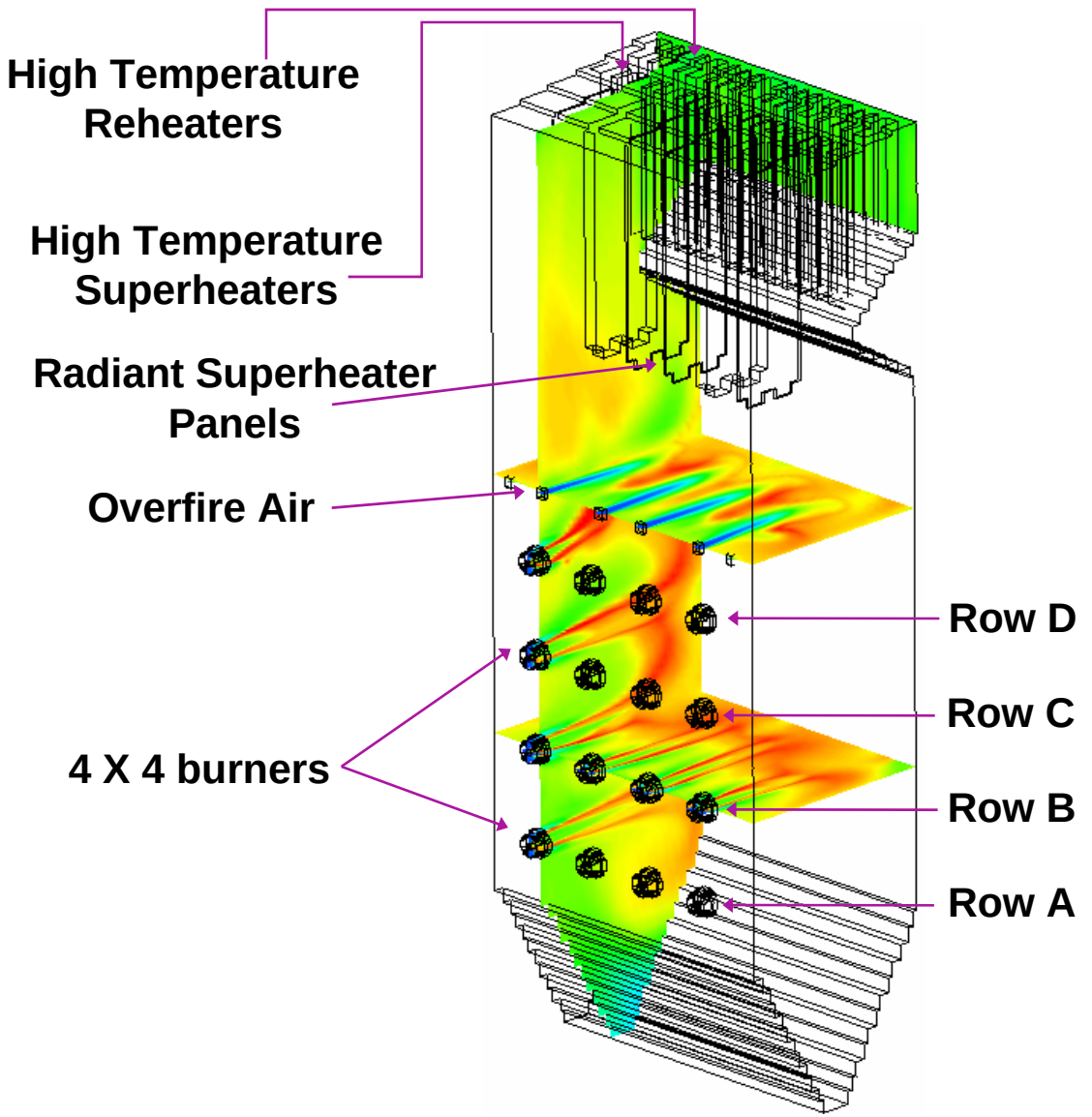
- **Successful transition to commercial systems can be problematic**
  - **each boiler unique**
  - **commercial systems more complex**
  - **technology must be retrofit**
- **Issues for air-based staging at full-scale**
  - **Flame stability**
  - **CO**
  - **Opacity**
  - **Unburned carbon in ash (LOI)**
  - **Waterwall wastage**

Full-Scale Demonstrations

- **Concept demonstrated at the City Utilities, Springfield MO, James River Unit 3**
  - **44 MW front wall-fired boiler**
  - **bituminous and bituminous-PRB blend tested**
- **Demonstration at Northeast Generation Services, Holyoke, MA, Mt Tom Station**
  - **125 MW (nameplate) front wall-fired boiler**
  - **Multiple coal types**
- **Evaluate O_2 effect on boiler operation**
  - **NOx, LOI, opacity, flame stability, CO**

Mt Tom Generating Station

- **125 MWg (nameplate)**
- **16 CCV Riley burners**
- **4 pulverizers**
- **6 Riley OFA ports**



Mt Tom - Limitations and Issues

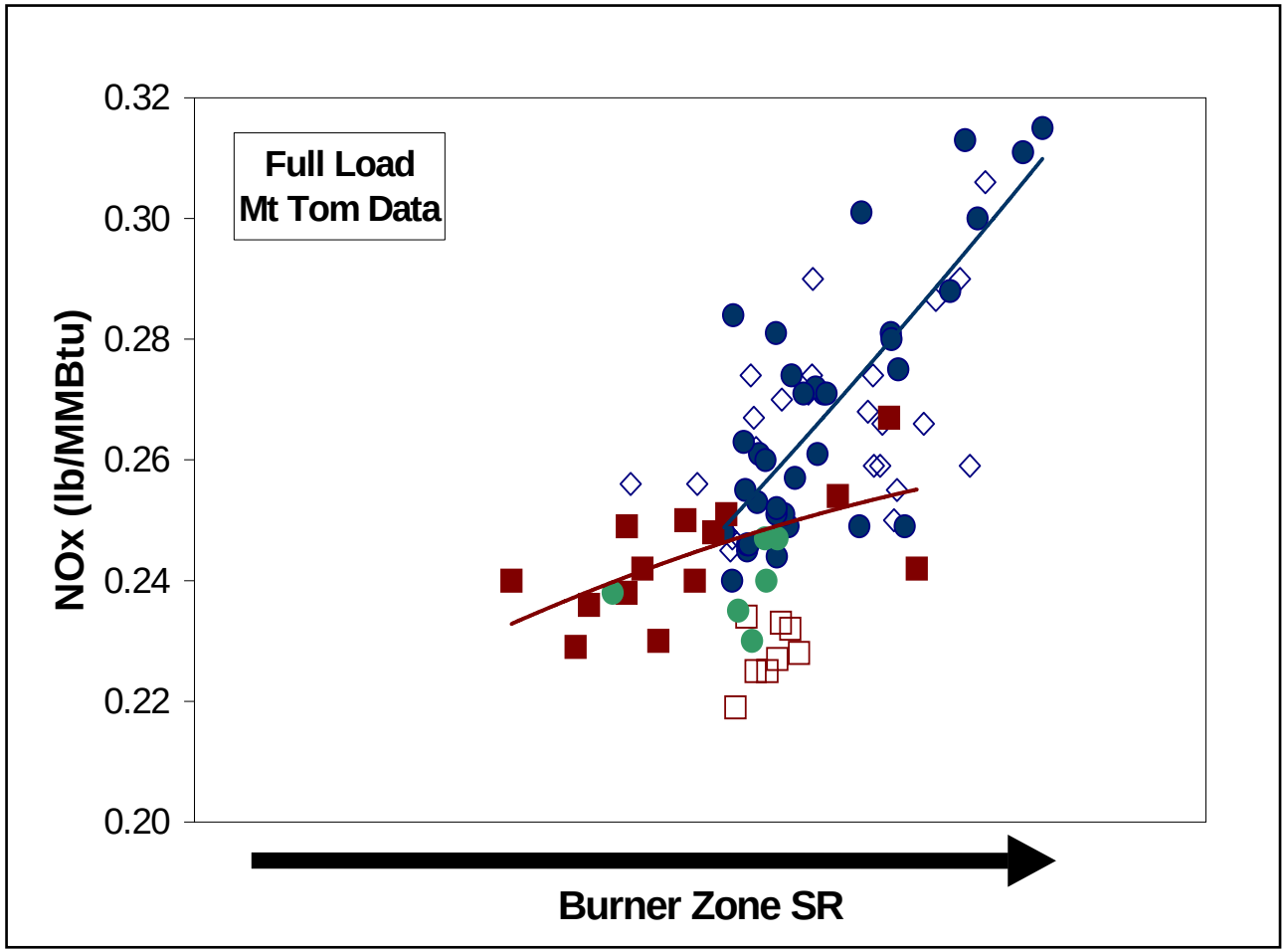
- **Issues at Mt Tom tend to be site specific**
- **plant operating max load is 24% over nameplate capacity**
  - **an extreme overfiring scenario**
  - **shortened residence time**
  - **higher temperatures after the OFA ducts**
    - **causes unacceptable superheat steam temps**
    - **can cause additional NOx formation**
  - **control mechanisms (ie; steam temperature control) at limits**

Mt Tom - Limitations and Issues (cont'd)

- **Short residence time**
  - **even at nameplate residence time is shorter than most units**
  - **degrades effectiveness of staging and OEC**
- **These limits have prevented deep staging at max operating load**

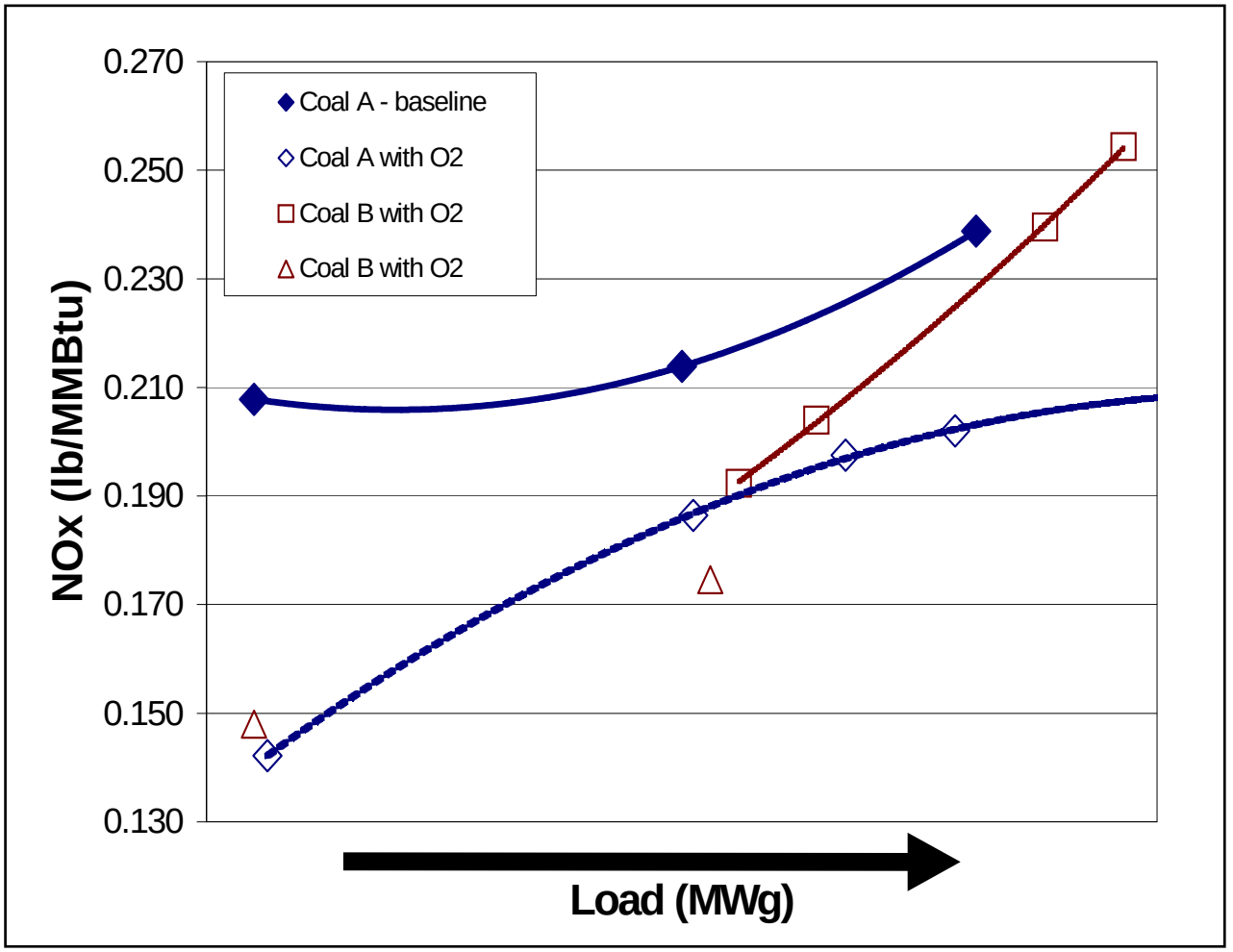
Staging at Full Load

- **Staging limited due to steam temp at full load**
- **NOx still decreasing at staging limit**
  - **did not hit limit of OEC**
- **Greater reductions possible if temps not a factor**



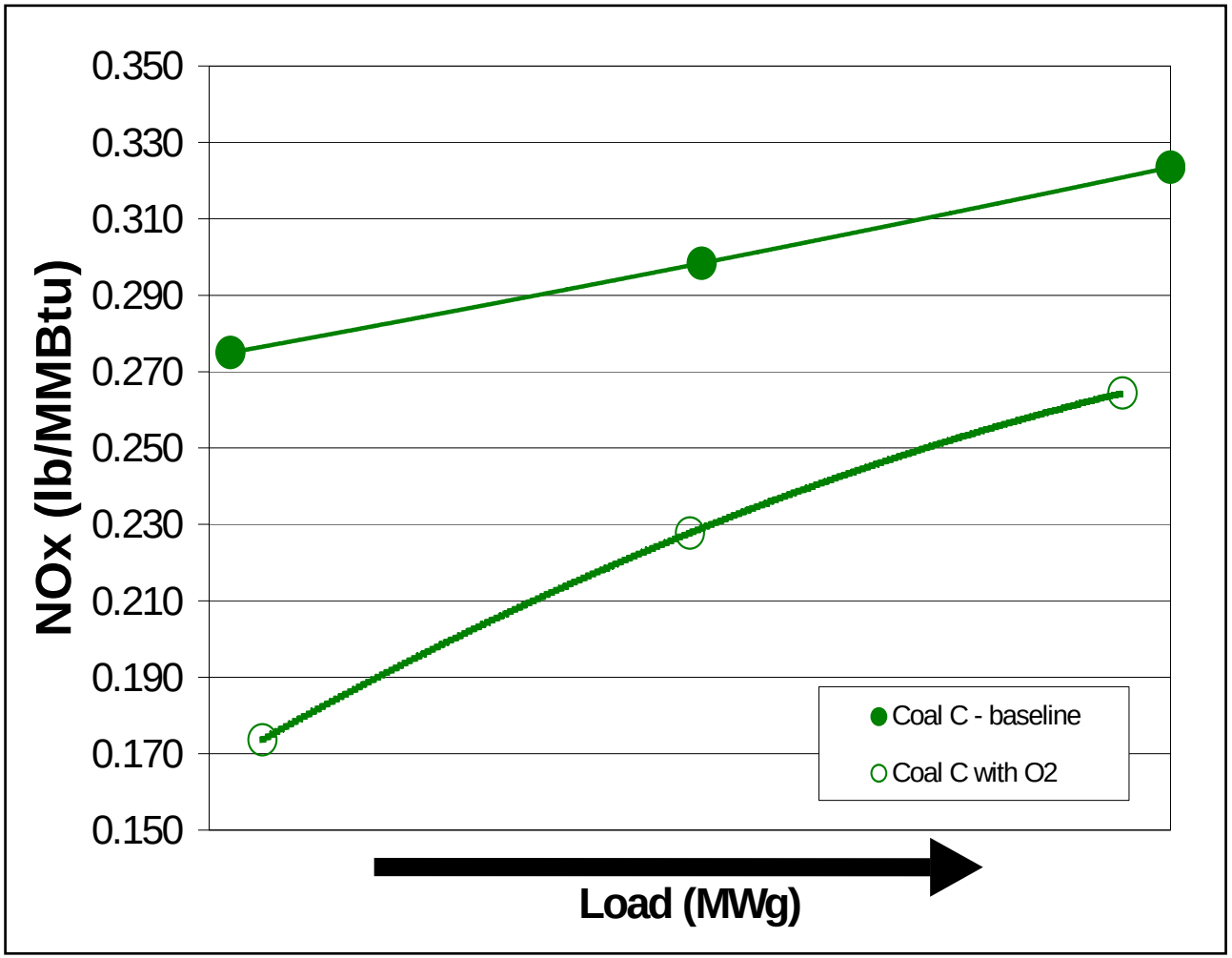
NOx vs Load - Class C Bituminous Coals

- **< 0.15 lb/MMBtu achieved w/O_2**
- **Reductions higher at part load**
  - **residence time increases**
  - **heat release rate decreases**
- **MA-specific CO regs (<200 ppm) limited staging**
  - **most units can stage deeper**



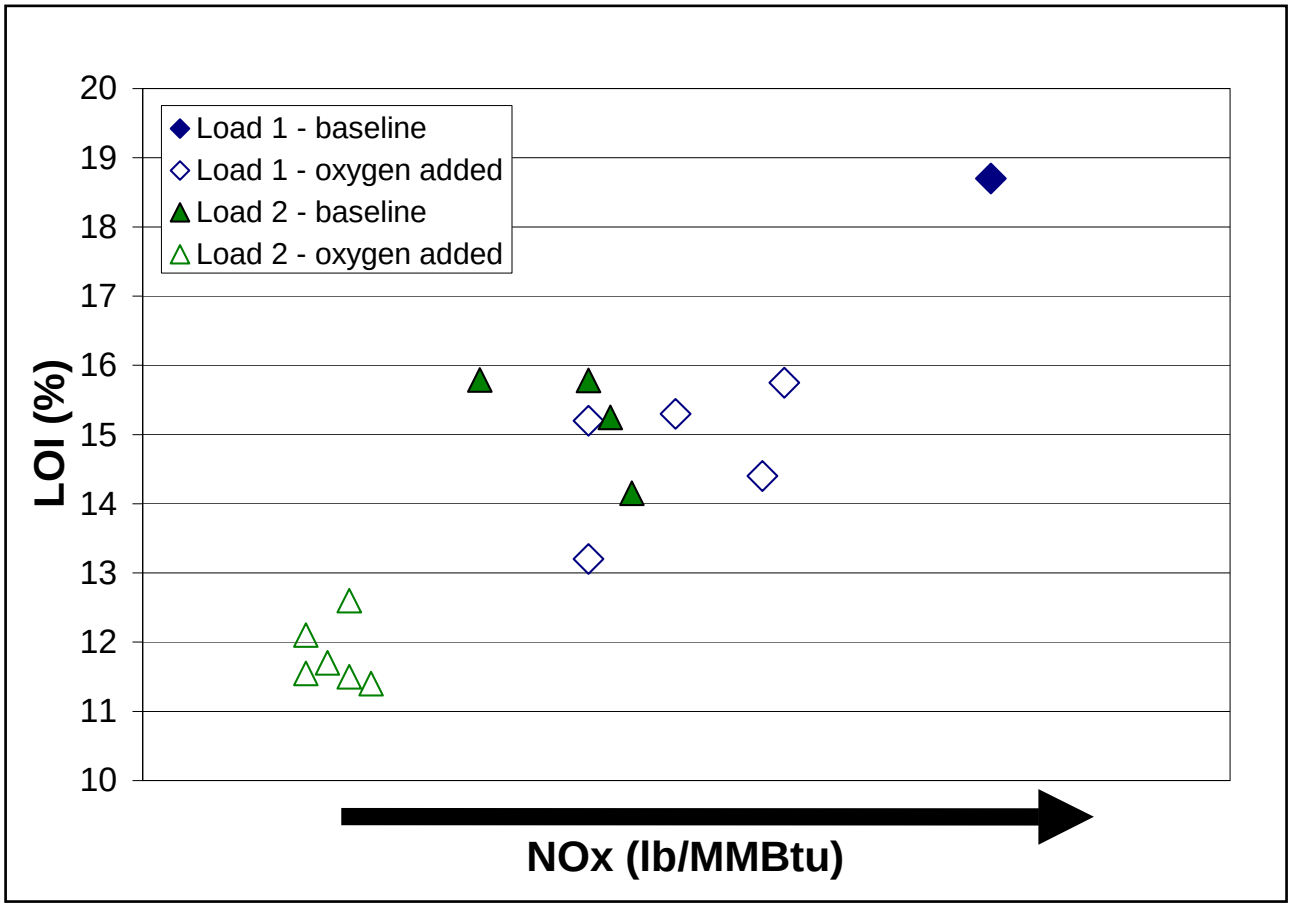
NOx vs Load - Class A Bituminous Coal

- **Significant reductions achieved w/O_2**
- **Part load conditions similar to City Utilities - NOx reductions similar**
- **CO ~ 120-170 ppm**



LOI vs NOx - Class C Bituminous Coal

- **LOI *reduced* at when NOx reduced**
- **With class A bituminous LOI stayed constant as NOx reduced**



Flame Stability at Mt Tom

Best Before

Best with Oxygen

Good Oxygen

Summary - Technology

- **Oxygen enhancement demonstrated at scales ranging from pilot to 125 MW boiler**
- **Typical results include**
  - **NOx reduction 40-60% from staged air baseline**
  - **LOI reduction ~30% from staged air baseline**
  - **Opacity decreased**
  - **Flame stability enhanced**
- **Small O_2 requirement for this application**
- **Technology is commercially available**

Did the Development Approach Work?

- **University contributions**
  - **provided a better understanding of the base technology and assurances of its effectiveness**
- **Industry contributions**
  - **provided a better understanding of how the fundamentals outlined at small-scale can be applied to more complicated commercial systems**
- **Collaboration provided best opportunity for successful technology development**

Acknowledgements

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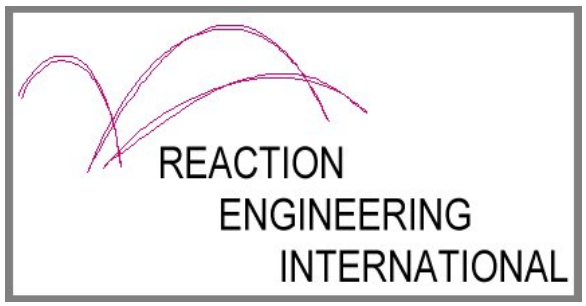

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