Model-Based Design and Full-Scale Demonstration of an Oxy-coal Firing System with Undiluted Oxygen and Minimal Flue Gas Recycle

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Abstract

The future use of coal as a fuel for industrial applications depends on economical technologies being made available to capture and store the CO_2 emitted as a product of the combustion process. One such technology is oxy-combustion, which involves burning of the fuel using pure oxygen as the oxidant rather than air. Since heat from combustion does not go toward the heating of nitrogen in the air, flame temperatures with oxy-combustion increase dramatically. First-generation application of the oxy-combustion depends on flue gas recycle (FGR) introduced in or around the burners to modulate flame temperatures to make the technology a retrofit option for existing power generating units. A second generation oxy-combustion technology that uses minimal FGR produces high-temperature flames in excess of 4000°F. Application of this technology shows promise for enabling capture, utilization, and sequestration of CO_2. However, a major step in the advancement of the technology and use in retrofit applications is the development of a burner design strategy capable of producing and sustaining the high-temperature conditions from oxy-firing of coal while providing protection to burner internals and near-burner surfaces from the high heat fluxes produced.

This paper discusses the development of a patented high-temperature oxy-coal firing system that has been constructed and tested in a full-scale demonstration. The patented design was achieved through Reaction Engineering International's commercial and government R&D programs involving CFD modeling coupled with multi-scale experiments. CFD model predictions corroborated by experimental data evaluated impacts of oxy-coal burner design on flame behavior, heat release and heat flux. The best performing designs were then modeled at an industrial-sized scale in a single burner test facility as well as in wall-fired and tangentially-fired utility-scale boilers. The paper describes the results of burner performance simulations that guided the evolution of high-temperature oxy-coal burner concepts to a design patented by Jupiter Oxygen Corporation (JOC). Full-scale testing of the JOC patented design will be performed with a single 60 MMBtu/hr burner to evaluate performance over a range of conditions including air firing. Performance metrics such as flame location/stability, local peak tube/burner temperatures and heat fluxes, carbon conversion, and NOx emissions will be discussed along with comparisons to CFD model simulations of the demonstration's test conditions.

Introduction

High-temperature oxy-combustion is an advanced combustion technology that uses minimal FGR in the burner to produce flame temperatures in excess of 4000°F. Application of this technology to steam generation in utility boilers is promising because of the potential for capture, utilization, and sequestration of CO_2. Reaction Engineering International (REI) has led teams of experts across academia and industry to perform multi-scale experiments, coupled with mechanism development and computational fluid dynamics (CFD) modeling, to develop data and tools to characterize and predict flame behavior, heat transfer, ash deposition and ash chemistry during high-temperature oxy-coal combustion. These properties must be understood and controlled to enable practical application of oxy-combustion in full-scale systems.

REI's commercial and government R&D programs have advanced the development of high-temperature oxy-combustion technology through the following key outcomes:

1. Multi-scale test data from 100 kW and 1.5 MW atmospheric combustors that describe differences in flame characteristics, heat transfer, surface material temperatures, fouling, and slagging for coal combustion under high-temperature oxygen-firing conditions, including sensitivity to oxy-burner design and operation.
2. Validated mechanisms suitable for inclusion in CFD models or process models that describe fouling, slagging, heat transfer, and char burnout under coal oxy-combustion conditions.
3. Principles to guide design of pilot-scale and full-scale coal oxy-firing burners and firing systems with minimum recycled flue gas such that heat flux and material surface temperatures are managed.
4. Assessment of oxy-combustion impacts in large-scale firing configurations using CFD modeling of oxygen-fired operation to identify potential challenges in scaling from pilot-scale to full-scale combustion systems.

The experimental data, oxy-firing system principles and oxy-combustion process mechanisms provided by this work can be used by electric utilities, boiler OEMs, equipment suppliers, design firms, software vendors, consultants, and government agencies to assess the use of high temperature oxy-combustion in current research; evaluate key combustion-related and balance of plant considerations in retrofit applications; and guide the development of new oxy-coal boiler designs.

Burner performance evaluations completed by REI have guided the design of a patented high-temperature oxy-coal firing system. The design patented by Jupiter Oxygen Corporation (JOC) is a concentric annular burner with undiluted O_2 that is capable of producing flame temperatures above 4000°F while introducing recycled flue gas to provide localized cooling and protection from high incident heat fluxes. A full-scale burner based on the patented design has been constructed and prepared for an upcoming demonstration in a single-burner test facility scheduled to begin in Fall 2022. This paper describes the process by which the patented burner was developed including lessons learned from conceptual burner design simulations applied to pilot-scale oxy-coal experiments to model predictions of burner performance at different scales and firing configurations.

Development of a high flame temperature oxy-combustion burner

Pilot-Scale Burner Design

Computational Fluid Dynamics (CFD) simulations were carried out to assist in designing a firing system with minimum flue gas recycle in a 1 MW Pulverized Coal Furnace (L1500) at the University of Utah. REI's proprietary CFD code, *GLACIER*, was used to investigate several burner arrangements and associated near field burner aerodynamics. The burner designs evaluated were all capable of producing an unswirled axial jet as well as more mixed combustion environments. Metrics of CO_2 evolution and burnout of particulate-bound combustible material were established and applied to describe heat release versus axial distance in the furnace. A firing system that produced elongated heat release and heat flux distribution was targeted for purposes of protecting the furnace from extreme conditions that could compromise the integrity of the equipment. Comparisons were made between burner concepts designed to produce internally stratified flames and a burner designed to rapidly mix fuel and oxidant to establish upper and lower limits of radiant heat flux, gas temperatures and wall temperatures.

The final design concept that is capable of producing an axial jet or more mixed combustion environments was fabricated, integrated into the L1500 control system, and utilized for 3 weeks of high-temperature oxy-combustion testing. Model-predicted gas and wall temperature profiles for un-swirled and swirled burner conditions are shown in Figure 1. As shown, adding swirl enhances mixing, which produces a broader and shorter flame shape along with higher peak gas and wall temperatures.

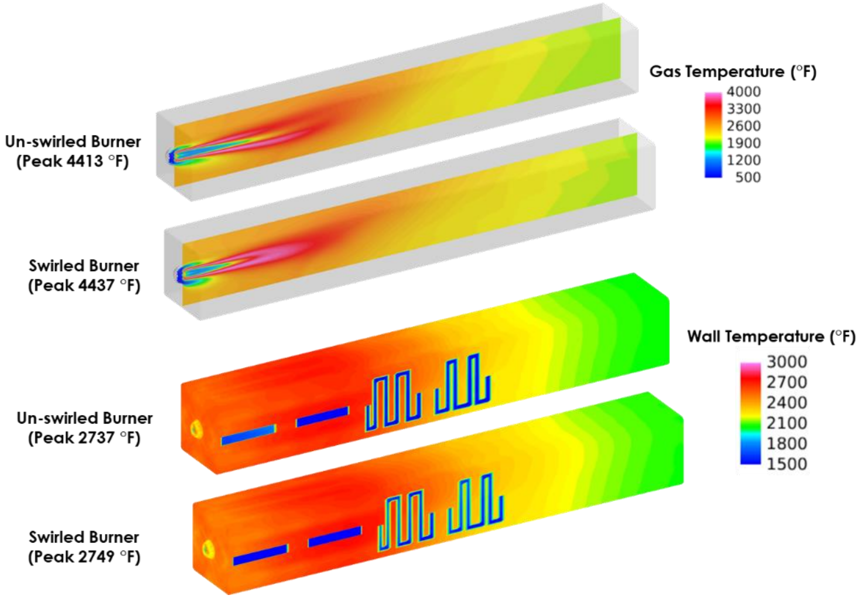


Figure 1. Gas and wall temperature profiles for high-temperature oxy-coal conditions in the L1500 furnace for un-swirled and swirled burners

Peak wall temperatures were a primary focus of burner design since excessive heat flux has the potential to raise refractory surface temperatures beyond acceptable limits of the materials. Since wall temperature was an important determining factor for burner design, a key step in validating the model predictions involved comparison of model-predicted wall temperature with the experimental data. Figure 2 shows the CFD model's predictions of wall temperature are in good agreement for the un-swirled and swirled conditions through Section 7 of the furnace, 26 ft downstream of the furnace front wall.

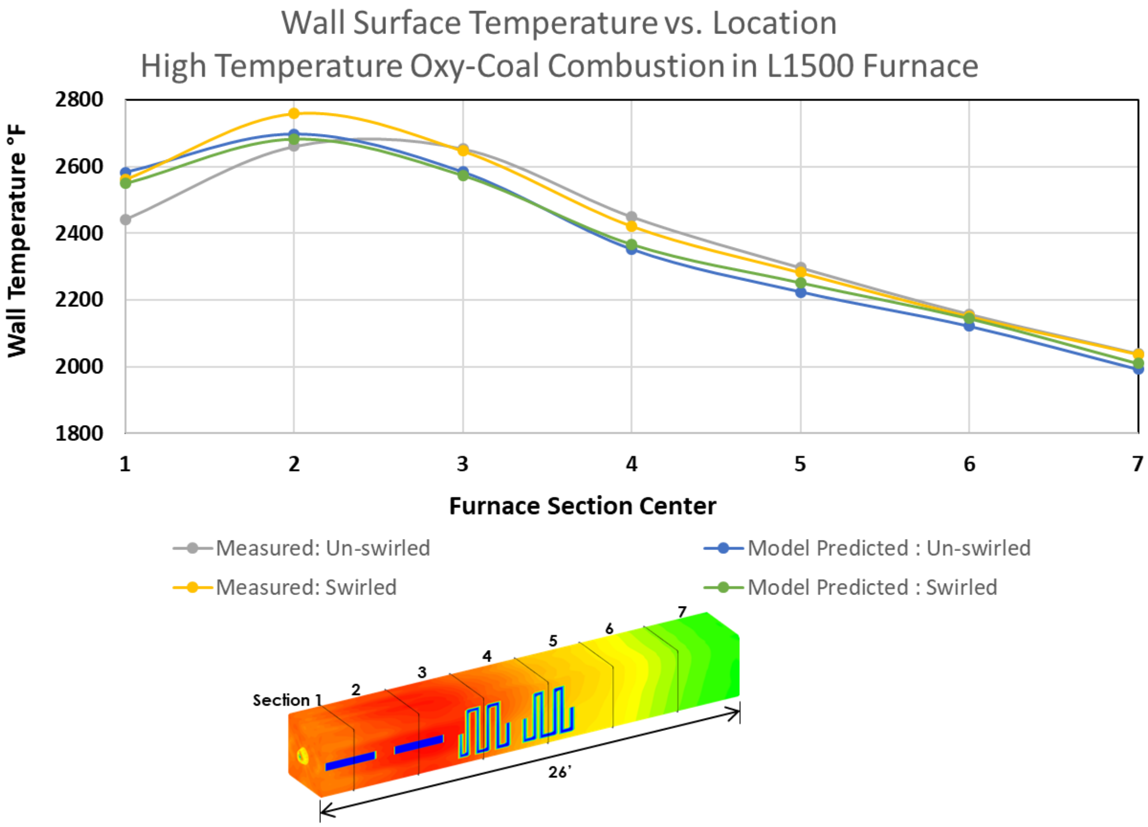


Figure 2. Comparison of measured and model-predicted wall surface temperature in the L1500 under high-temperature oxy-coal combustion

Evaluation at Large Scales

Building on the successful application of REI's modeling tools to guide the design of the 1 MW burner, REI leveraged its CFD code to predict oxy-combustion impacts at scales larger than the test furnace. Simulations covered a range of furnace firing rates from 30 MW to nearly 1000 MW and focused on flame geometry, flame temperature, surface heat flux, coal burnout and ash properties. The objective of this evaluation was to investigate utilizing the high-temperature oxy-coal technology in practical applications. In this instance, REI was focused on the retrofit of a pulverized coal-fired boiler with particular attention given to addressing potentially damaging impacts of high-temperature flames and high radiant fluxes on burner and furnace surfaces. Several burner design configurations were simulated with varying degrees of complexity.

Axial Jet Burner with Discrete O_2 Injection

REI constructed a CFD model of a conventional steam generating boiler equipped with 4 conceptual 30 MWt burners located on the furnace front wall. A cross section of the boiler is provided in Figure 3 showing half of the furnace, which is symmetric around the furnace centerline. The burner design was based on an axial jet burner with O_2-enriched motive FGR used to convey the fuel along with discrete ports to introduce O_2. As shown in Figure 4, Burner1 consists of 6 discrete O_2 injection locations arranged circumferentially along the outer perimeter of the burner. A seventh O_2 port is located at the burner center and is encircled by the primary annulus that delivers fuel with an O_2/FGR carrier.

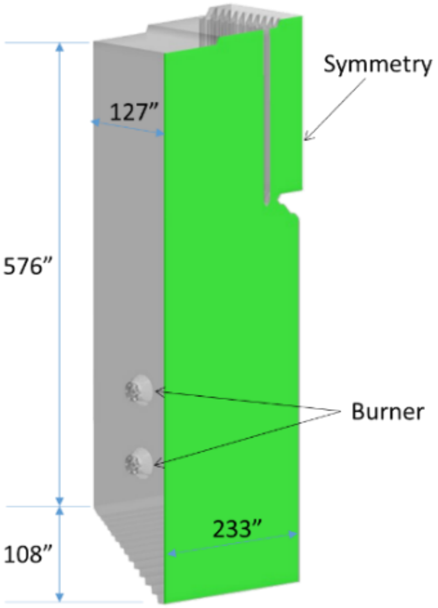


Figure 3. Model of conceptual burners in a conventional boiler furnace arrangement

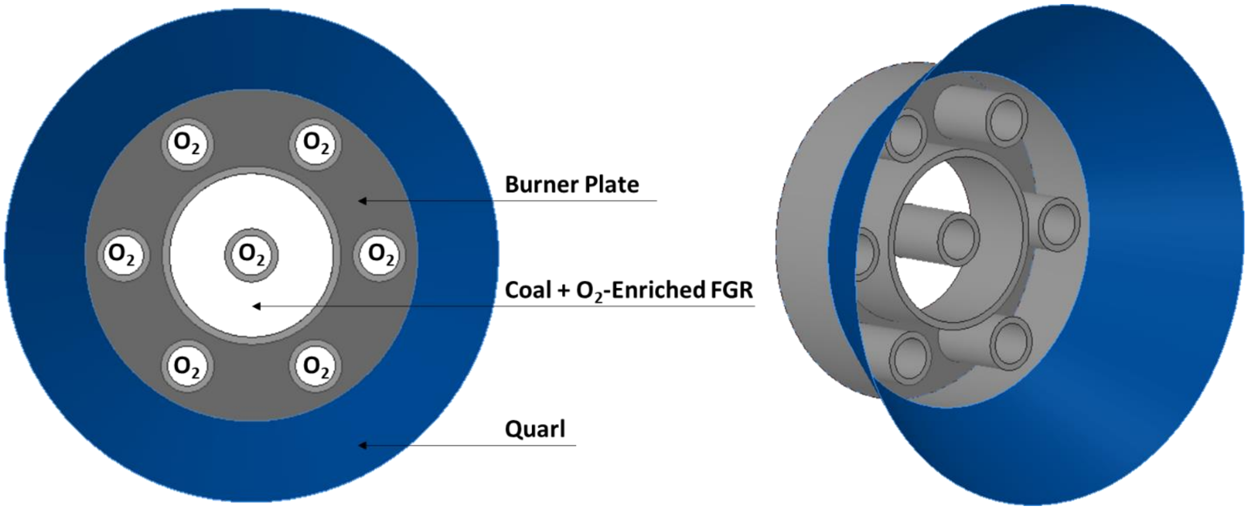


Figure 4. Burner1: Conceptual 30 MW_t burner for high-temperature oxy-coal at atmospheric pressure

Burner operating conditions were based on test conditions in the L1500 during the program’s experimental campaigns and scaled according to the higher thermal input. Relative flow rates of the Utah bituminous coal, FGR and O_2 streams were proportionately increased to maintain similar conditions at 30 MW_t as in the 1 MW_t experiments. Since the use of discrete ports to introduce O_2 in the 30 MW_t burner was a deviation from the approach used with the annular burner in the L1500, registers and O_2 ports were sized in order to maintain consistency with inlet velocities in the experiments. The operating conditions prescribed for the 120 MW_t furnace simulations are shown in Table 1.

Table 1. Furnace operating conditions assumed for a steam generating boiler equipped with 30 MW_t conceptual burners firing bituminous coal.

	Bituminous w/ 30MW_t Burners
Coal Type	Bituminous
Total Heat Input (MBtu/hr)	408 (120 MW_t)
Total Coal Flow (lb/hr)	34,504
Total Oxidant Flow (O_2) (lb/hr)	72,816
Total FGR Flow (lb/hr)	48,076
Overall Stoichiometric Ratio	1.039
Excess O_2 in Flue Gas (vol%, wet)	2.0 (3.0 dry)
Total Primary Flow (klb/hr)	60.40 (23.5% O_2)
Primary Gas/Coal	1.75
Primary Temperature (°F)	150
Primary Velocity (ft/s)*	67.4
Total Secondary Flow (klb/hr)	60.52 (100% O_2)
Secondary Temperature (°F)	100
Secondary Velocity (ft/s)	157
Overall O_2 in O_2/FGR mix	63.2%

* Including coal H_2O

The 120 MW_t furnace model was a significant step in the burner development as it expanded the analysis to the impacts of burner to burner interactions and assessment of impacts of firing configuration on near-burner heat fluxes. As shown in Figure 5, the burner produces flames with a relatively cool, fuel-lean core; a high temperature annulus where the fuel and O_2 are mixing; a relatively cool, fuel rich annulus; and a high-temperature envelope at radii larger than the burner quarl where fuel and oxidant are mixing to produce gas temperatures above 4000°F.

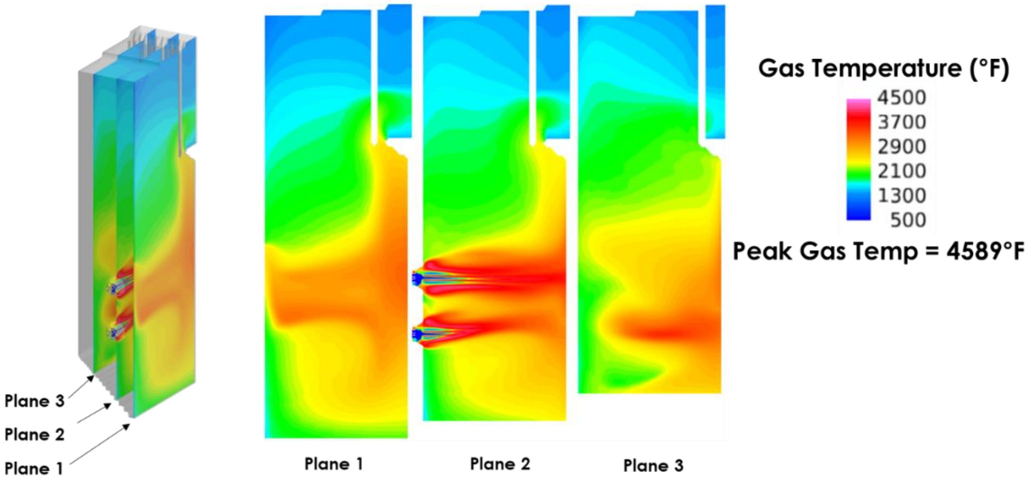


Figure 5. Cross-sections of gas temperature in furnace model with conceptual burner

It should be noted that this evaluation was not intended to be a furnace optimization task and results reflect some features that are sub-optimal. For example, this single-wall fired furnace is not an ideal design as stratified conditions that develop in the burner zone persist beyond the vertical nose. This would present a particularly challenging scenario for effective use of convective heat transfer surfaces downstream of the radiant section. In addition, the depth of the fire box is such that flame impingement on the rear wall would be a considerable problem, which is indicated by the model predictions of high heat flux on the rear wall. Although this information is of value, the real focus of this model is on near-burner conditions, and the sub-optimal furnace dimensions and firing configuration are factors that do not reduce the usefulness of near-burner predictions.

The color contours in Figure 6 show incident heat flux on the front wall of the furnace as well as the burner components. The peak on the furnace wall is predicted to be 224,000 Btu/h ft^2, which is higher than what has been typically observed in conventional boilers using air as the oxidant. For the burners, the areas where heat fluxes are highest are adjacent to the discrete points where pure oxygen is delivered. The intense heat release in these discrete locations produces temperatures in excess of 4500°F and corresponding high radiant fluxes to the burner. The high incident flux to the burner quarl is the result of the high rate of mixing between fuel and oxidant within the high-temperature envelope in the outer edges of the flames.

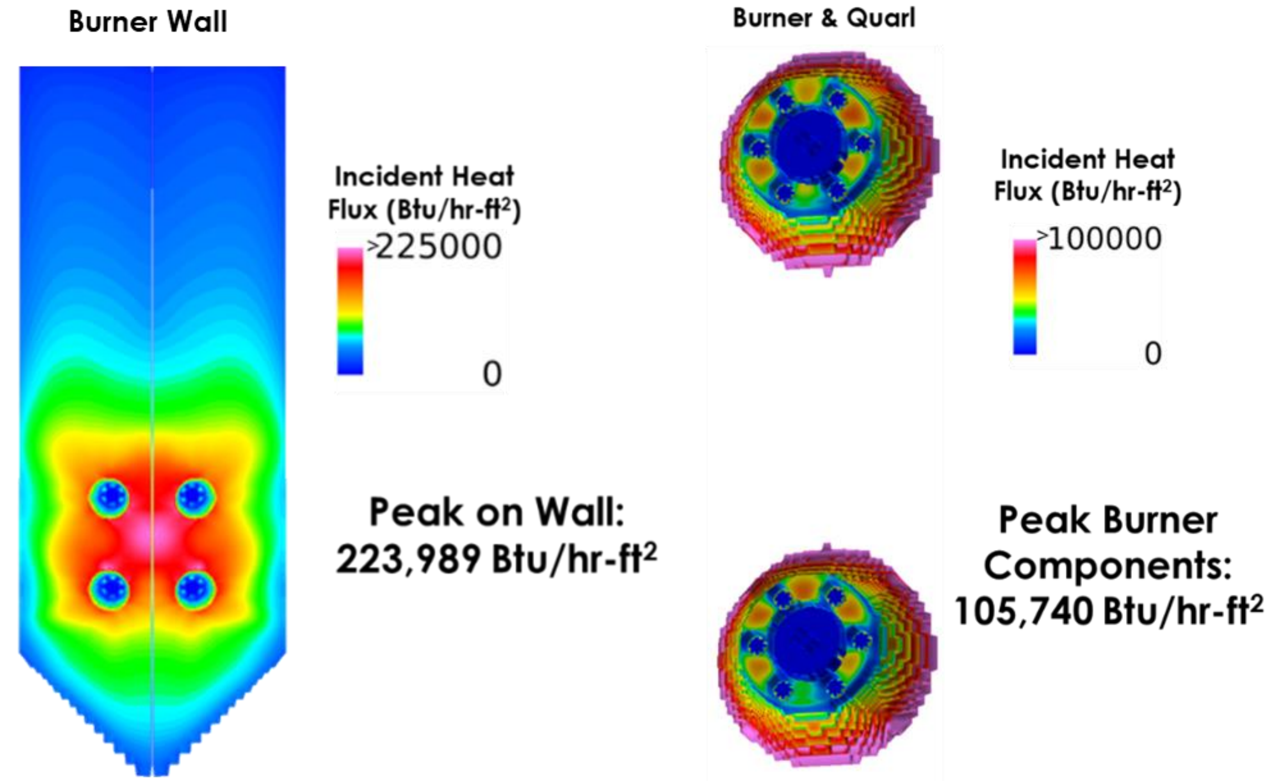


Figure 6. Profile of incident radiant flux in half-furnace model with conceptual burner

Model predictions of surface temperatures on burner components indicated peak temperatures of 830°F, which is well within the tolerable limits of materials that would typically be used for fabricating a burner of this kind. However, a contemporaneous assessment of the sensitivity to thermal boundary conditions prescribed to the burner surfaces indicated that as the burner parts become more thermally resistive, the surface temperatures can change significantly and quickly exceed acceptable limits for materials conventionally used for coal burners. For this reason, an alternative burner concept was designed to alleviate the hotspots produced between the O_2 ports.

Impacts of Distributed FGR on Burner Components

An alternative design using FGR ports located within the gaps between the O_2 ports is shown in Figure 7. In Buner2, the FGR ports are designed to provide local cooling to the burner components to prevent wall temperatures exceeding tolerable limits for non-exotic materials.

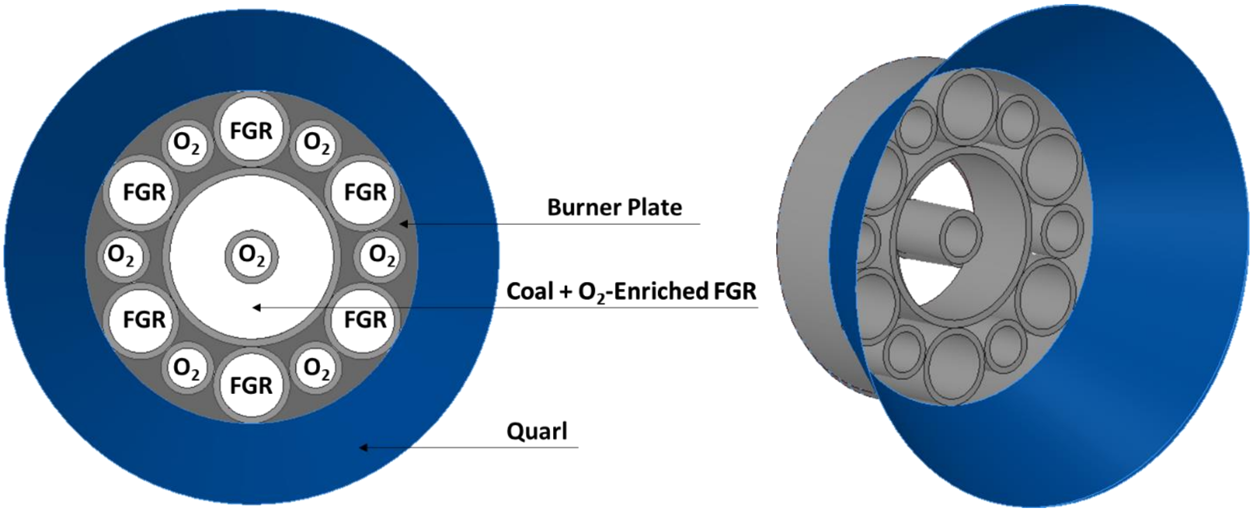


Figure 7. Burner2: Modified conceptual 30 MWt burner equipped with FGR ports for localized cooling

Operating conditions for the case with secondary FGR located in the burner are shown in Table 2. The FGR flow rate was determined by finding the amount of FGR required to decrease the adiabatic flame temperature by 300°F, which was a conservative estimate intended to provide local cooling to burner components without impacting peak temperatures within the flame. The ports were sized to achieve a relatively low velocity stream that would keep the recycled gas close to the burner and absorb heat radiated from adjacent hot spots.

Table 2. Operating conditions for cases with and without secondary FGR

	Bituminous w/ 30MW_t Burners	
Case Numbers	Case 1	Case 3
Burner Concept	Burner1	Burner2
Coal Type	Bituminous	Bituminous
Total Heat Input (MBtu/hr)	408 (120 MW_t)	408 (120 MW_t)
Total Coal Flow (lb/hr)	34,504	34,504
Total Oxidant Flow (O_2) (lb/hr)	72,816	72,816
Primary FGR Flow (lb/hr)	48,076	48,076
Total Primary Flow (klb/hr)	60.40 (23.5% O_2)	60.40 (23.5% O_2)
Primary Gas/Coal	1.75	1.75
Primary Temperature (°F)	150	150

	Bituminous w/ 30MW$_t$ Burners	
Case Numbers	Case 1	Case 3
Primary Velocity (ft/s)*	67.4	67.4
Secondary O_2 Flow (klb/hr)	60.52 (100% O_2)	60.52 (100% O_2)
Secondary FGR Flow (klb/hr)	N/A	8,156
Secondary O_2 Temperature (°F)	100	100
Secondary FGR Temperature (°F)	N/A	150
Overall Stoichiometric Ratio	1.039	1.039
Excess O_2 in Flue Gas (vol%, wet)	2.0 (3.0 dry)	2.0 (3.0 dry)
Overall O_2 in O_2/FGR mix	63.2%	59.5%

Color contours of gas temperature in Figure 8 are for the case with secondary FGR added. The profiles look very similar to the preceding case without FGR shown in Figure 5. Furthermore, the peak gas temperature drop of less than 10°F met the objective of minimizing the impact of the additional FGR streams on peak gas temperature.

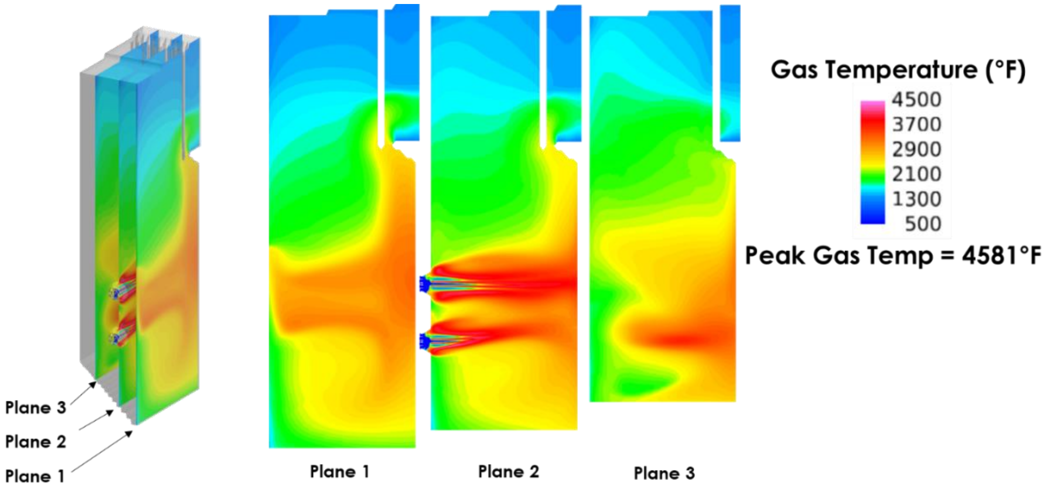


Figure 8. Cross-sections of gas temperature in furnace model with conceptual burner modified with secondary FGR ports for local cooling

The impact the secondary FGR has on radiant flux and peak temperature to the burner components is significant. Figure 9 shows incident flux profiles on the furnace front wall and the burner components for Burner2. In Case 3, there is a more than 10% drop in peak radiant flux on the front wall, but the greater change is on the burner components, which are 15% lower. The peak temperature on the burner components decreases from 831°F to 774°F while peak temperature on the furnace front wall decreases from 1661°F to 1580°F. A comparison of predicted temperatures and heat fluxes in the furnace with the initial burner design and the revised design with distributed FGR ports is shown in Table 3.

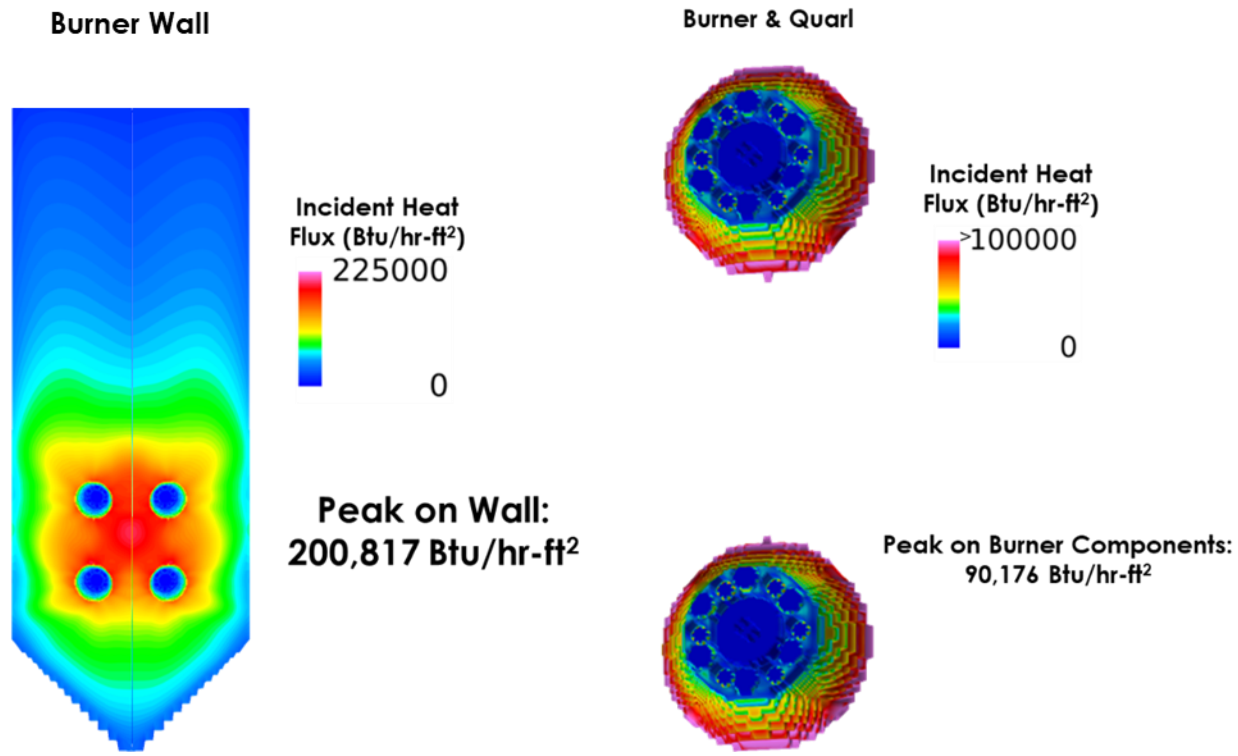


Figure 9. Profiles of incident radiant flux in half-furnace model with conceptual burner modified with secondary FGR ports for local cooling

Table 3. Model predictions for cases exploring impacts of secondary FGR with non-adiabatic and adiabatic wall boundary conditions

	Case 1	**Case 3**
Peak Gas Temp in Domain (°F)	4589	4581
Max Incident Heat Flux on Burner Components (Btu/hr-ft^2)	105,740	90,176
Peak Wall Temp on Burner Components (°F)	831	774
Max Incident Heat Flux on Front Wall (Btu/hr-ft^2)	223,989	200,817
Peak Wall Temp on Front Wall (°F)	1661	1580

Burner2 showed significant improvement over Burner1, but an alternative design was sought that could achieve similar or better performance with a simpler design. A revised design was developed that offers advantages in terms of simplicity and uniformity in the distribution of O_2 and FGR. The revised design is a concentric annular burner that simplifies the delivery of O_2 and FGR by replacing individual O_2 and FGR ports with annular registers. For consistency, velocities through each register were essentially unchanged from the individual port velocities in preceding designs. The multi-register axial jet burner allows heat release and heat flux to be stretched out to avoid damage to near-burner surfaces while still producing stable flames. Meanwhile, an outer annular shroud of FGR provides adequate cooling to the burner and near-burner surfaces; keeping surface temperatures within tolerable limits of materials conventionally used in an industrial furnace. The heat release profile of this burner differs from the burner with discrete ports as indicated by the gas temperature profiles in Figure 10, which shows longer and narrower flames from the annular burner (Burner3) compared to Burner1 with discrete ports.

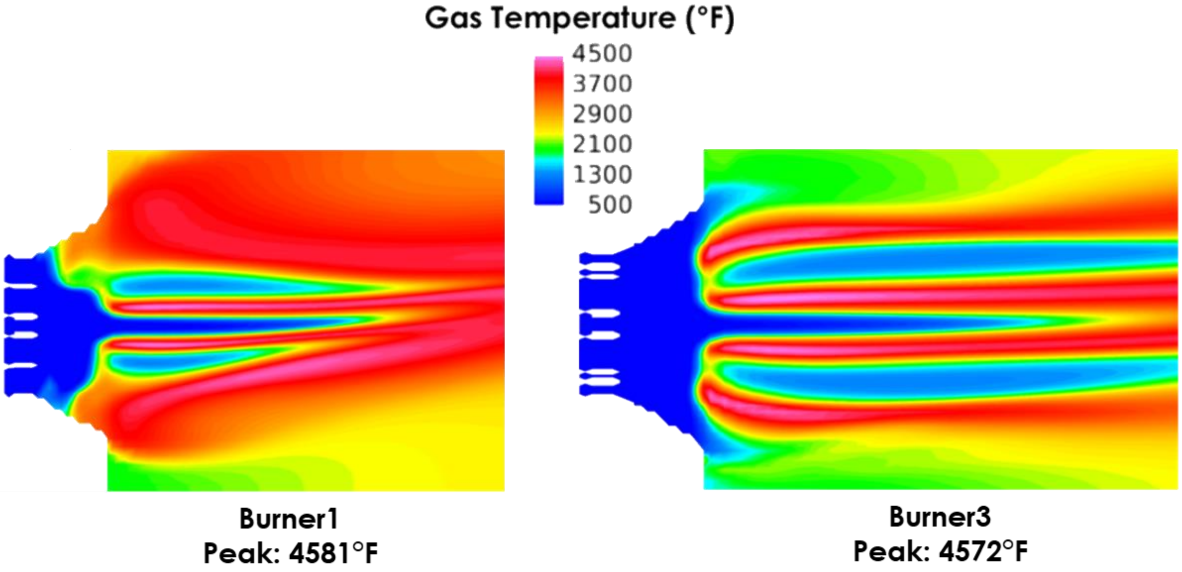


Figure 10. Comparison of near-burner gas temperature profile for Burner1 and Burner3

Alternating regions of high and low velocity gases at the same radial distance from the burner centerline accelerates the rate of mixing in the design with discrete ports. The Burner3 design produces an elongated heat release profile with slower rates of mixing between the fuel and O_2. When the annular burner was simulated in the front-wall fired boiler, the predicted impacts on peak wall temperatures and incident flux were significant. Table 4 compares performance metrics for the Burner 3 simulation (Case 5) to Case 1 and Case 3.

Table 4. Model predictions for alternate burner designs

	Case 1 (Minimum FGR)	**Case 3 (Secondary FGR Ports)**	**Case 5 (Annular Shroud FGR)**
Burner Concept	Burner1	Burner2	Burner3
Peak Gas Temperature (°F)	4589	4581	4572
Max Incident Heat Flux on Burner Components (Btu/hr-ft^2)	105,740	90,176	21,876
Peak Wall Temp on Burner Components (°F)	831	774	584
Max Incident Heat Flux on Front Wall (Btu/hr-ft^2)	223,989	200,817	128,091
Peak Wall Temp on Front Wall (°F)	1661	1580	1293

The maximum incident heat flux to the burner components decreased 15% with additional FGR in Case 3. This peak incident flux drops a further 75% with the Burner3 design in Case 5. The maximum heat flux to the furnace front wall tubes also dropped significantly although not as much as what was seen for the burner itself. Peak heat flux dropped 10% with the additional FGR in Case 3, but an additional decrease of 36% was predicted in Case 5. Large decreases to peak wall surface temperatures for the burner metal and front wall tubes were also predicted in Case 5 to correspond with the decreases in incident radiant fluxes. An important parameter in the table is the peak gas temperature. Although Case 3 and Case 5 showed substantial reductions to peak incident flux and peak wall surface temperatures, the burner designs in each case were still capable of producing peak gas temperatures that were nearly as high as the Burner1 design with minimum FGR. These very promising results led to a successful patent application for the Burner3 annular shroud concept. The patent assigned to JOC is an integral part of detailed retrofit studies for utility boilers as described in the following section.

Full-Scale Demonstration and Boiler Retrofit

REI is working with JOC and other team members (Sargent & Lundy, Babcock & Wilcox, Air Liquide, Main Line Engineering, University of Wyoming Enhanced Oil Recovery Institute, EPRI, Graycor) towards a full-scale retrofit of PacifiCorp's Dave Johnston Unit 2 (DJ2) with the JOC patented high-temperature oxy-combustion process. The retrofit will include installation of the patented JOC high-temperature annular shroud burner. A Phase I Feasibility Study was completed May 2019. This study showed the technical and economic viability of the project. During this phase, REI provided a conceptual burner design based on CFD modeling, including single-burner modeling and full-scale modeling of DJ2. Process modeling of the entire oxy-combustion system proposed at DJ2 was performed to evaluate energy balance considerations including fire-side/steam-side coupling.

The CFD modeling work provided insight into key issues including heat transfer, burner geometry optimization, operational tuning, load variations, and flue gas recycle rate. Metrics for these evaluations focused on performance characteristics such as flame location/stability, local peak tube/burner temperatures and heat fluxes, carbon conversion (CO and carbon-in-ash), NOx emissions, particulate carry-over, tube corrosion, and ash deposition/sintering. Key findings in the CFD modeling showed increased heat transfer in the radiative furnace during oxy-firing compared to current air-fired operation. Average and peak net heat flux increased under oxy-firing (Figure 11), which led to increased waterwall tube OD temperatures; however, peak temperatures remained below limits suggested by boiler manufacturers[1]. Advanced deposition CFD modeling shown in Figure 12 indicated a dramatic improvement in deposition under oxy-firing.

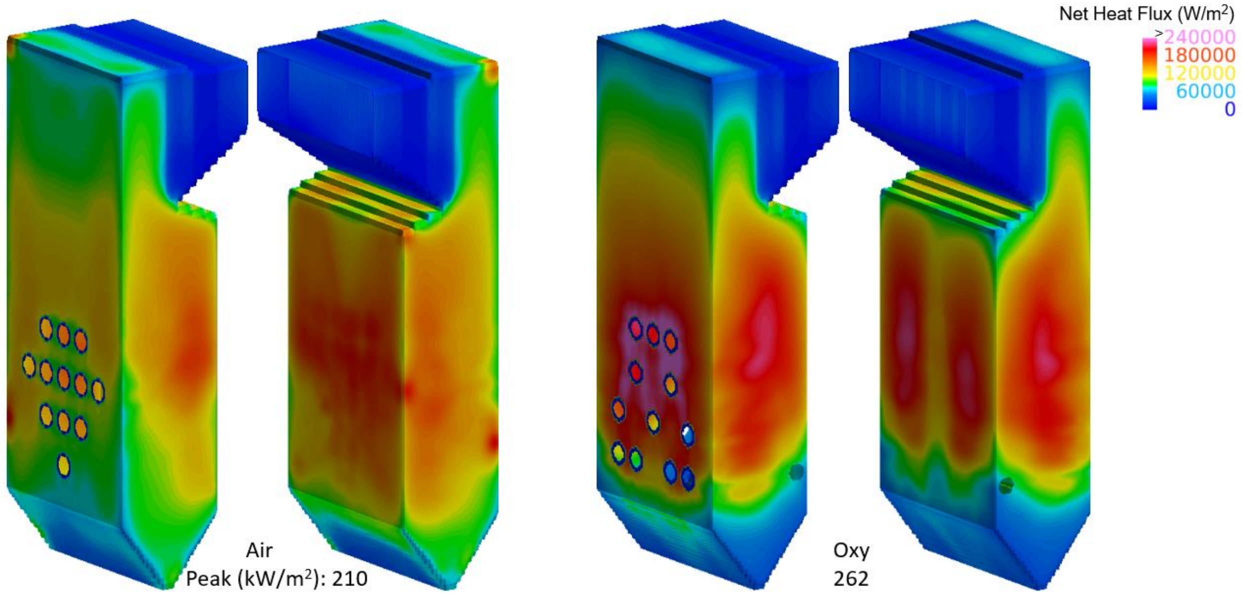


Figure 11. Net Heat Flux from CFD Simulation of Air- and Oxy-Fired Condition.

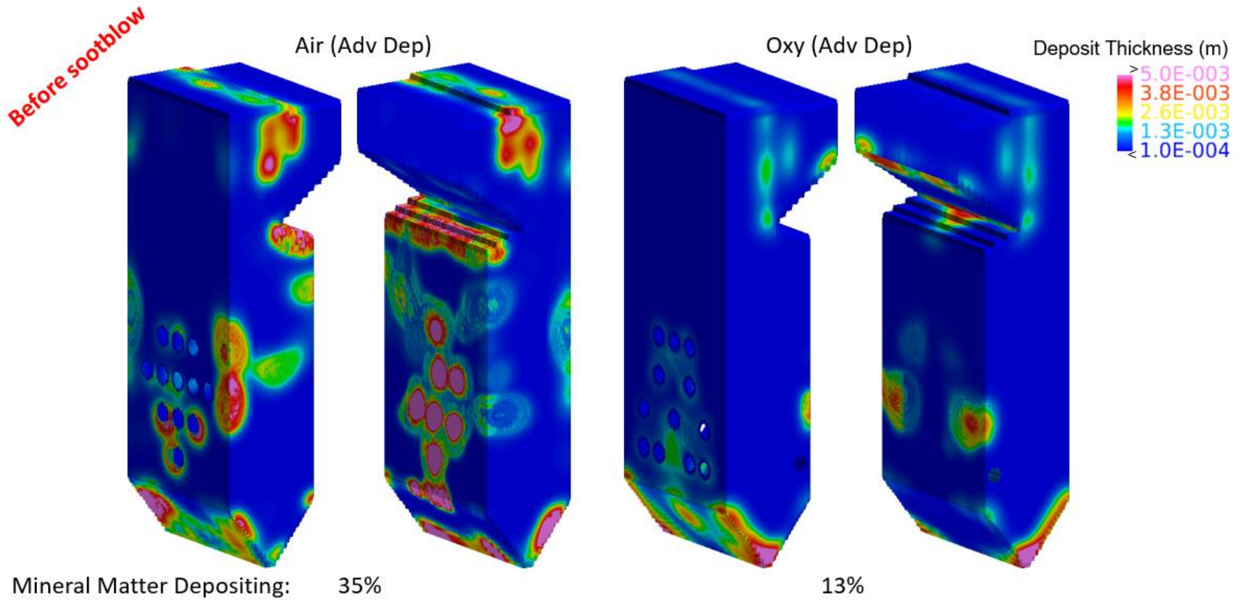


Figure 12. Deposit Thickness from Advanced Deposition CFD Simulation of Air- and Oxy-Fired Condition.

Process modeling of DJ2 was performed to evaluate the overall mass and energy balance of the unit under oxy-firing. Key results showed that while the radiant-dominant heat transfer surfaces (WW, SSH) transfer more heat to the steam under oxy-firing (as shown in the CFD modeling), the convective surfaces have decreased heat transfer (Figure 13). This balance of heat transfer that was achieved at a specific recycle rate allows for preservation of steam properties and flow, a key feasibility factor when evaluating a boiler retrofit scenario.

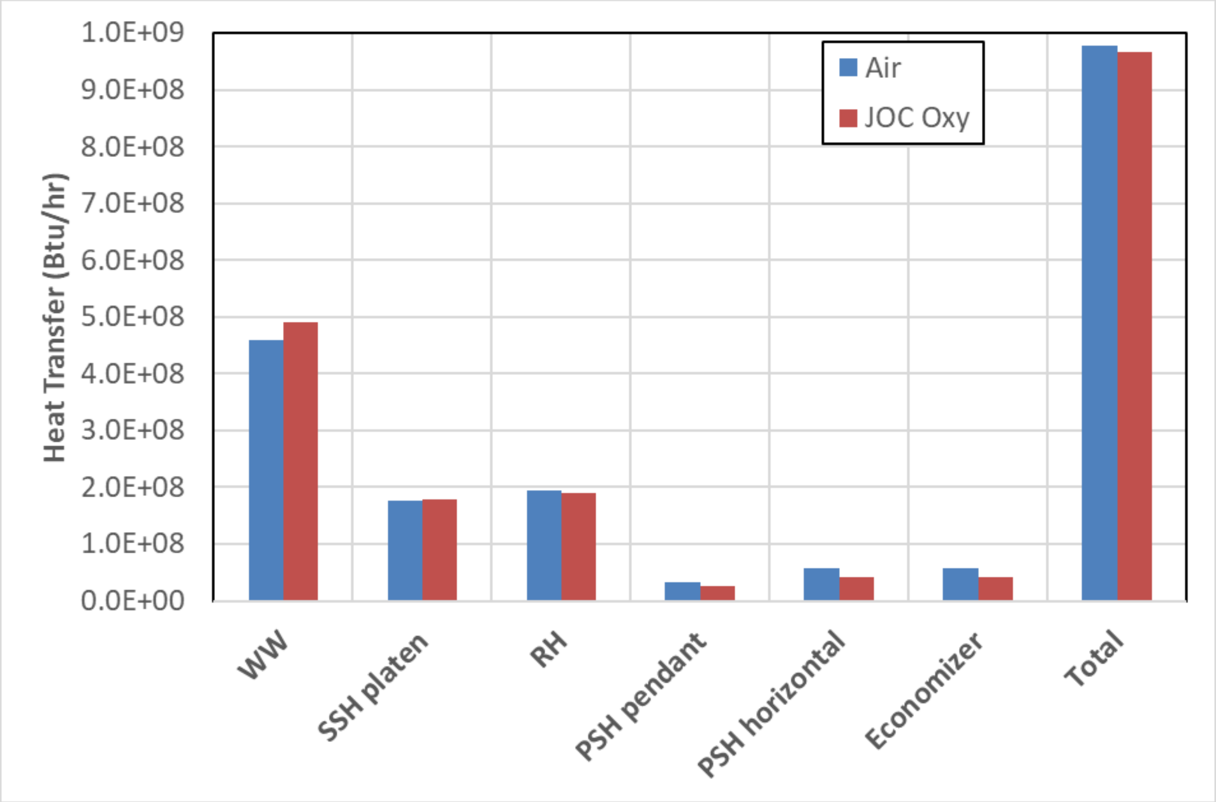


Figure 13. Overall Heat Transfer Assessment for Dave Johnston Unit 2

A subsequent Phase II Front-End-Engineering-Design (FEED) Study was completed in July 2021. The FEED study documents the preliminary engineering and design of the various process and balance-of-plant (BOP) components, which are the basis of the project cost estimate and schedule development. The results of the FEED Study validate the project's technical viability. REI further refined the CFD and process modeling in this study. Start-up and shut-down procedures were investigated, which involve firing the JOC burner on air. This led to a more detailed burner design, shown in Figure 14. The burner has an annular shroud design consisting of 4 annular registers. At the center of the burner is an igniter for startup. Surrounding the igniter is the first register, where an oxygen stream is introduced. The next register contains the fuel and carrier (FGR with some oxygen enrichment). The third register provides an outer annular stream of oxygen. The outer-most register contains an FGR stream with swirl vanes providing a temperature shroud for near burner components. This patented oxy-coal burner is suited for boiler retrofit applications such as DJ2 and does not require any structural or material changes to the existing boiler.

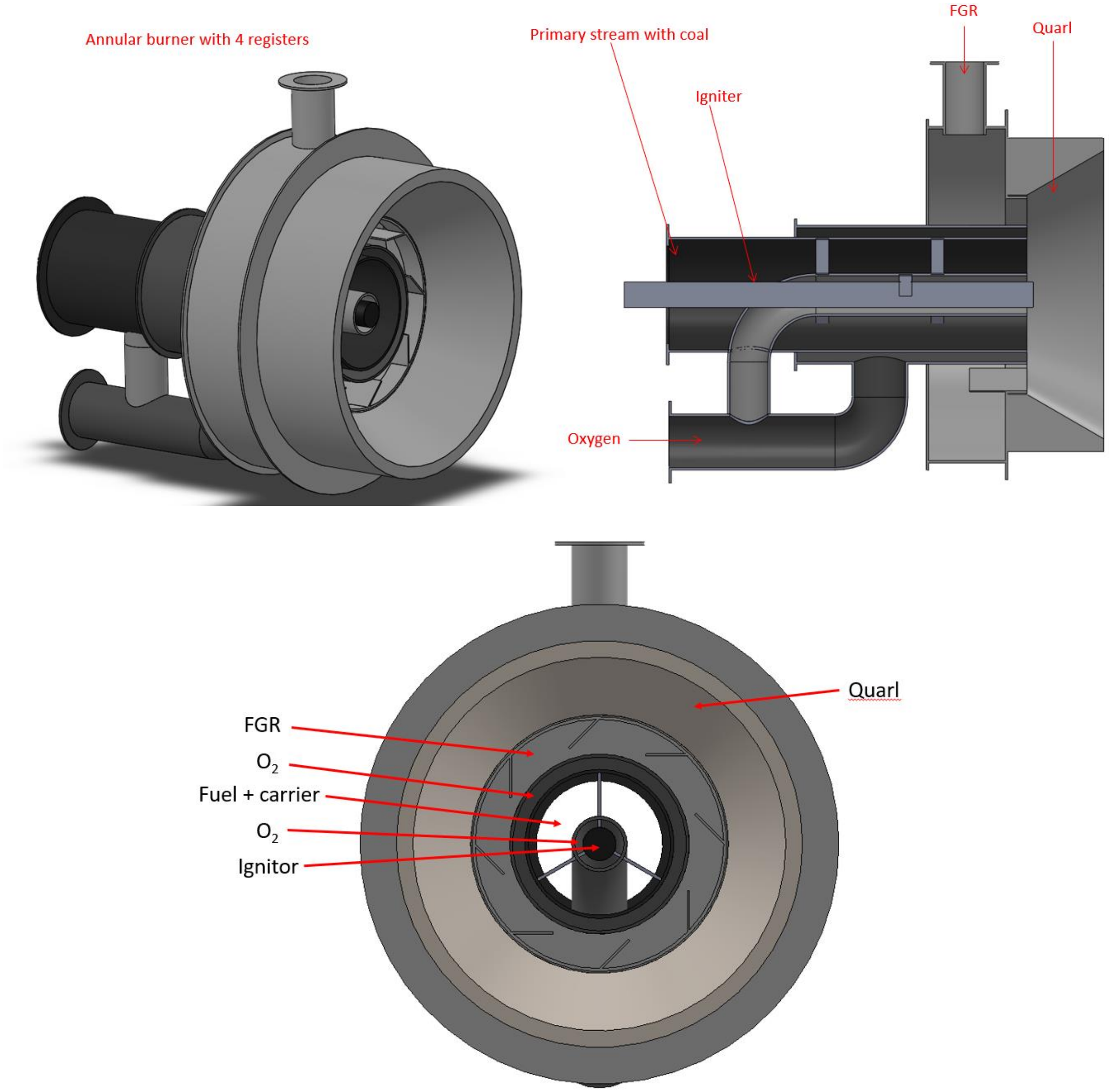


Figure 14. JOC Annular Shroud High-temperature Oxy-burner

The next phase of the project involves detailed engineering, permitting, procurement, and construction. The first step currently underway is full-scale single-burner testing. This testing is scheduled to take place Fall 2022 at GE's Clean Energy Center Industrial Scale Burner Facility (ISBF). The testing will be performed with a 60 MMBtu/hr burner firing PRB coal. Combustion parameters including firing rate, primary stream oxygen enrichment, FGR rate through the burner, air leakage, primary gas/coal ratio, and excess oxygen will be varied to investigate burner characteristics. Testing will also be performed under air-firing conditions. Metrics for evaluations focus on performance characteristics such as flame location/stability, local peak tube/burner temperatures and heat fluxes, carbon conversion (CO and carbon-in-ash), and NOx emissions. Detailed CFD modeling will be performed for comparison to test results. In preparation for testing, CFD modeling has been performed to aid in refractory design to ensure preservation of equipment under high-temperature oxy-firing. Key burner characteristics are predominantly axial flow with delayed fuel/oxidant mixing yielding elongated heat release while maintaining peak flame temperature >4000°F (Figure 15). Burner construction is complete and the burner has been installed at the ISBF as shown in Figure 16.

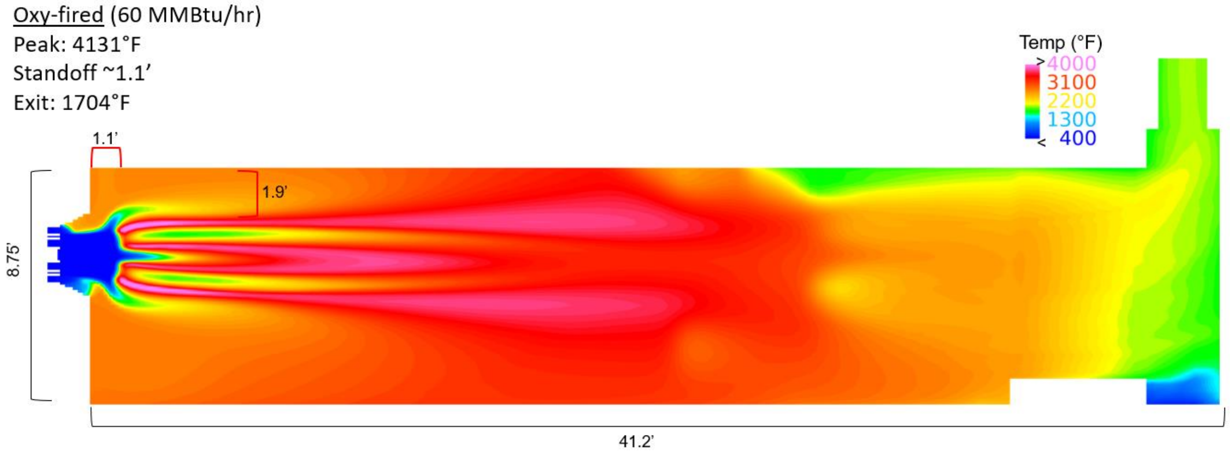
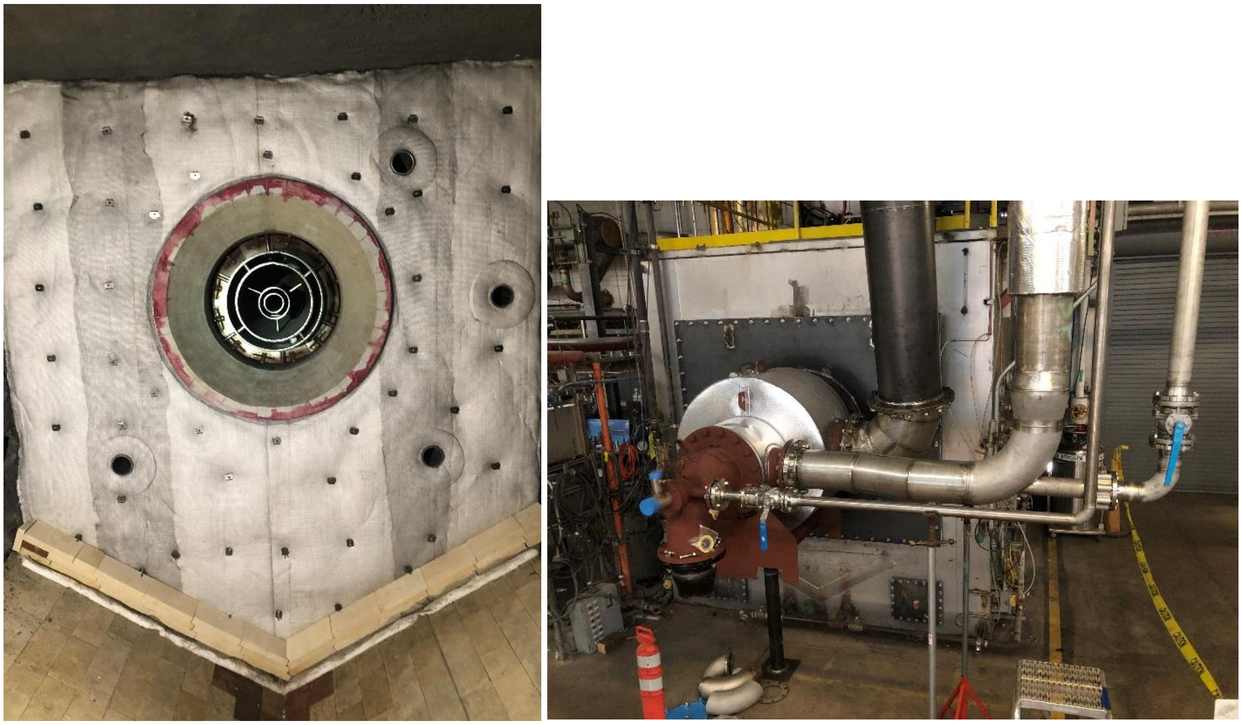


Figure 15. CFD modeling of the JOC Annular Shroud High-temperature Oxy-burner in the GE Clean Energy Center ISBF.



(a) **(b)**

Figure 16. JOC Annular Shroud High-temperature Oxy-burner installed in the GE Clean Energy Center ISBF (a) Internal View, (b) External View.

Conclusions

Reaction Engineering International's commercial and government R&D programs on the advancement of high-temperature oxy-coal technology has led to the development of patented burner design that is prepared for a full-scale demonstration. REI has coupled multi-scale experiments with CFD and process modeling tools to determine burner specifications that produce high flame temperatures along with localized cooling and protection of burner components and near-burner surfaces from high incident heat fluxes.

The burner patented by Jupiter Oxygen Corporation is being evaluated for a full-scale retrofit of PacifiCorp's Dave Johnston Unit 2. A Phase I feasibility study completed in May 2019 showed the technical and economic viability of the proposed project. During this phase, REI provided a conceptual burner design based on CFD modeling, including single-burner modeling and full-scale modeling of DJ2. Process modeling of the entire oxy-combustion system proposed at DJ2 was performed to evaluate energy balance considerations including fire-side/steam-side coupling. The modeling completed in Phase I showed that retrofit of DJ2 with the JOC burner results in stable flames with peak temperatures greater than 4000°F; acceptable protection of furnace surfaces from high-temperatures and high heat fluxes; existing boiler heat balance, steam flows and temperatures maintained; and no detrimental impacts to balance-of-plant identified.

A Phase II Front-End-Engineering-Design (FEED) Study was completed in July 2021. The FEED study documented the preliminary engineering and design of the various process and BOP components. The results of the FEED Study validated the project's technical viability and included refinement of the burner design to include air-fired operation for start-up and shut-down procedures. This design has now been fabricated and installed for an upcoming full-scale demonstration at GE's Clean Energy Center Industrial Scale Burner Facility. The testing will be performed with a 60 MMBtu/hr burner firing PRB coal and evaluate performance metrics such as flame location/stability, local peak tube/burner temperatures and heat fluxes, carbon conversion (CO and carbon-in-ash), and NOx emissions.

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Disclaimer

References

[1] http://www.eecpowerindia.com/codelibrary/ckeditor/ckfinder/userfiles/files/1_Boiler%20Tube%20failures.pdf