Proceedings of the ASME 2011 Power Conference
POWER2011
July 12-14, 2011, Denver, Colorado, USA

POWER2011-55270

BURNER COMPONENT UPGRADES FOR WALL-FIRED COAL BURNERS – RPI RESULTS AND EXPERIENCES

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ABSTRACT

Improving the operation and emissions performance of coal fired utility boilers equipped with first and second-generation wall fired low NO_x coal burners is of significant interest to many utility companies today. The recent development of cost effective components for existing first and second-generation wall fired burners permits better combustion performance, increased wear life reliability, and decreased NO_x emissions. Existing air register systems can typically remain in place, resulting in reduced capital cost and reduced outage time for installation.

Computational fluid dynamic (CFD) modeling is used to assist in the design of key burner components and operating conditions that enable further reduction of NO_x emissions. Results include better flame attachment, better airflow recirculation patterns, and early ignition and pyrolysis of the coal in a more controlled primary combustion zone. NO_x reductions of 10-20% have been demonstrated using burner component upgrades with improved overall boiler operation.

This paper gives a brief description of the component-only retrofit design methodology that Riley Power Inc., a Babcock Power Inc. company developed for other OEM's low NO_x burners in wall-fired furnaces. The numerical modeling to assist in the design of these low NO_x systems and the corresponding CFD results are also discussed.

INTRODUCTION

During the past two decades, reduction of NO_x emissions in pulverized coal firing systems has become a high priority for environmental authorities after the Clean Air Act of 1990 and the Clean Air Interstate Rule (CAIR) were promulgated. Among the available technologies, the installation of some form of low NO_x burner technology with or without an overfire air (OFA) system is a primary means or first step to meet EPA emission requirements and reduce the operating and maintenance cost of post-combustion solutions such as selective catalytic reduction (SCR). In order to meet the increasingly stringent NO_x emission requirements, utilities have recently focused on either replacing first or second generation low NO_x burners or upgrading existing burners with newer and more advanced low NO_x combustion technology. Within this context, the newer burner technology not only decreases NO_x emissions additionally 10-20% or more from controlled levels, but also provides greater operating longevity and decreased maintenance.

Since the early 1980s Riley Power Inc. (RPI), a subsidiary of Babcock Power Inc. has been developing the Venturi Series Burner technology to lower NO_x emissions from pulverized coal firing systems. This advanced controlled combustion technology is capable of achieving significant NO_x reductions in various types of applications including full burner installation or component only retrofit. The component only retrofit is often preferred by utility customers due to its cost effectiveness, because it involves fewer hardware modifications and easier, less time consuming installation. RPI determined that retrofitting existing original equipment manufacturer (OEM) low NO_x burners with RPI's Venturi Series Burner components would significantly enhance combustion system burner performance. To date, RPI has completed 14 components only retrofit projects totaling nearly 320 burners.

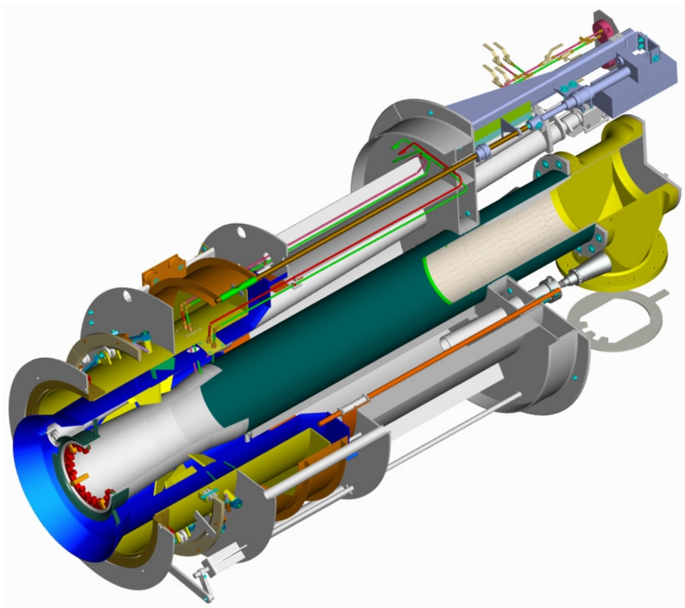

Figure 1: RPI VS III™ Coal Fired Low NO_x Burner

RPI has implemented components type upgrades to 1st and 2nd generation RPI burners as well as B&W DRB and XCL Burners. In all cases, CFD modeling was performed to refine the final burner design and to shorten the commissioning time by identifying the initial startup settings of the equipment. Field-testing of the installed equipment showed that the modeling accurately represented the field results.

In the past two years, RPI has performed CFD modeling of the same component retrofit methodology applied to other OEM's low NO_x burners where the components haven't yet been applied in a retrofit situation. The modeling results show that similar improved burner performance can be achieved on other low NO_x burner designs, by applying the same basic RPI components. The CFD results of the B&W XCL Burner, FW PF/SF Burner, and the FW IFS burner are discussed.

COMPONENT-ONLY RETROFIT METHODOLOGY OVERVIEW

Many pulverized coal wall fired utility boilers are equipped with 1st or 2nd generation low NO_x coal burners. These burners typically comprise a nozzle that fires a mixture of pulverized coal and air surrounded by two concentric cylindrically shaped barrels known as secondary (inner) and tertiary (outer) air barrels. The secondary and tertiary air barrels are oriented axial to the coal nozzle. These designs typically have an adjustable damper that controls the airflow into the secondary and tertiary air barrels, as well as axial or radial vanes in the tertiary air (TA) and possibly the secondary air (SA) annuli in order to create a swirling motion of the air exiting the burner. This common type of low NO_x burner is generally referred to as a dual air zone burner, double register burner, swirl induced burner, or some combination thereof. Dual air zone burners were designed for their low NO_x capabilities, specifically the ability to stage the combustion process by gradually mixing the combustion air with the coal. The gradual mixing of air and coal reduces the peak flame temperature and creates a more oxygen-starved environment as compared to traditional burner designs, two critical mechanisms for low NO_x combustion.

The same design capabilities that give dual air zone burners low NO_x capabilities can also create an adverse impact on flame length, combustion efficiency, CO emissions, and unburned carbon in the fly ash. RPI's latest burner design, the VS III™ low NO_x coal-fired burner, shown in Figure 1, addresses these deficiencies while lowering NO_x emissions by another 10-20% beyond other OEM burners. The key to the design is several critical components that create very precise air and coal flow dynamic interactions. These critical components can be added to numerous OEM dual air zone burners.

RPI's approach to improving the performance and reliability of existing OEM low NO_x burners is straightforward. First, the existing coal nozzle is removed and replaced with RPI's patented Venturi coal nozzle assembly (US Patent 6,474,250) and associated anti-roping device (US Patent Application #12/112,571). Second, if the existing coal nozzle employs a tangential inlet, the nozzle inlet receiving chamber is replaced with RPI's standard straight inlet receiving chamber. Minimal coal piping modifications are required to accommodate RPI's standard inlet receiving chamber. However, if the existing nozzle inlet receiving chamber utilizes a straight inlet, it may be reused and preclude any coal piping modifications. Third, air diverters, similar to the secondary and tertiary air diverters used on the RPI VS III™ burner, are installed on the existing inner and outer barrels of the OEM burners. Lastly, fixed swirl vanes are installed within the inner air zone if either fixed or adjustable swirl vanes don't already exist.

These are the only modifications required to significantly improve the near field flow patterns and downstream recirculation zones of the existing OEM low NO_x burner. The typical components that would be added to the existing OEM low NO_x burners are illustrated in Figure 2. The SA Swirl Vanes and Coal Spreader Assembly are applied only if necessary, as described in the following section.

DESCRIPTION OF COMPONENT PERFORMANCE

The anti-roping device, in tandem with a ceramic kicker located at the entrance to the coal nozzle, redistributes the coal particles entering the pulverized coal burner to break up the coal "rope" that develops in any typical coal piping system. Coal ropes can contribute to high CO emissions and high flyash UBC by presenting too dense a coal stream to the combustion field.

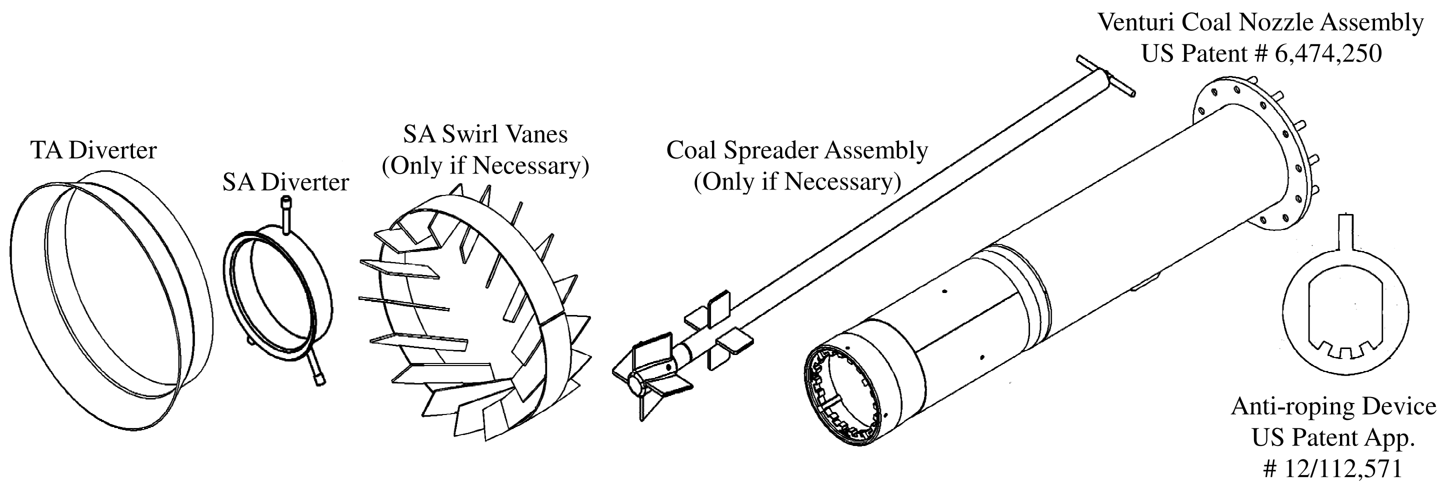

Figure 2: Typical Shippable Components

The venturi coal nozzle assembly then takes the homogeneously mixed coal stream and concentrates the fuel in the center of the coal nozzle creating a fuel-rich mixture with a leaner mixture or concentration of coal near the nozzle periphery. This helps to reduce the NO_x by creating fuel rich combustion, which minimizes fuel NO_x conversion and reduces peak flame temperature to reduce thermal NO_x formation. It also helps to reduce the wear of the flame stabilizer ring (FSR) by having the larger heavier coal particles pass through the nozzle center untouched by any burner part. The leaner mixture on the nozzle periphery passing over the flame stabilizer ring teeth stimulates early ignition and pyrolysis of the coal, which also helps to reduce the NO_x emissions and provides excellent and uniform flame attachment.

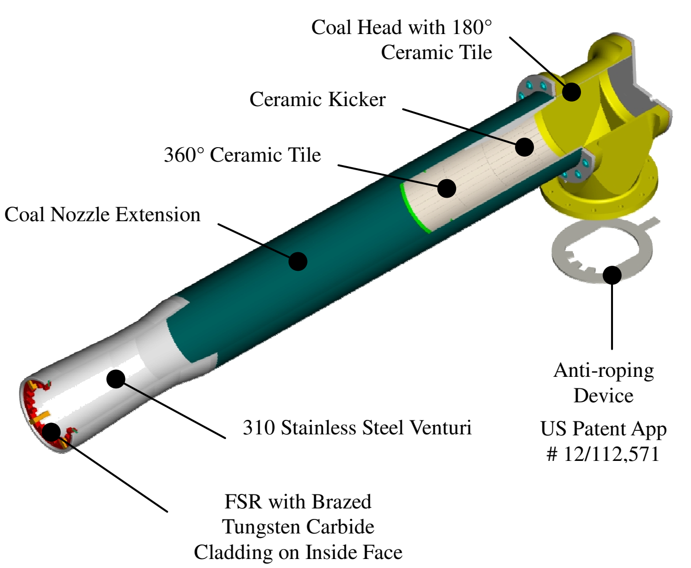

Figure 3: Venturi Coal Nozzle Assembly, Patent 6,474,250

On boilers with limited furnace depth that require flame length control to preclude flame impingement, a coal spreader will enable further control of the primary mixing in the furnace.

The VS III™ Burner low NO_x venturi coal nozzle assembly is illustrated in Figure 3.

The existing air register of the original OEM burner is reused for control of the secondary air delivered to the furnace. The register is typically divided into two (2) streams: secondary (inner) and tertiary (outer) air. The split between secondary and tertiary air streams will be controlled using the existing dampers and swirl vanes. Previous testing conducted in a 100 MMBtu/hr combustion test facility has shown the flow split between SA & TA annuli to have a strong influence on burner NO_x performance **[1]**. Damper and swirl vane settings for optimum flow splits are determined and preset based on the CFD modeling of the burner. The existing tertiary air swirl vanes are typically adjustable from the burner front plate and must be functional at the time of the retrofit. If not already present a set of fixed swirl vanes will be installed inside the inner air annulus, enhancing the gradual mixing of fuel and air.

A new secondary air diverter located inside the inner air annulus causes the air stream to initially flow away from the primary air combustion zone thus creating an oxygen-lean zone immediately at the burner discharge. It also creates recirculation zones downstream of the secondary air diverter that are necessary to produce a well-attached and stable low NO_x coal flame throughout the boiler load range. The tertiary air diverter is located in the outer air annulus and diverts tertiary air away from the primary combustion zone, further controlling the near field burner zone stoichiometry. This dual air stream and air diverter concept enhances the gradual mixing of air and fuel, controls the stoichiometry in the primary combustion zone, reduces the peak flame temperature and provides an environment for rapid devolatilisation of the coal in a reducing

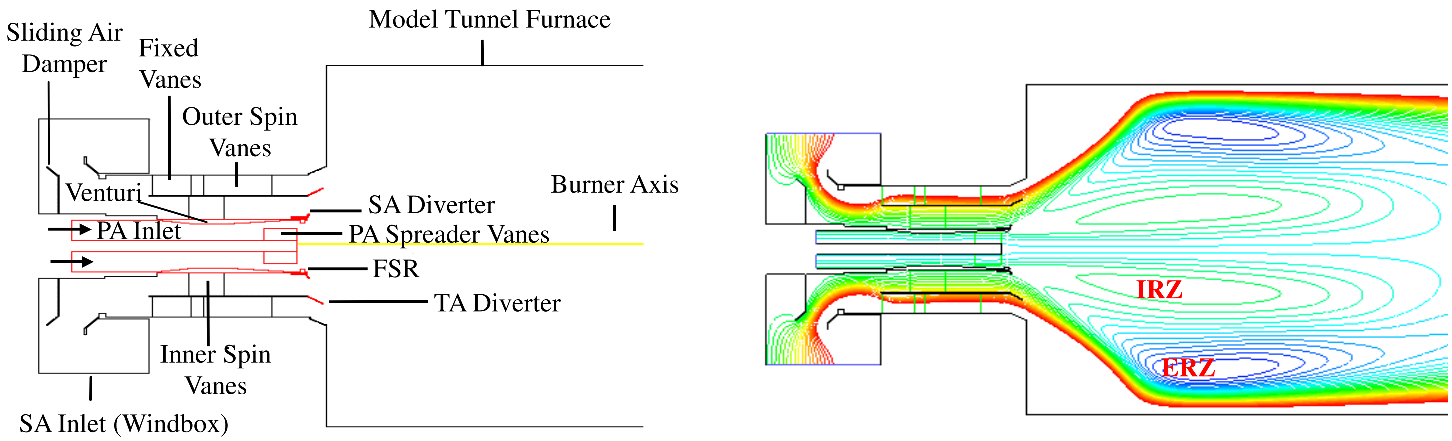

Figure 4: CFD Single Burner Model Geometry (left), and Computed Streamlines (right) for Component-Only Retrofitted B&W XCL Burner

atmosphere, all of which are crucial elements of low NO_x combustion.

The benefits demonstrated from this component retrofit approach on multiple installations have been thoroughly discussed previously **[2-4]**.

Performance benefits from these component upgrades can include:

- Improved reliability and wear life of primary air side burner components
- Lower NO_x emissions under the same load conditions
- Lower unburned carbon (UBC) in the flyash
- Improved flame length and CO emissions control
- Improved flame scannability
- Reduced furnace exit gas temperature (FEGT)
- Reduced attemperator spray flow

Economic benefits from these components can include:

- Reduced outage time (over 50% reduction) during installation as compared to a complete burner replacement. None of the proposed modifications require burner removal or windbox alterations. All modifications are completed from the furnace or burner deck. The existing air register system remains intact, saving significant demolition time if completely new burners were to be installed.
- Low capital cost. Typically 30-50% of the cost of a complete burner replacement.
- SCR Ammonia consumption savings

CFD BURNER MODELING

CFD is a powerful tool and has been used by RPI for over 25 years to assist with the design of burner replacement or burner retrofit activities. CFD modeling permits customized burner hardware and also minimizes start-up and setting time in the field by identifying initial burner settings. In terms of customizing the burner hardware and minimizing on-site initial start-up setting time, Particularly, RPI employs single burner CFD modeling to determine the desired near-field flow patterns for best flame behavior (e.g., flame length and attachment). The single burner model uses aero-dynamics only to establish near-field recirculation zones, which are essential to produce good low NO_x combustion. In this approach, single burner air flow is simulated in an idealized tunnel furnace representing the equivalent firing region of the burner. The model tunnel diameter is similar in size to the actually firing environment but without flame-to-flame interactions that may affect the flow behavior several throat diameters from the firing wall **[5]**.

RPI's experience has shown that when single burner modeling exhibits optimal near-field flow behavior, the burner performance in the field correlates well with the CFD results. For example, predicted near burner results in the form of streamline plots for an RPI low NO_x CCV-DAZ® coal burner at three different tertiary air (TA) swirl vane settings were given in a previous study **[6]**. Illustrating the flow directions and highlighting the internal recirculation zones, streamlines are useful in the single burner modeling. The actual UBC and NO_x emissions were also reported. Results indicated that, as the primary air (PA) driven internal recirculation zone (IRZ) is balanced with the secondary air (SA) driven external recirculation zone (ERZ), the balanced flow behavior leads to a reliable, low NO_x flame where the UBC and NO_x emissions are both at optimum levels **[6]**. As the flow pattern deviates from the "optimum" pattern, where too much PA recirculation or too

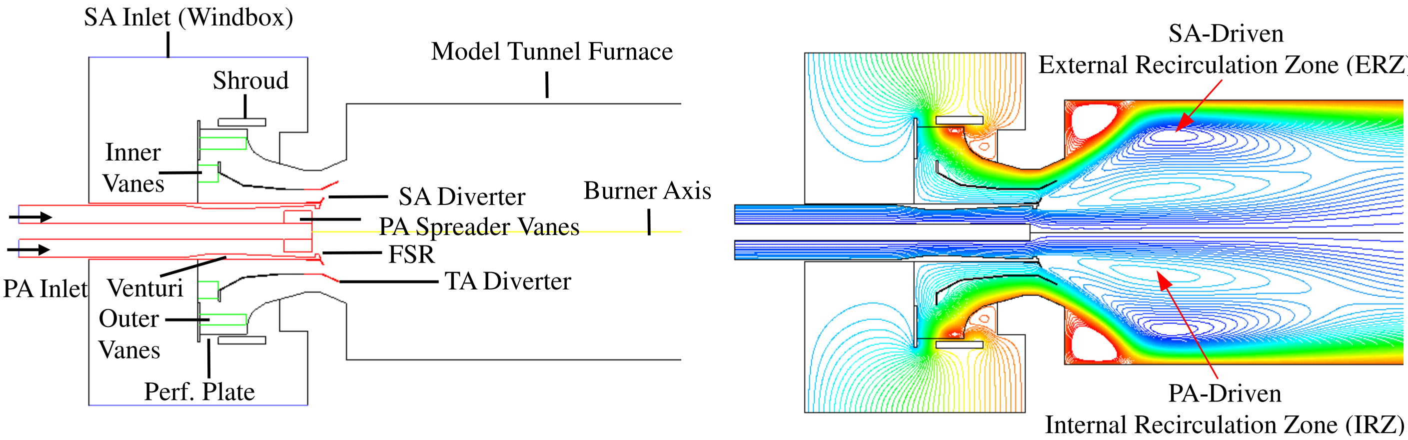

Figure 5: CFD Single Burner Model Geometry (left), and Computed Streamlines (right) for Component-Only Retrofitted FW IFS Burner

strong PA axial momentum occur, the measured UBC and NO_x emissions also diverge from the optimum levels. The responsiveness of the test data demonstrates the good correlation between the actual burner behavior in the field and the RPI's CFD model predictions.

LOW NO_X COMPONENT-ONLY RETROFIT OF B&W COAL FIRED XCL BURNERS

Due to economic and installation advantages, a partial burner upgrade is more preferable for some combustion system improvement projects **[4]**. In 2006, RPI performed a component-only retrofit to the existing B&W XCL dual register burners of a nearly 350 MW wall-fired furnace burning a bituminous coal. Based on RPI's component-only retrofit methodology, the modifications included only the installation of the patented venturi coal nozzle with low swirl coal spreader, FSR, and special air diverters. The burner CFD modeling was utilized as a design tool to customize the burner hardware and to determine the burner initial start-up settings.

In Figure 4, the burner model geometry is given (left), where the RPI low NO_x coal burner components are colored in red. The post-retrofit computed streamlines are also shown (right). The streamline results indicate that the component-only retrofitted burner geometry produces good near-field aerodynamics where well-established recirculation zones are clearly seen. This type of behavior in the burner near-field region is essential for good flame attachment at the burner tip to lower UBC values. Additionally, the discrete recirculation zones of PA flow and SA flow streams are of significance to reduce NO_x emissions.

The pre-retrofit and post-retrofit acceptance test data were also consistent with the CFD findings. NO_x emissions were reduced by 10% and unburned carbon (UBC) in the flyash was simultaneously reduced by 15% from the component retrofit alone.

LOW NO_x COMPONENT-ONLY RETROFIT OF FW COAL FIRED BURNERS

In addition to the completed component-only retrofit projects, RPI conducted several in-house CFD modeling studies within the past two years to determine the applicability of RPI's component-only retrofit methodology to the other OEM dual-air register type burners. FW IFS and FW PF/SF burners were used in those studies where the burner modeling was the primary design tool. Multiple burner cases were conducted for both the original FW burners and the RPI component-only retrofit burner designs. Modifications to the original FW burners include only the critical VS III™ low NO_x coal burner components: coal nozzle with low swirl coal spreader, FSR, and SA and TA diverters. In the case of the FW PF/SF burner, fixed SA swirl vanes were also added for enhanced mixing.

In Figure 5, the CFD burner model geometry with the Venturi Series burner component-only upgrade is given for the FW IFS burner (left). As the figure indicates, the modification includes only the major VS III™ low NO_x coal burner components (colored in red): patented coal nozzle with low swirl coal spreader, FSR, and SA and TA diverters.

Figure 5 also shows the post-retrofit computed streamlines (right). The indicated strong PA-driven IRZ and SA-driven ERZ would produce very well attached flame with a relatively short PA core flow down the burner axis. This would result in shortened flame length and increased PA and coal dust mixing within the flame base, which would lead to lower UBC values. Also, the separate internal and external recirculation zone structure completely isolates the primary ignition zone from

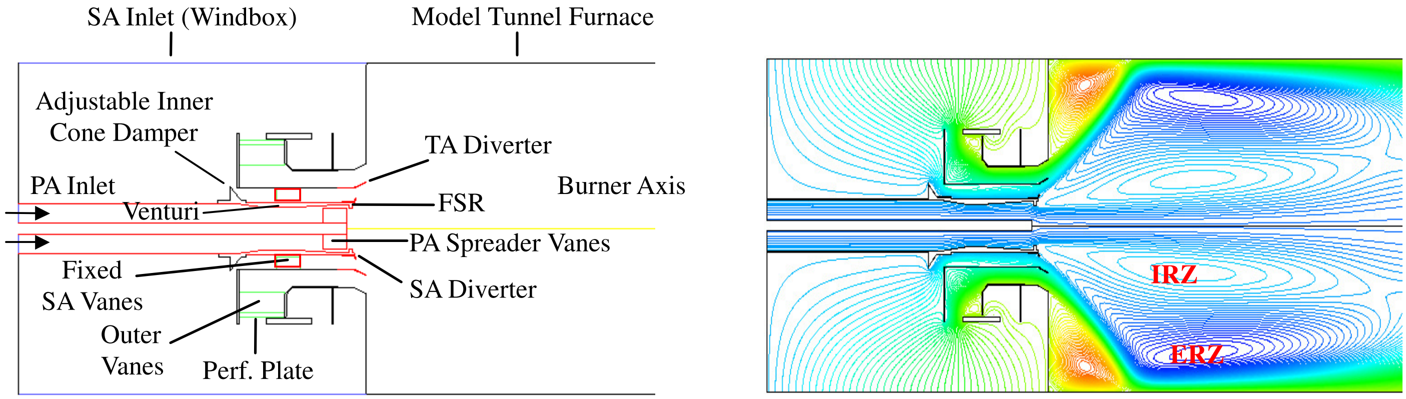

Figure 6: CFD Single Burner Model Geometry (left), and Computed Streamlines (right) for Component-Only Retrofitted FW PF/SF Burner

oxygen in the SA/TA flow to further reduce NO_x production. In contrast, the streamlines for the original burner configuration (not shown here) lack the PA-driven IRZ, which can result in a longer tubular flame with high UBC values due to insufficient mixing of coal with the combustion air.

The model geometry for another Foster Wheeler dual-air register type burner retrofitted with the VS III™ low NO_x coal burner components is provided in Figure 6 (left). The retrofit of this FW PF/SF type burner is limited to the installation of VS III™ low NO_x coal burner components (colored in red) including the venturi coal nozzle with integrated FSR and low swirl coal spreader (US Patent #6,474,250), SA and TA diverters, and fixed SA swirl vanes.

In Figure 6, the computed streamlines for the post-retrofit FW PF/SF type burner is also shown (right). The desired recirculation zones for good flame attachment and low NO_x are clearly seen in this figure. The computed results for the original burner configuration (not shown here) also have a somewhat similar flow pattern with multiple recirculation zones. However, computed streamlines for the original burner configuration indicate early mixing of the PA flow with the oxygen rich SA flow is occurring very close to the burner throat, which can lead to high NO_x values. Excessive slagging around the burner throat is another drawback from the early mixing at the burner throat.

SUMMARY

The operators of coal fired power plants today are interested in improvements that can be made to prevent the adverse impact on boiler performance, combustion efficiency, and CO emissions associated with existing low NO_x burners, without the high cost and long outage duration of traditional full burner replacement. RPI has demonstrated components-only burner solutions to address these problems on several low NO_x burner designs. In all cases, CFD modeling was used to assist in the burner design and proved valuable. The same approach has now been applied to several other low NO_x burner designs, demonstrating similar results to those observed in new burner installation. In the competitive atmosphere of today's energy market, it is important for utility companies to seek proven, cost effective, and technology-based solutions for achieving environmental compliance goals.

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