LOW NOx CONTROLLED COMBUSTION VENTURI (CCV®) BURNERS FOR ALL WALL-FIRED BOILERS FIRING PULVERIZED COAL

Riley Power
a Babcock Power Inc. company

OVERVIEW

The first generation Low NOx CCV® Burner was introduced in the early 1990's by Riley Power Inc., a Babcock Power Inc. Company, to respond to the market demand to meet lower NOx emissions. The original CCV® burner was designed for all wall-fired applications firing pulverized coal, including front, rear, opposed, and cellfired arrangements. This design was subsequently followed by the Dual Air Zone (DAZ) CCV® burner that offered separate air flow control and improved levels of NOx reduction.

Our latest design, the VS III™ burner, has upgrades in both design and have been incorporated to provide improved mechanical reliability and performance.

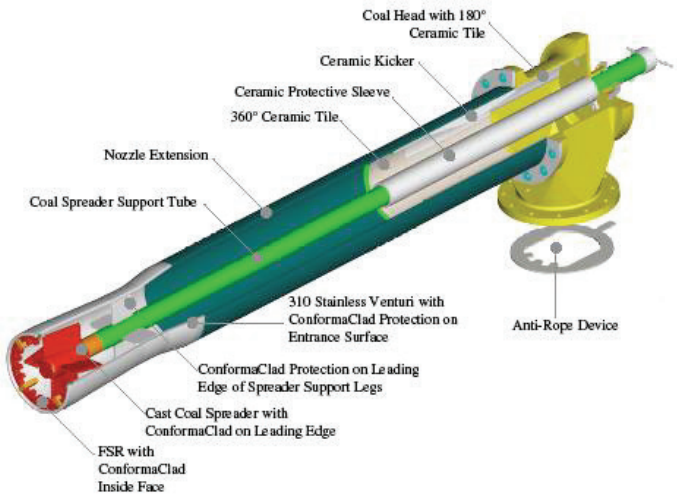

Figure 1 VS III™ Burner Low NOx Coal Nozzle Design

The Riley Power Inc. VS III™ low NOx coal burner utilizes a Riley Power Inc. patented (US Patent 6,474,250) low NOx venturi coal nozzle and low swirl coal spreader located in the center of the burner for NOx emissions control. *Figure 1* shows a schematic of the low NOx venturi coal nozzle design.

FEATURES / BENEFITS

- Nearly 3000 units sold for over 150 utility and industrial boilers generating from 20 to 1,300 MW per unit. Patented venturi coal nozzle assembly included with every VS III™ burner
- Concentrates the coal to the center providing a rich mixture which is then divided into smaller individual streams.
- Produces a less turbulent, slower mixing flame, providing more gradual coal/air mixing, and lower NOx.
- Excellent flame length and shape control.

Low overall pressure drop

- Minimizes losses through the burner to 3.5 - 4.0" wg.
- Lower operating cost.

VS III™ burner incorporates two separate air zones

- Improves the ability to stage the air surrounding the primary combustion zone.
- Allows for independent control of secondary and tertiary air zones providing better NOx control, often eliminating the need for OFA.
- Independent burner air flow measurement probes are available.
- Register swirl vanes and operating mechanism designed for many years of reliable mechanical operation.
- Burner air flow shroud incorporates specially machined edges to shed fly ash for years of trouble-free operation.
- Many burners have been in operation for over 10 years without mechanical binding issues.

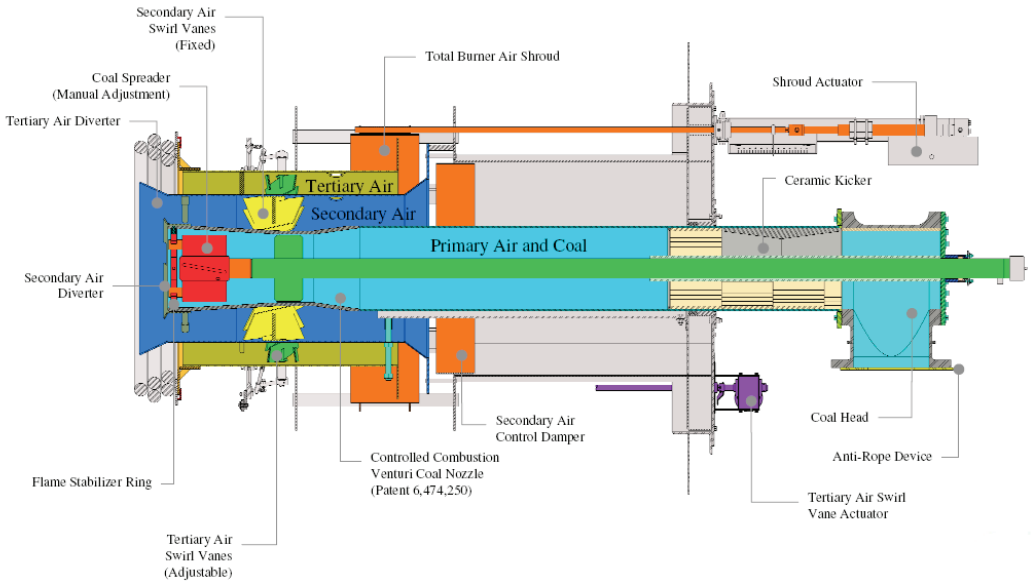

Figure 2

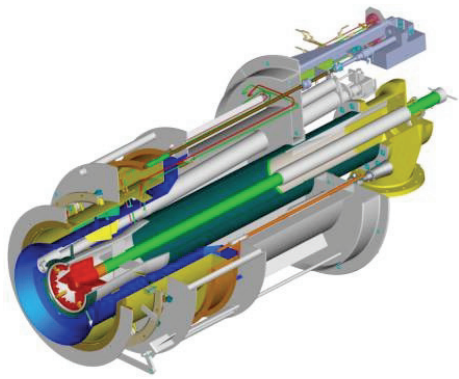

Figure 3 VS III® Burner – Key Features

- Riley Power Inc. Combustion Test Furnace
- 100 mmBtu/hr capacity
- Bituminous Coal

The anti-roping device, in tandem with a ceramic kicker located at the entrance to the coal nozzle, is designed to redistribute the coal particles entering a pulverized coal burner and break up the coal "rope". The venturi nozzle concentrates the fuel in the center of the coal nozzle creating a very fuel-rich mixture. As this mixture passes over the coal spreader, the blades divide the coal stream into four (4) distinct streams, which then enter the furnace in a gradual helical pattern producing very gradual mixing of coal and air.

As shown in Figure 2, the combustion air passageway into the furnace is divided into two (2) streams; secondary and tertiary air, with independent flow and swirl control.

As shown in Figure 3, the VS III™ burner provides several unique features for controlling NOx emissions as well as other emissions, flyash unburned carbon and combustion characteristics (flame length) throughout the load range with the burner on-line. Manual adjustability is provided to compensate for changes in fuel composition when necessary. The design provides manual on-line adjustability to minimize NOx emissions but can also be "de-tuned" to minimize flyash unburned carbon (UBC) if necessary.

FEATURES / BENEFITS (CONT.)

Flame Stabilizer Ring (FSR) included in all new VS III™ or retrofit burners

- Enhances flame attachment.
- Further reduces NOx emissions.
- Maintains or reduces fly ash UBC/LOI.
- Reduces slagging at burner front and lower furnace walls.

For most retrofit applications, burners plug into existing burner openings without modifying pressure parts

- Easier and less costly retrofit (material, labor and time off-line).

Extensive experience retrofitting cell fired arrangements

- Nearly 8,000 MW of cell-fired utility units have been successfully retrofitted by Riley Power with no pressure part replacement, no OFA, and no burner respacing.

The unique flow aerodynamic pattern produced by VS III™ burners is shown through CFD modeling in *Figure 6.* Note the strong "outside-in" recirculation of the secondary and tertiary air flow streams into the flame zone. This "outside-in" recirculation occurs uniformly around the entire burner throat opening. The "outside-in" recirculation will keep the hot sticky ash particles from collecting on and adhering to the burner throat, which will minimize slag buildup and subsequent eyebrows.

Figure 4 VS III™ Low NOx Burner Flame in Combustion Test Furnace

Figure 5 VS III™ Low NOx Burner Flames in 340 MW Foster Wheeler Boiler (2 flames shown)

FEATURES / BENEFITS (CONT.)

Wear protection options available for VS III™ coal nozzles

- Provides extended life.
- Cast coal spreaders – cast Riloy 74; protective tungsten carbide coating (Riloy 76) can also be added to leading edges.
- Alumina ceramic protective sleeve for spreader support tube.
- Ceramic lined coal head.
- Single piece stainless steel venturi with Conforma® Clad protective coating.
- Ceramic lined coal nozzle.

In-house CFD modeling capability

- Predict burner settings necessary to achieve optimum burner aerodynamics for low NOx emissions and low UBC.
- Optimize design of FSR.
- Furnace modeling.
- Analyze furnace gas temperature, CO and O2 profiles which will result from low NOx retrofit.
- Design boundary air system for protecting waterwalls from corrosion, if needed.
- Minimize time and cost required to tune burners during commissioning.

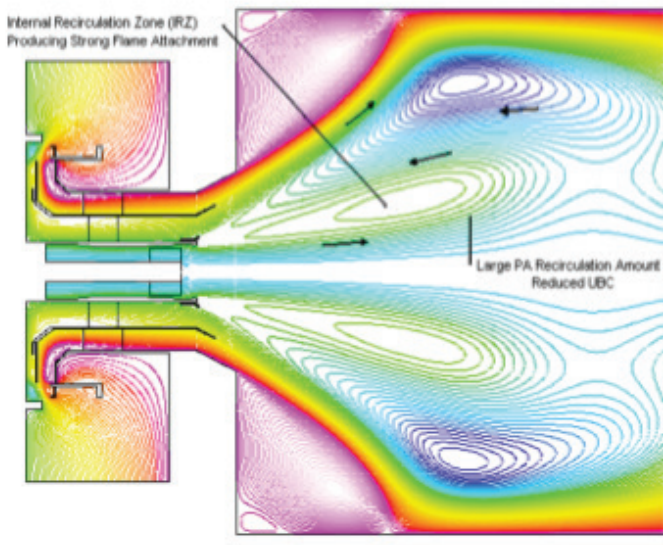

Figure 6 Riley Power Inc. VS III™ CFD Modeling Results

APPLICATION OF IGNITERS TO VS III™ BURNERS

It is Riley Power Inc.'s standard practice to locate igniters in the secondary air annulus of the VS III™ burner, as shown in *Figure 10*. Riley Power Inc.'s experience indicates that NOx reduction is strongly dependent upon the burner aerodynamics and near field flow patterns within the first few burner throat diameters downstream of the burner discharge. The igniter profile is kept to a minimum to avoid flow obstruction that can diminish the swirl produced by the SA swirl vanes.

Note that scallops and cutouts are not needed to accommodate the igniters and scanners providing a very symmetrical design of the burner exit.

Figure 7 210 mmBtu/hr capacity burner on Foster Wheeler unit after 2 ½ years of operation (medium abrasive Galatia Bituminous coal)

Figure 8 Coal Spreader with Conforma Clad® coating after 2 years of operation (highly abrasive Bituminous/pet coke blend)

Figure 9 150 mmBtu/hr capacity burner after 3 years of operation on PRB Coal – 750 MW Opposed fired boiler

Figure 10 VS III™ Burner Installation w/Igniter in SA Annulus