CFB Boiler Upgrades at IRPC Restore Capacity, Improve Reliability, and Reduce Emissions

PROJECT CASE HISTORY

Plant Description

Integrated Refinery & Petrochemical Complex (IRPC), the first fully integrated petrochemical complex in Southeast Asia, is located in an industrial area of Rayong, Thailand, with energy and sea port operations to support the area's businesses. A subsidiary of Global Power Synergy PCL, IRPC Clean Power Company, Ltd., (IRPC CP) owns and operates a cogeneration plant that produces and sells steam and electrical power.

The existing circulating fluidized-bed (CFB) boiler was commissioned in the mid-1990s. It is comprised of a naturally circulating water-cooled furnace, primary/secondary/tertiary superheaters, and economizer.

The CFB steam generator was designed with a maximum continuous rating (MCR) main steam flow of 130 T/h (286,600 lb/h) at 525C (977F) and 115 bar (1668 psi), with a normal feedwater temperature to the boiler of 195C (383F) while firing bituminous coal.

For emissions control, the unit included a mechanical system for limestone addition into the furnace for sulfur oxides (SO_x) control, staged combustion for nitrogen oxides (NO_x) and carbon monoxide (CO) control, and an electrostatic precipitator (ESP) for particulate matter control.

Project Challenge

Immediately after final commissioning and commercial operations were turned over to IRPC, the unit began experiencing operational and maintenance issues. The primary operational issue was the inability to control furnace temperature. The high furnace temperatures resulted in the unit typically being run at no higher than 70% MCR load.

The unit also experienced maintenance issues with high levels of erosion at the tube-refractory interface and the external recirculation loops (L-valves). Significant back sifting was occurring through the primary air distribution system (bubble cap arrangement and design) in the lower furnace, as well as several other operation and maintenance issues that had to be addressed to improve the reliability of the unit.

Many enhancements used on properly designed CFB boilers can be retrofitted onto existing units, and thus allow operation with improved reliability and reduced maintenance.

Solution

Babcock & Wilcox (B&W) conducted an extensive engineering review and determined that 100% MCR operating condition of the CFB boiler could be achieved by considering the following key functional conditions and fundamentals of the CFB design:

- The capability to control the furnace temperature within a proper range, requiring:
  - Recycling sufficient solids to the furnace for both steady loads and transient conditions
  - Producing and maintaining sufficient solids inventory in the furnace to allow the necessary heat transfer for temperature control, in conjunction with good distribution of the recycle solids to the furnace
  - Proper fuel distribution into the primary zone at the bottom of the furnace
- Proper fuel/air mixing in both the primary and secondary zones
- The capability to adjust primary air/secondary air splits
- The capability to inject sufficient limestone with good distribution to the furnace
- Controls capability to maintain the necessary conditions with the ability to respond to changes in fuel, load, demand, ambient conditions and other conditions

B&W Scope

To achieve these project goals, B&W's modifications focused on three areas: furnace temperature control, furnace heat absorption and erosion protection, and emissions control.

Furnace temperature control

The furnace operating temperature depends on achieving a balance between the amount of furnace inventory that is developed, the heat transfer that occurs between the solids in the furnace and the furnace heating surface, and the heat that is released during combustion of the fuel.

The furnace inventory on the IRPC CFB steam generator is controlled using a two-stage particle capture and recycle system. The first stage is accomplished by U-beams located both in the furnace and after the furnace exit. The second stage is by a combination of an air heater outlet hopper and the first field of an electrostatic precipitator (ESP).

Primary solids recycle modifications

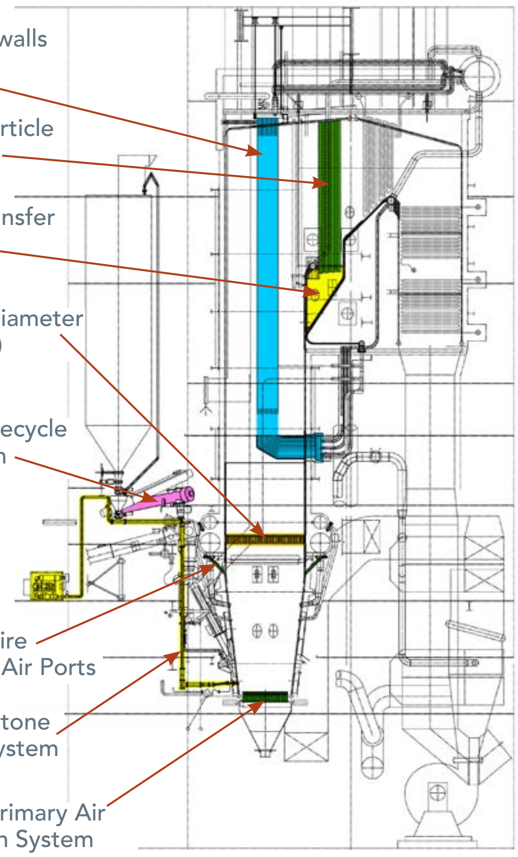
Prior to the retrofit, solids exited the U-beams, entered a particle storage hopper, then were recycled back to the furnace through external loops (L-valves). The L-valves were very inconsistent in their ability to return the captured solids back to the furnace, resulting in a lower than expected furnace inventory and an unacceptably high furnace operating temperature.

B&W removed the L-valves and replaced the particle storage hopper with a particle transfer hopper. All solids captured by the U-beams are recycled back to the furnace through the self-controlling particle transfer hopper. This design effectively recycles all the captured material back to the furnace without the significant maintenance and control issues associated with an external recirculation loop.

Secondary solids recycle modifications

The retrofit modifications to the secondary solids capture and recycle system consisted of converting the recycle ash vacuum transport system into a vacuum/pressure system and the replacement of the original air heater hopper discharge screw conveyor with mini-hoppers. B&W also modified the injection system to more evenly distribute the recycled solids into the furnace.

The advantage of a two-stage solids capture and recycle system is that the flow rate of secondary solids recycling can be adjusted to control the furnace operating temperature and furnace inventory. This feature allows load changes or operational upsets to be handled without large upsets to the steam generation process.



Primary modifications to IRPC CFB boiler.

Furnace heat absorption and erosion protection

The original furnace arrangement had the following serious deficiencies leading to operational and maintenance issues:

- The transition between the refractory-coated portion and the bare portion of the wall experienced significant levels of erosion in this area and caused excessive maintenance and reliability issues.
- The heat transfer surface in the furnace was insufficient when combined with the lower-than-expected furnace inventory. This caused the furnace to operate at elevated temperatures and SO_2 emissions levels.
- An insufficient lower furnace plan area resulted in high flue gas velocities. IRPC unit operators limited the use of fresh inert material to make up the deficiency in furnace inventory to limit erosion rates in the furnace, but this resulted in the unit running at a de-rated load.

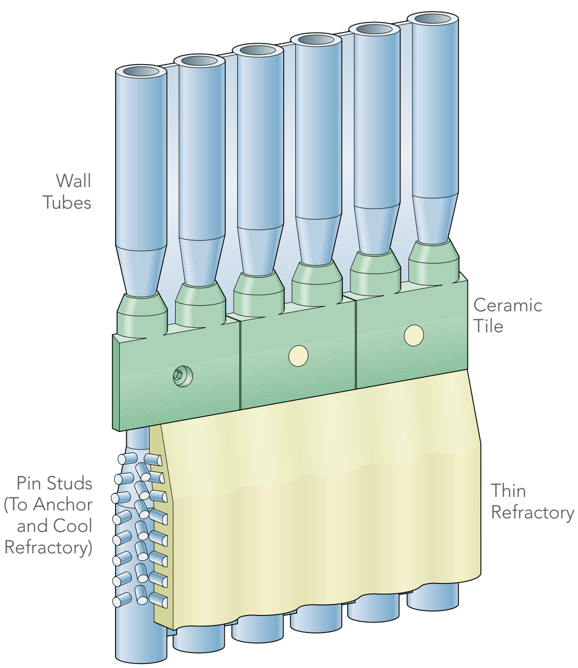
Furnace modifications

The retrofit project included two large modifications to the furnace to improve the performance of and reduce the maintenance on the unit while designing within the limitation of the fixed furnace size.

The first modification was the addition of two water-cooled wing walls on the rear wall of the furnace. The additional water-cooled wing walls were intended to lower the furnace operating temperature without relying on the addition of fresh inert material to raise furnace inventory.

The second modification was the addition of a reduced diameter zone (RDZ) at the interface between the refractory coated and bare tube surfaces in the lower furnace. The RDZ is a very effective method of significantly reducing the erosion at the refractory-to-bare-tube transition and is easily maintained.

In consideration of the modifications to the furnace, B&W performed a detailed circulation analysis to ensure the existing furnace water walls, existing wing walls, and new wing walls would perform within its circulation design standards. The circulation analysis was also used to determine the appropriate number of risers and supplies to add as part of the retrofit.



The reduced diameter zone tube section has proven to reduce maintenance by eliminating localized membrane wall erosion above the refractory interface in the lower furnace.

Primary and secondary air distribution

Primary air distribution grid modifications

The air distribution grid on a CFB boiler is designed to provide uniform distribution of primary combustion air across the entire bottom of the furnace while simultaneously preventing the back-sifting of bed material into the wind box or air distribution headers. The original system experienced considerable erosion of the bubble caps and the air distribution grid design was incapable of providing good air distribution while preventing back-sifting of bed material.

B&W conducted a computational fluid dynamic (CFD) analysis and engineered a redesigned air distribution system which included repairing and reusing the existing air supply headers and most of the stems and redesigning the bubble caps for more effective air distribution.

The redesigned bubble caps and bifurcated stems were part of the modified primary air system which provided more effective air distribution to the lower furnace.

Secondary air modifications

Between 40 to 60% of the total air enters the CFB furnace through the primary air distribution grid. The remainder enters the furnace through nozzles located in the lower furnace near the refractory transition elevation as secondary air.

B&W determined that the air penetration and distribution of the original system was inadequate to properly distribute air into the furnace above the bed. The secondary air system nozzles were modified to increase the capability and coverage of the system. Also, the nozzles closest to the side walls were angled away from the furnace side walls for improved coverage and to reduce erosion potential of the furnace walls during high-load operation.

Emissions control

The emissions control system was reviewed prior to the retrofit and found to be insufficient to meet the desired emissions requirements.

The mechanical/gravity-fed limestone feed system was not adequately distributing limestone throughout the furnace resulting in higher than desired SO_x emissions. B&W replaced the mechanical feed system with a pneumatic limestone injection system. The pneumatic injection system resulted in significantly improved sorbent distribution within the furnace, leading to lower SO_x emissions and lower sorbent usage.

A dry sorbent injection (DSI) system was also added to the unit upstream of the ESP. While the limestone injection system achieved the required SO_x emission limit for the unit, the DSI system was added for additional SO_x reduction capability to eliminate the need for SO_x capture systems elsewhere at the refinery.

New pneumatic limestone injection system.

Results

The modifications proved successful in improving the boiler performance. The unit successfully reached and has continuously operated at full load capacity. Throughout the entire operating range of the unit, the bed temperature remains controlled at target values and a proper furnace inventory is maintained. Achieving the target furnace operating temperatures also has resulted in achieving the target flue gas temperature profile throughout the entire steam generation system.

Major Scope Provided by Babcock & Wilcox
Modify upper furnace to facilitate primary ash recycle system and removal of the Loop Seals (L-valves)
New B&W U-Beams
Modify the existing overfire air (OFA) system
Added water-cooled wing wall furnace surface to maintain proper furnace gas temperature
Air system modifications to double the quantity of bubble caps and improve air distribution to the lower furnace
Modify coal feed chute and sweep air system
Modify recycle ash / sand feed arrangement
Add reduced diameter zone (RDZ) panels at bed-to-furnace transition
New pneumatic limestone feed system from the existing silos to the furnace
Modified refractory to B&W standards in bed, wing wall, and convection pass side walls at the U-beam location
Limestone truck unloading system
Dry sorbent injection (DSI) system
Ash recirculation system (bottom, air heater and ESP)

The Babcock & Wilcox Company
20 South Van Buren Avenue
Barberton, Ohio, U.S.A. 44203
Phone: +1 330.753.4511

www.babcock.com

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