The Introduction of Foster Wheeler's 660 MWe Supercritical CFBC Technology for the India Market

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ABSTRACT

The advantages of once through supercritical (OTSC) technology have become a focal point for increasing coal-based thermal power generation sector in India. Indian Ultra Mega Power Projects (UMPPs), typically 4,000 MW each, were undertaken during the 11th five year plan (ended in 2012) and are slated to address increasing coal-based thermal power generation throughout the 12th and 13th five year plans. OTSC technology is expected to account for 40% of all coal-based thermal capacity additions during the upcoming 12th five year plan and all coal-based capacity additions for the 13th plan. These aggressive plans are set against a backdrop of fuel shortages as coal consumption has increased 6% while proven domestic reserves have increased only about 2.5%. The use of imported coals continues to address indigenous coal supply shortfalls. The Indian Central Electricity Authority (CEA) stipulated in 2011 that all future indigenous coal based thermal power plant boilers are to be designed for utilization of fuel blend ratios of 30% imported coal/70% indigenous coal. Thus fuel flexibility will become an issue of increasing importance in the adoption of OTSC technology in India.

Playing into the fuel flexibility requirement, recent developments in Circulating Fluidized Bed (CFB) OTSC have qualified this technology to be offered for Utility scale projects competing head to head with Pulverized Coal (PC) OTSC offerings. The Łagisza 460 MWe Super Critical CFB Power Plant in Poland, owned by Poludniowy Koncern Energetyczny S.A. (PKE), has now been in commercial operation for three years since initial full load operation and continues to show very good performance. The performance has validated Foster Wheeler's utility scale design for units in the 660 MWe and 800 MWe size ranges offering net efficiency of ~43% (LHV basis). This operating unit also validated the design of the world's first FW/BENSON™ vertical tube OTSC low mass flux technology. The Łagisza original international tender was for OTSC PC technology so it is of importance to note that the alternative selection of CFB OTSC technology over conventional PF technology is of historic significance.

This paper will highlight the technical advantages of the 660 MWe super critical CFBC technology using multi fuel blends which offer favorable economics and fuel arbitrage advantages not only today but in the future . Also discussed will be the recent contract award from Korea Southern Power Company to Foster Wheeler for 4 units of 550 MWe CFB OTSC technology which utilizes a 2 on 1 configuration of 2 x 550MWe CFB OTSC boilers on two single 1000 MWe turbines. Essentially this provides a fuel flexible low emissions alternative for a 2 x1000 MWe solid fuel power block.

INTRODUCTION

Over the past 35 years, circulating fluidized bed (CFB) boiler technology has evolved from a robust industrial boiler technology used to burn difficult fuels in the late 1970s through the successful installation and commercial operation in 2009 of the world's largest CFB boiler rated at 460 MWe. Established benefits of improved efficiencies, reduced emissions, fuel flexibility and lower costs all combine making CFB technology a highly competitive option for large-scale utility applications. CFB technology is now challenging pulverized coal technology in large scale energy generation with now over 80 CFB units of over 200 MWe and a 460 MWe supercritical unit in operation.

FEATURE	BENEFIT
• Low furnace temperatures	• Low NO_x • Low SO_2
• Hot circulating solids	• Fuel flexibility • Handles low grade fuels • Simple feed systems
• Long solid residence time	• Good fuel burnout • Good sorbent utilization

Source: Foster Wheeler

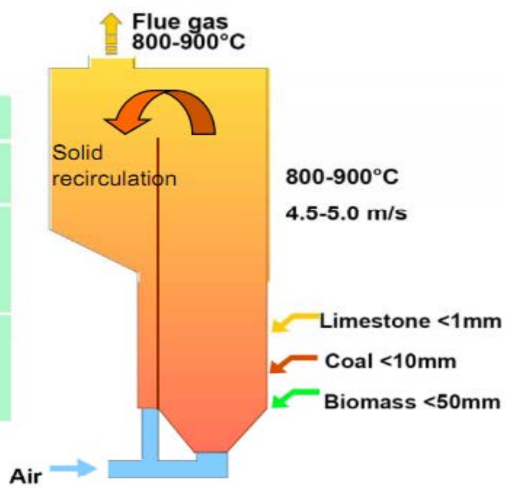

Figure 1. Principles and Benefits of CFB Combustion

As indicated in Figure 1, the features of CFB combustion provide major benefits over pulverized coal steam generators. Utility scale PC fired steam generators are designed for a narrow range of fuels, typically coals with heating values above 6000 kcal/kg. CFB steam generators afford the maximum flexibility in fuel selection covering all coal types including low rank coals, petroleum coke, coal slurries, anthracite culm, biomass, and peat. As such, the fuel procurement flexibility for CFB steam generators provides long term fuel security and full access to the arbitrage in the global fuel market.

CFB combustion occurs at about 850°C vs. 1500°C for a PC boiler. In the PC boiler, melting ash has a high propensity for slagging in the furnace and soot blowing is required. Slagging and soot blowing are avoided in a CFB furnace.

Another major feature of CFB is control of NO_x and SO_2 emissions in the boiler. This avoids the EPC capital costs associated with SCR and FGD equipment. For a 600 MWe plant, Capex savings can exceed US$100 million. In addition, operating costs for ammonia and SCR catalyst management for SCR and limestone or lime for wet or dry FGD are avoided.

OTSC CFB DESIGN PLATFORM

Lagisza 460 MWe

As CFB boilers evolved into the utility size range with a large number of subcritical units in operation in the 250-300 MWe capacity range, the startup and successful commercial operation of the Lagisza 460 MWe power plant in 2009, shown in Figure 2, employing supercritical once-through technology is a breakthrough milestone[1]. This 460 MWe Foster Wheeler CFB unit is owned by Poludniowy Koncern Energetyczny SA (PKE), located in the Katowice area of southern Poland and represents the largest and first supercritical CFB boiler. The selected steam pressure and temperature (282 bar and 563^{o}C) were proven in other pulverized coal supercritical units and conventional boiler steel materials were used. Main fuel for the boiler is bituminous coal sourced from 10 local coal mines with wide range of coal parameters including an as-received heating value ranging from 4300-5500 kcal/kg attesting further to the fuel flexibility of the CFB technology. In addition, the design allows provision for introduction of coal slurry through lances up to 30% total fuel heat input.

The Lagisza plant design also incorporated the world's first Foster Wheeler's FW/BENSON™ vertical tube OTSC low mass flux technology. The BENSON vertical evaporator with low mass fluxes provides a self-compensating natural circulation characteristic accommodating heat flux variations in the furnace. The BENSON vertical tube design also affords clear advantages over multi-pass and spiral designs providing lower pressure drop over the furnace tubing reducing the power required for feedwater pumps and more power delivered to the grid. The OTSC technology produces steam with a single pass of water through the furnace tubes, eliminating the need for a steam drum and the associated steam circulation system. The supercritical steam properties allow high steam heat absorption with resulting net plant efficiency in excess of 43% (LHV), a marked increase from the 35% efficiencies for the original PKE subcritical PC coal fired plant.

Operating experience at the Lagisza plant has met all expectations firing Polish bituminous coals with a 28% reduction of CO_2 emissions and NO_2 and SO_2 reductions to levels less than those set by the European Union Directive for Large Combustion Plants. The Lagisza project was complete with handover to the owners 38.5 months following contract signing.

Figure 2. 460 MWe Łagisza CFB OTSC Unit

Samcheok Green Power – Ultrasupercritical CFB to 550 MWe

A major Korean utility, Korean Southern Power Company (KOSPO), is on at the forefront of world class clean coal power with the 2011 commencement of its Samcheok Green Power project. The plant will be constructed in coastal Samcheok City in Gang Won Do province in northeast South Korea. The plant site will occupy 2.5 million m^2 of reclaimed coastal land and utilize a tiered landscape to minimize total space requirements. The site will also contain a world class CO_2 research center employing technical experts from around the world. A rendering of the final plant shown in Figure 3 illustrates the attractive plant layout which will include bilateral mooring for coal barges, an indoor coal yard, and underground conveyors for coal, limestone, and wood chips.

Figure 3. Rendering of Samcheok Green Power Facility

When fully complete, the Samcheok project is planned to have eight 550 MWe ultrasupercritical CFB steam generators contributing 4,400 MWe firing imported coals and co-firing up to 5% biomass. In addition to the CFB steam generators, the Samcheok site will generate an additional 600 MW from totally renewable sources to bring the total site capacity to 5,000 MW. The additional sources encompass a complete array of renewable technologies with wind turbines mounted at the plant's seawall, solar panels/PV arrays covering the coal yard, building rooftops and slopes, wave power generation at the seawall, small hydro power at the plant drainage canal, and fuel cells from nearby Korea Gas Corporation. Ash from the plant's electrostatic precipitators will be recycled and used as light weight aggregate for construction and land reclamation.

For the Samcheok project, KOSPO selected CFB technology over PC technology due to the CFB's fuel flexibility, lower combustion temperature, and elimination of any back-end flue gas desulfurization equipment for SO_2 removal. The plant will fire imported and domestic coals with heating values from 4,000-6,000 kcal/kg and co-fire biomass attesting to the fuel flexibility of CFB technology. The steam data falls into the ultrasupercritical range (270 bar and 602^{o}C) providing increased efficiencies and reduced fuel consumption for a given output. Net plant efficiency is estimated at 42.4% (LHV).

INDIA'S COAL-BASED THERMAL POWER OUTLOOK AND FUEL ISSUES

As India enters its 12th Five Year Plan (2012-2017), some 80-90 GW of additional power generation capacity from all sources will be required. Currently, coal accounts for about 56% of the total generating capacity (coal, gas, nuclear, diesel, renewable), and if a similar fuel mix breakdown continues into the 12th five year plan, an additional 45-50 GW of coal fired capacity will be required. It is expected that India's 13th Five Year Plan (2017-2022) will require at least as much additional generating capacity.

These aggressive coal based capacity additions are largely based on the development of supercritical projects and Ultra Mega Power Projects (UMPPs) under tariff-based competitive bidding. Typical multiple 660 MW power blocks comprising the UMPPs have to date utilized OTSC pulverized coal boilers, and during the 12th plan India is slated to adopt OTSC for 40% of all thermal power generation capacity additions, and during the 13th plan OTSC will account for virtually all thermal power capacity additions.[2] Faster capacity additions at reduced costs and increased efficiencies are the prime drivers for adopting OTSC boilers.

Coal supply and quality pose major issues for India. Total coal demand for 2010-2011 was about 625 million tons (MT) with about 535 MT available from Indian mines located largely in the eastern states. Thus for 2010-2011 approximately 90 MT of coal was imported. For the upcoming 12th Five Year Plan, the projected annual coal requirement increases to 842 MT and the estimated domestic coal availability is 700 MT by 2016-2017 thus India's dependence on imported coals is expected to increase to 142 MT annually.

Indigenous Indian coals exhibit high ash content (35-40%), high levels of silica and alumina, and are highly abrasive. Average coal consumption is estimated at 5,000 tons/MW, which is higher than most imported coals because of a low heating value (3,500 kcal/kg) and high ash content. In an effort to address the need for higher quality coal (typ 5,000-6,000 kcal/kg), several Indian power producers are acquiring coal fields in countries such as Australia, Indonesia, and South Africa and erecting power plants is coastal Indian cities such as Mundra in the state of Gujurat.

Reflecting the awareness of the dependence on imported coals, India's Central Electricity Authority in 2011 advised that all power project developers and power equipment manufacturers incorporate flexibility in boiler designs to utilize a blend of imported coal and low grade indigenous coal in a ratio of 30%/70% (or higher).

CFB OTSC – CLEAR ADVANTAGES FOR INDIAN POWER PROJECTS

The fuel flexibility of CFB OTSC technology translates directly to lowering operating costs associated with fuel procurement, the largest component of a plant's operating costs. The annual fuel arbitrage advantage for a 600 MW (net) CFB OTSC unit operating at a 90% capacity factor and plant efficiency of 43% (LHV) can be illustrated by the utilization of US$ 30/MT Indian coal (3,500 kcal/kg) versus a high quality US$ 80/MT Russian coal (6,000 kcal/kg). As shown in Table 1, the CFB fuel flexibility value is over US$ 48 million per year representing a 10-year Net Present Value of US$ 298 million.

Plant Parameter	Units	6000 Kcal West Russian Coal	3500 kcal Indian Coal	Annual Fuel Arbitrage ($/yr)	10 yr NPV Fuel Arbitrage ($)
Plant Net Power	MWe	600	600		
Fuel Cost	$/ metric Ton	80	30		
Fuel Heating Value	kcal/kg	6000	3500		
Fuel Heating Value	MJ/Kg	25.1	14.64		
Plant Capacity Factor	%	90%	90%		
Fuel consumption	metric ton/year	1,698,232	2,912,003		
Fuel Cost	$/year	135,858,560	87,360,090		
Difference in Fuel Price				$48,498,470	$298,002,103

Table 1. Fuel Arbitrage Value for a 600 MWe (net) CFB OTSC Coal Power Plant at 90% Capacity Factor

CFB OTSC, with lower combustion temperatures and substantially increased particle residence time has the capability to burn a wider blend of fuel combinations compared to the narrow band of blends associated with PC OTSC. Further, as shown in Figure 4, CFB flexibility extends well into a wide range of difficult-to-burn fuels.

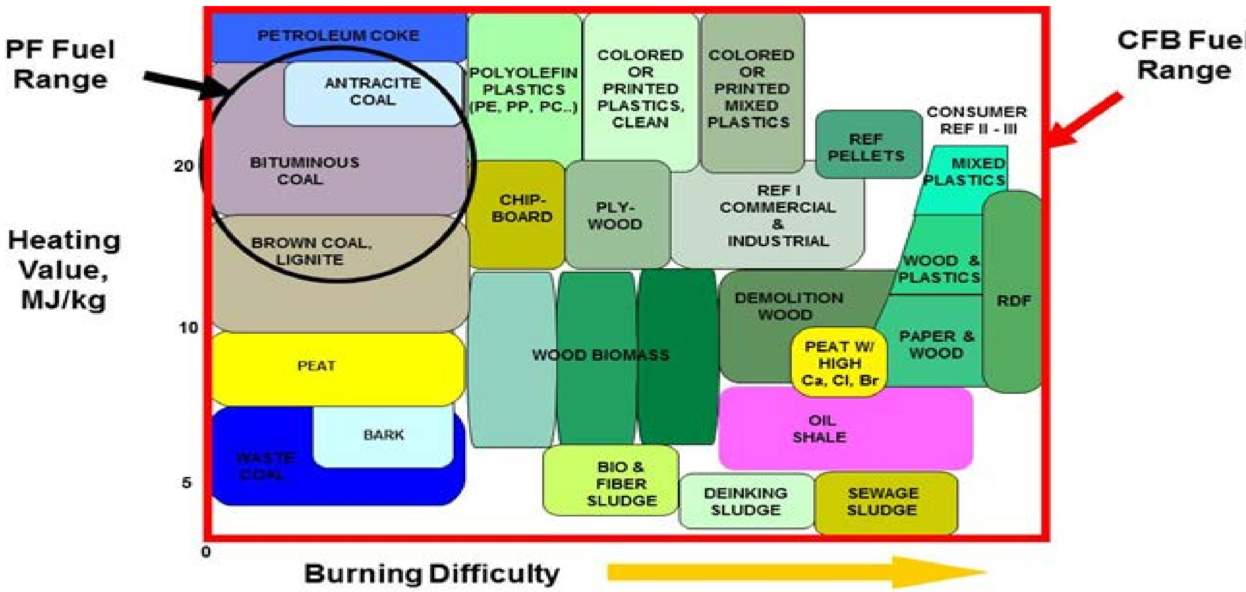

Figure 4. Fuel Range Comparison for CFB vs PC

Figure 5 illustrates the differences in the CFB vs. PC operating ranges covering fuels blends from 100% Indian domestic coal to 100% imported coal. Per the Indian Central Electricity Authority positions and current specifications, boilers at the UMPPs will be designed to fire 30% imported/70% domestic coals or higher ratios. As shown in Figure 5, the fuel window for CFB covers the complete range of ratios (0-100%) of domestic/imported coal. PC boilers, designed for narrow fuel blends, do not take advantage of fuel contracts based on prevailing prices (opportunity fuels). Foster Wheeler developed a 2 X 660 MWe financial model comparison of OTSC CFB vs. OTSC PC installations utilizing domestic vs. imported fuel. Input delivered costs of \$75/MT and \$28/MT were used for imported and domestic coals, respectively. For both types of boilers, costs for fuel utilization decrease with higher percentages of domestic fuel utilization.

As illustrated in Figure 5, a PC boiler designed for burning blends of imported and domestic coals realize a substantially narrow range of cost savings compared to a CFB boiler capable of burning all blend combinations from 0-100% domestic fuel. The 2 X 660 MWe evaluation model yielded a maximum 70% domestic fuel utilization for the PC boiler with an associated cost savings of \$110 million per year vs. a \$156 million annual cost savings for a CFB boiler, an additional fuel arbitrage value of \$46 million per year.

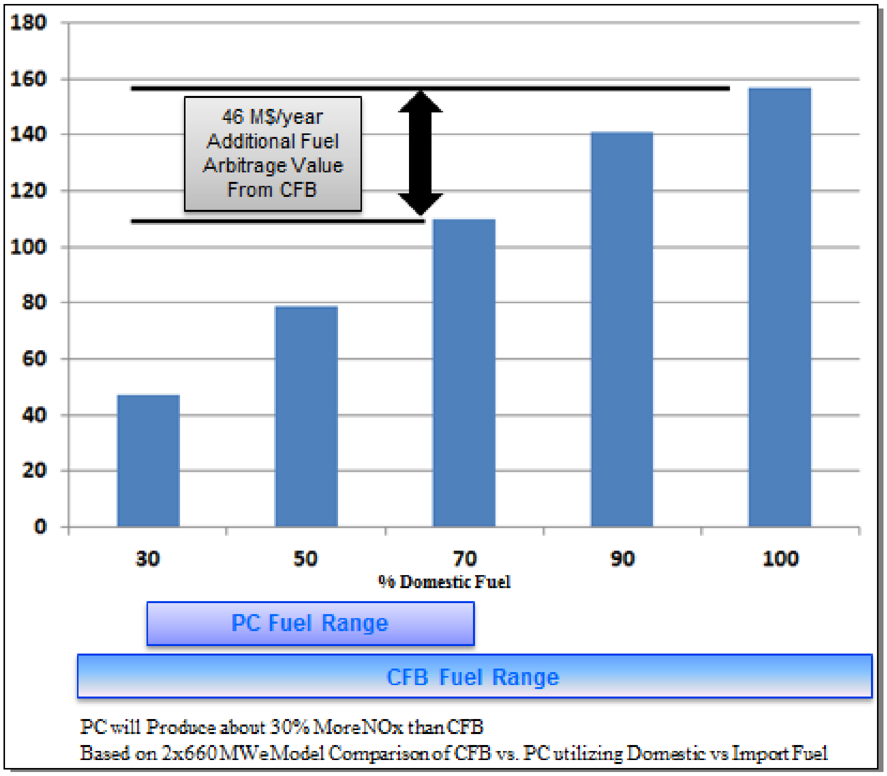

Figure 5. Plant Operating Cost Savings as Domestic Fuel Utilization Increases (M$/Yr)

OTSC CFB ALTERNATIVE ADDRESSES THE CURRENT AND FUTURE COAL SUPPLY ISSUES IN INDIA

India's high demand for reliable, low cost power is under constant pressure to balance power generation requirements with Fuel Supply Agreements (FSAs) in an environment where coal demand outstrips coal supply. The chronic coal shortages within India are delaying plans to construct new coal-fired power generation facilities. Power producers with existing OTSC PC coastal plants, designed for firing imported coals, face costly challenges in converting to lower cost, lower calorific value Indian coals. Costly modifications of pulverizers, fans, air heaters, and water cannons to control slagging can hamper the efficacy of converting to the point where some power producers are delaying UMPP projects. These modifications are not necessary when utilizing OTSC CFB technology due to its inherent fuel flexibility.

Further, some power producers relying on importing high cost coals have been quoted as taking a "go slow" approach to capacity additions.

Coal India Limited (CIL) has been directed to sign FSAs with both privately-owned and state-owned coal-fired power plants where penalties can be imposed of coal supply dips below 80% of those specified in the FSAs. This increases India's reliance on expensive importation of coal from Indonesia, South Africa, and other markets. To this end, CIL and Government Ministry official have determined that only independent power producers will be guaranteed supply of domestic fuel if contracts are in place for a 20-year commitment.

Reliability as a Value Proposition

Foster Wheeler's CFB Steam Generators have consistently delivered high availability and in many cases exceeded expectations to an industry where high plant load factor (PLF) is not only an unwritten requirement but is central to the economic viability of an operating plant. The India power market is no exception to these widely held operating standards. To illustrate the value of reliability/availability, a sample of increasing the PLF from 1, 3 & 5% in a 600 MW OTSC CFB net operating plant is shown in Figure 6.

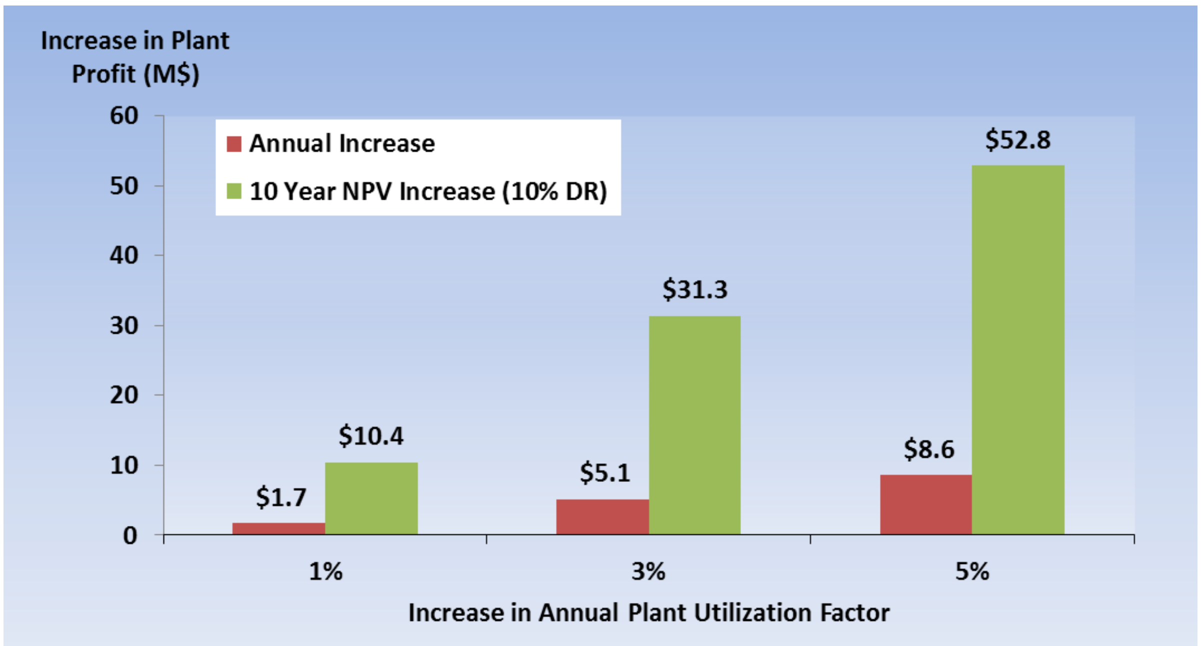

Figure 6. Results from power plant proforma analysis based on 60$/MWe electricity tariff, 30 $/tonne coal, and a base capacity factor of 90%

CONCLUSION

OTSC CFB technology virtually eliminates concerns for Indian project developers faced with uncertain fuel supply scenarios. Using OTSC CFB, a vast array of fuels can be fired at the initial design stage, but the designs are highly adaptable to future fuel mixes which can offer substantial increases in operational profits without costly modifications. OTSC CFB technology affords the maximum flexibility for India's future IPP's and UMPPs in view of dynamic international and domestic coal arbitrage opportunities. With the successful commercial operation of the Lagisza unit in Poland and 30 million hours of operational experience on the world's most difficult fuels, Foster Wheeler's OTSC CFB technology can play a significant role in India's Power Sector growth challenges well into the 12th and 13th Five Year Plans.

Refernences

1. Giglio, R., “World’s Largest Circulating Fluidized Bed Boiler Begins Commercial Operation”, CoalPower, December 10, 2009. http://www.coalpowermag.com/plant_design/Worlds-Largest-Circulating-Fluidized-Bed-Boiler-Begins-Commercial-Operation_237.html

2. Mathur, N., Central Electricity Authority Power Sector Overview Presentation, New Delhi, October, 2011