Circulating Fluidized Bed Technology
Towards 800 MWe Scale – Lagisza 460 MW
Supercritical CFB Operation Experience

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Presented at
Power Gen Europe
Milan, Italy
June 7 – 9, 2011
TP_CFB_11_02
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ABSTRACT

The world's largest and first supercritical circulating fluidized bed (CFB) boiler, designed and constructed by Foster Wheeler (FW) at the Polish utility PKE's Lagisza power plant, went successfully into commercial operation in early 2009. The unit demonstrated the well-known features of circulating fluidized bed (CFB) combustion and once-through supercritical boiler technologies. The 460 MW_e Polish bituminous coal fired plant has achieved a net efficiency in excess of 43 % (LHV), thus reducing considerably CO₂ emissions compared with the replaced old power plant capacity. This paper presents the project overview and summarizes the operational experiences.

There is an increasing demand for boilers in the size range of 600 to 800 MW_e, as existing power plants are aging and new replacement capacity has to be built. FW has developed its CFB technology now to commercially offer the 600 - 800 MW_e size, with the steam parameters of 600 / 620°C, 300 bar, enabling a net efficiency of about 45 % (LHV). The paper describes the 800 MW_e supercritical CFB boiler concept and presents the main technical solutions of the boiler.

Circulating fluidized bed (CFB) technology has established its position as a utility-scale boiler technology.

1 INTRODUCTION

Cutting CO₂ emission has become increasingly important after the Kyoto Protocol. As coal will remain an important source of energy, the focus has been set to improve the efficiency of coal fired power plants. To achieve this goal, supercritical steam parameters have been applied. Most large European thermal power plants built for fossil fuels such as coal and brown coal over the last decades have had supercritical steam parameters and have been based on pulverized coal (PC) fired once-through boiler technology. Circulating Fluidized Bed (CFB) boiler technology has been growing in size and number over the past three decades and it has established its position as utility scale boiler technology. Plant sizes up to 460 MW_e are in commercial operation today, including the 460 MW_e Łagisza CFB plant with supercritical steam parameters.
The Polish utility company Południowy Koncern Energetyczny SA (PKE) selected Foster Wheeler’s 460 MWₑ supercritical CFB boiler for their Łagisza power plant. In 2001, PKE announced a bidding process for supercritical once-through boiler delivery for 460 MWₑ unit in their Łagisza plant, with two alternative combustion technologies: pulverized combustion and circulating fluidized bed combustion. Foster Wheeler submitted proposals for both combustion alternatives. Both boiler proposals were based on BENSON technology with vertical tubing and low mass flux. Foster Wheeler signed the delivery contract on December 30, 2002, with both combustion technologies. Finally CFB technology was chosen by PKE for Łagisza OTU boiler after additional two months of detailed technical comparisons, as well as economical studies with the following conclusions:

- Total plant investment cost is lower for CFB alternative. The installation of wet desulfurization and SCR systems that are essential for a PC-based solution can be eliminated, and all emissions requirement are still fulfilled.

- Overall plant performance is better. Net plant efficiency using CFB technology and an advanced flue gas heat recovery system is approximately 0.3 %-unit better than with PC solution with similar heat recovery system.

- Fuel flexibility provides a perfect safety margin. The unique multi-fuel capability of the CFB boiler provides a wider fuel range and the additional possibility of using opportunity fuels.

Łagisza has validated Foster Wheeler’s supercritical CFB design platform providing a solid base for further units. Another good example of success of supercritical CFB is Novocherkasskaya CBF project. In January 2008, Foster Wheeler was awarded a contract by the Russian company JSC Energo Mashinostroitelny Alliance (EMA) for the design and supply of 330 MWₑ OTU CFB with supercritical steam parameters. The end client is a Russian power producer OGK-6. The boiler will be built at the Novocherkasskaya GRES thermal power plant in the Rostov region, Southern Russia. The boiler will be fuelled with anthracite and bituminous coals and with anthracite slurry. Start of commercial operation is scheduled for the end of 2012.

Foster Wheeler has finalized the development of supercritical CFB up to scale 800 MWₑ for bituminous coals meeting the highest requirements for plant efficiency and environmental performance. The study has developed a basic conceptual boiler design to help understand the
feasibility of a large CFB boiler of this size. Imported bituminous coal has been used as the
base fuel in the study. Ultra-supercritical steam parameters, with a steam pressure of 300 bar,
a superheated steam temperature of 600°C, and a reheat steam temperature of 620 °C to
maximize the plant efficiency have been used in the plant design. Plant net efficiency of
approximately 45% (LHV) is calculated. Based on continuous development work including
an experience of over 370 reference boilers in operation or under construction worldwide,
Foster Wheeler is offering today supercritical CFB up to scale 800 MW_e in size with full
commercial guarantees.

2 LAGISZA PROJECT

The new 460 MW_e (gross) unit replaces old power blocks of the Łagisza Power Plant. The
existing blocks were erected in 1960’s and consist of seven units (110-125 MW_e each). One
of them was shut down during construction phase of the new 460 MW_e unit and second one of
them was closed soon after the hand over the new 460 MW_e unit. The new boiler is located
adjacent to the old boilers and many of the existing plant systems like coal handling and water
treatment plant were renovated and utilized for the new CFB unit.

Foster Wheeler’s turnkey boiler island delivery included engineering and design, civil works
and foundations for the boiler, boiler house enclosure with steel structures, boiler pressure
parts, auxiliary equipment, main steam piping to turbine and reheated steam piping, coal
bunkers and fuel feeding equipment, electrostatic precipitator and cold end flue gas heat
recovery system, erection, construction, start-up, and commissioning.
The time schedule of the project is presented in Table 1.

Table 1  Project execution schedule

<table>
<thead>
<tr>
<th>Event</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contract Signing</td>
<td>December 30, 2002</td>
</tr>
<tr>
<td>Notice to Proceed:</td>
<td></td>
</tr>
<tr>
<td>I Stage – Basic Engineering</td>
<td>March 1, 2003</td>
</tr>
<tr>
<td>II Stage – Execution</td>
<td>December 31, 2005</td>
</tr>
<tr>
<td>Actual Hand Over</td>
<td>June 27, 2009</td>
</tr>
</tbody>
</table>

Main fuel for the boiler is bituminous coal. The source of fuel consists of 10 local coal mines with wide range of coal parameters, proving once more the fuel flexibility of the CFB technology. Table 2 shows parameters of the design fuel and overall fuel range.
The steam parameters for the boiler were specified by the PKE. The selected steam pressure and temperature were proven in other supercritical units and conventional boiler steel materials could be used. Table 3 presents main design steam parameters of this 460 MW<sub>e</sub> CFB boiler.

Table 3  Design Steam parameters at 100 % load

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SH flow</td>
<td>kg/s</td>
<td>361</td>
</tr>
<tr>
<td>SH pressure</td>
<td>MPa</td>
<td>27.5</td>
</tr>
<tr>
<td>SH temperature</td>
<td>°C</td>
<td>560</td>
</tr>
<tr>
<td>RH flow</td>
<td>kg/s</td>
<td>306</td>
</tr>
<tr>
<td>RH pressure</td>
<td>MPa</td>
<td>5.48</td>
</tr>
<tr>
<td>Cold RH temperature</td>
<td>°C</td>
<td>315</td>
</tr>
<tr>
<td>Hot RH temperature</td>
<td>°C</td>
<td>580</td>
</tr>
<tr>
<td>Feed water temperature</td>
<td>°C</td>
<td>290</td>
</tr>
</tbody>
</table>

The plant net efficiency is dictated by the selected steam parameters, steam cycle configuration, cooling tower conditions and boiler efficiency. In the Łagisza design the boiler efficiency is improved by a flue gas heat recovery system, which cools the flue gases down to 85 °C thus improving the plant net efficiency. The calculated net plant efficiency for Łagisza is 43.3 % and net power output is 439 MW<sub>e</sub>.

The emission requirements for the Łagisza boiler are according to the European Union directive for Large Combustion Plants (see table 4). The emissions for sulfur dioxide are
controlled with limestone feeding into the furnace. With the design coal, a sulfur reduction of 94% is required and that is easily achieved with a limestone feeding into the furnace. The nitrogen oxide emissions are controlled with low combustion temperature and staged combustion. The provisions were made also for a simple ammonia injection system (SNCR). Particulate emissions are controlled by electrostatic precipitator.

Table 4 Emission limits

<table>
<thead>
<tr>
<th>Emission (6% O₂, dry)</th>
<th>mg/m³(n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SO₂</td>
<td>200</td>
</tr>
<tr>
<td>NOₓ</td>
<td>200</td>
</tr>
<tr>
<td>Particulates</td>
<td>30</td>
</tr>
</tbody>
</table>

3 ŁAGISZA COMMISSIONING SCHEDULE

Erection works in the Łagisza boiler island were mostly completed on July 2008 and mechanical completion was achieved on 29th of August, exactly according to project schedule. Cold commissioning of the boiler plant started in middle of the July simultaneously with last minor erection work still ongoing.

- Start of Hot Commissioning Aug 2008
  - First firing, Acid cleaning, Steam blowing
- First steam to turbine Feb 2009
- Turbine Synchronization Feb 2009
- Full load achieved March 2009
  - Commissioning continued with 720h Trial Run
- Start of Commercial Operation 27 June 2009
4  LAGISZA COMMERCIAL OPERATION

After twenty one months of commercial operation, it can be stated that the operation experience of the Łagisza boiler has been excellent. Over the whole load range boiler has performed as designed and operation has been steady and easily controllable. All performance values were demonstrated already during trial operation.

Basic process parameters on different levels of load are shown on following table.

### Table 5  Process parameters on different load levels

<table>
<thead>
<tr>
<th>Parameter</th>
<th>40 %MCR</th>
<th>65 %MCR</th>
<th>80 %MCR</th>
<th>100 %MCR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main steam flow kg/s</td>
<td>144</td>
<td>235</td>
<td>287</td>
<td>361</td>
</tr>
<tr>
<td>Main steam pressure Bar</td>
<td>131</td>
<td>186</td>
<td>231</td>
<td>271</td>
</tr>
<tr>
<td>Main steam temperature °C</td>
<td>560</td>
<td>560</td>
<td>560</td>
<td>560</td>
</tr>
<tr>
<td>Reheat temperature °C</td>
<td>550</td>
<td>572</td>
<td>580</td>
<td>580</td>
</tr>
<tr>
<td>Flue gas exit temperature °C</td>
<td>80</td>
<td>81</td>
<td>86</td>
<td>88</td>
</tr>
<tr>
<td>SO2 emission* mg/m³n</td>
<td>143</td>
<td>197</td>
<td>140</td>
<td>&lt;200</td>
</tr>
<tr>
<td>NO2 emission* mg/m³n</td>
<td>167</td>
<td>154</td>
<td>188</td>
<td>&lt;200</td>
</tr>
<tr>
<td>CO emission* mg/m³n</td>
<td>45</td>
<td>48</td>
<td>48</td>
<td>22</td>
</tr>
</tbody>
</table>

* @ 6 % O2, dry

4.1  Evaporator operation

Peak heat fluxes in a CFB boiler are clearly lower than experienced in PC boilers. In the CFB highest heat flux occurs just above the refractory covered zone in the lower furnace. At that level the fluid is at a low temperature at supercritical pressures and is a sub-cooled liquid at reduced loads (sub-critical steam pressure). Because of the low heat fluxes in a CFB furnace, and the small tube sizes used in BENSON vertical tube supercritical steam technology, the full load water-steam mass flux can be in the 550 – 650 kg/m²s range. This low mass flux greats a “natural circulation” characteristic that together with stable circulation of the solids results in a more uniform heat flux distribution and reduced tube –to-tube temperature differentials.
Based on the detailed analysis result from Łagisza CFB, heat flux profiles to furnace walls have been low and uniform during coal firing. Highest heat fluxes have been measured above the refractory lining in lower furnace as it was expected. Due to uniform heat fluxes to furnace walls, steam temperature variation after evaporator has been minimal when operating above Benson-point.

4.2 Process behavior

Fuel flexibility, high combustion efficiency and low emissions are well known advantages of CFB boilers. In this point of view, once-through CFB boiler does not differ from drum boiler. Łagisza boiler has shown an excellent environmental – and economical performance as it has been operated on full load range firing coal. See below (Figure 2) the typical operating mode from winter 2010 when the boiler has been operated on day time at 100%MCR and on night time between 40%MCR to 65%MCR conditions.

![Figure 2. Generator output [MW]](image)

Emissions have been lower than set by the Large Combustion Plant (LCP) directive and a low flue gas exit temperature together with good combustion efficiency are guaranteeing high thermal efficiency.
Control concept chosen for the Łagisza boiler has turned out to be a success. The boiler is behaving well on transient conditions and on the other hand all the parameters are extremely stable as the boiler is operated on steady state conditions.

During the commercial operation attention has been given for optimizing the sealing of the rotary air preheater and for optimizing the cleaning of the flue gas heat recovery system (HRS).

4.3 Mechanical scale up

The boiler’s general layout was based on the conventional in-line arrangement that has been applied in Units 4 – 6 at the Turów power plant. Mechanical scale up was also reasonable modest since physical size of the Łagisza boiler is not significantly bigger than boilers already in operation for lower grade fuels like brown coal in Turów units. No problems regarding mechanical scale up of the boiler occurred during commissioning.

5 DESIGN STUDY OF A 800 MWₑ CFB

Łagisza has validated Foster Wheeler’s supercritical CFB design platform providing a solid base for the further scale-up of the CFB technology. Foster Wheeler is offering today supercritical CFB up to scale 800 MWₑ in size for bituminous coal, meeting the highest requirements for plant efficiency and environmental performance. The actual scale-up of the dimensions and size of the plant components required is moderate, due to modular approach adopted for the boiler design. The similar design features validated in Łagisza will be used:

- Proven and Efficient CFB Process
- High Plant Efficiency with Supercritical Steam parameters and Sliding Pressure Operation
- BENSON Vertical Tube Technology
  - Vertical Tube Furnace Walls
  - Low Pressure Drop
- Integrated Steam Cooled Solids Separators with minimum amount of refractory
- INTREX™ Fluidized Bed Heat Exchanger
  - High Heat Transfer Rates Minimize Surface Area
- Regenerative Air Heater
For the study a plant size of 853 MW\textsubscript{e} gross output, which corresponds to 800 MW\textsubscript{e} of net output, utilizing a steam turbine-driven feed water pump has been selected. The following steam parameters have been specified, reflecting current state-of-the-art figures for available materials for the boiler and turbine.

### Table 6 Steam parameters at 100% load at the steam turbine.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SH flow</td>
<td>kg/s</td>
<td>598</td>
</tr>
<tr>
<td>SH pressure</td>
<td>MPa</td>
<td>30</td>
</tr>
<tr>
<td>SH temperature</td>
<td>°C</td>
<td>600</td>
</tr>
<tr>
<td>RH flow</td>
<td>kg/s</td>
<td>518</td>
</tr>
<tr>
<td>RH pressure</td>
<td>MPa</td>
<td>4.5</td>
</tr>
<tr>
<td>Hot RH temperature</td>
<td>°C</td>
<td>620</td>
</tr>
</tbody>
</table>

The plant’s net efficiency is dictated by the selected steam parameters, steam cycle configuration, cooling water temperature, and boiler efficiency. In the CFB800 design, the boiler efficiency is further improved by a flue gas heat recovery system, which cools the flue gases down to 90°C, thus improving plant net efficiency. Condenser cooling is via direct seawater cooling, with a design temperature of 18°C. The calculated net plant efficiency for the CFB800 plant is 45%.

The European Union directive for Large Combustion Plants has been used as the basis for the emissions performance for the CFB800 plant (see Table 7). The emissions for sulfur dioxide are controlled by feeding limestone into the furnace. Using the design coal, a sulfur reduction of 85% is required, and this can be easily achieved with a calcium to sulfur molar ratio of less than 1.5. Nitrogen oxide emissions are controlled by the furnace’s low combustion temperature, staged combustion and ammonia injection. An electrostatic precipitator (ESP) is used to control particulate emissions.

### Table 7 Emission limits.

<table>
<thead>
<tr>
<th>Emission (6% O\textsubscript{2}, dry)</th>
<th>mg/m\textsuperscript{3}n</th>
</tr>
</thead>
<tbody>
<tr>
<td>SO\textsubscript{2}</td>
<td>200</td>
</tr>
<tr>
<td>NO\textsubscript{x} (as NO\textsubscript{2})</td>
<td>150</td>
</tr>
<tr>
<td>Particulates</td>
<td>30</td>
</tr>
</tbody>
</table>
The selected design fuels for the boiler are imported hard coal (main fuel) and petroleum coke (additional fuel). Typical fuel analyses are given in Table 8. An analysis of Columbian coal has been used for imported coal.

### Table 8  Fuel Analyses.

<table>
<thead>
<tr>
<th></th>
<th>Imported coal</th>
<th>Petroleum coke</th>
</tr>
</thead>
<tbody>
<tr>
<td>LHV (a.r.) (MJ/kg)</td>
<td>25.63</td>
<td>31.05</td>
</tr>
<tr>
<td>Moisture (%)</td>
<td>12.0</td>
<td>7.18</td>
</tr>
<tr>
<td>Ash (dry) (%)</td>
<td>9.15</td>
<td>0.82</td>
</tr>
<tr>
<td>Volatile matter (dry) (%)</td>
<td>37.47</td>
<td>12.41</td>
</tr>
<tr>
<td>Sulfur (dry) (%)</td>
<td>0.83</td>
<td>6.2</td>
</tr>
</tbody>
</table>

a.r. = as received.

The overall arrangement of CFB 800 boiler is shown in Figure 3.

![Figure 3  800MW<sub>e</sub> CFB Boiler Design](image-url)
6 BOILER DESCRIPTION

6.1 Water and Steam Circuitry

The feed water in the CFB800 boiler enters the boiler at a temperature of 290°C for preheating in a bare tube economizer. Water is then fed to the enclosure walls of the INTREX™ fluidized bed heat exchangers and further to the distribution headers of the evaporator (furnace) walls. The water is heated in the evaporator wall tubes, and dry steam exits at the evaporator outlet. As the boiler operates in sliding pressure mode, dry-out will occur in the subcritical region, as in all once-through designs, at a certain elevation of the evaporator, causing a reduced internal heat transfer coefficient and locally increased tube and fin temperatures. In CFB boilers, the furnace heat flux is considerably lower than in PC boilers, and the highest heat flux occurs in the lower furnace, where water is always sub-cooled. Detail studies have shown that in CFB conditions proper cooling of the evaporator wall tubes is achieved within a wide load range, using normal smooth tubes with a mass flux of 500 – 700 kg/m²s at full load.

During boiler start-up and shut-down, a circulation pump is used to secure minimum water flow through the evaporator. The two-phase flow from the outlet headers of the evaporator walls is collected in vertical water/steam separators, where the water is separated from the steam and led to a single the water-collecting vessel, see Figure 4.

![Figure 4 Steam Circuitry.](image-url)
Dry steam from the water/steam separators is led to the furnace roof, which forms the first part of the superheating system. From here, the steam is taken to the hanger tubes, convection pass walls, and cross over duct walls that form superheater I.

After superheater I, the steam is divided between eight parallel solids separators that form superheater II. The separator walls are formed of gas-tight membrane walls covered with a thin refractory lining providing high heat conductivity.

Following this stage, the steam is led to INTREX™ superheaters, forming superheater III and final superheating stage. The main steam temperature is controlled with a three-stage feed water spray, and by adjusting fuel feeding.

Steam after the high-pressure turbine is returned to the boiler for reheating. The first-stage reheater is located in the convection pass and the hanging superheaters inside the furnace are used for the final reheater stage.

### 6.2 Furnace design

#### 6.2.1 Flue gas side

The flue gas side of the furnace design for the CFB800 boiler is based on analyses of the imported hard coal and limestone proposed for the unit. Data from these has been fed in the design models to predict the particle size distribution of the circulating material, solids densities, and the heat transfer and gas temperatures. The design resulted in a furnace cross-section of 40 x 12 m, and a furnace height of 50 m. The furnace dimensions are slightly larger than those found in existing units. See a comparison of the key reference boilers shown in Table 9 below.

<table>
<thead>
<tr>
<th>Table 9. Comparison of furnace dimensions.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Furnace</strong></td>
</tr>
<tr>
<td>Width (m)</td>
</tr>
<tr>
<td>Depth (m)</td>
</tr>
<tr>
<td>Height (m)</td>
</tr>
</tbody>
</table>

The furnace has one fluidizing grid, below which there are four separate air plenums for introducing primary air to the furnace. The primary air flow for these four air plenums is
measured and controlled separately to ensure equal air flow to all sections of the grid and uniform fluidization.

The lower furnace is tapered, and the grid area is approximately 50% of the cross-section of the upper furnace. This provides high internal turbulence for the fluidized bed and ensures efficient mixing of the fuel and secondary air.

Fuel feeding takes place along the long walls of the furnace. Secondary air is also introduced along the long furnace walls at three elevations, to provide staged combustion for minimizing NOx emissions.

A 3D computer calculation model has been used to optimize boiler performance. Figure 5 shows the heat flux of the furnace walls. The heat flux is very typical for a CFB boiler, with a uniform profile and relatively low numbers. The oxygen profile at the center line of the furnace is presented in 6, and shows that there is sufficient oxygen content in the middle of the furnace.

![Figure 5. Furnace Heat Flux Profile.](image1)

![Figure 6. Oxygen Profile at the Center Line of the Furnace](image2)

### 6.2.2 Water / Steam side

The water and steam side of the design is based on low mass flux BENSON once-through technology licensed from Siemens AG of Germany. This technology is ideal for CFB
conditions, as it utilizes vertical furnace tubes rather than the spiral-wound tubing used in many other once-through designs. Vertical tubing is the normal arrangement in natural circulation CFB designs.

The heat transfer rate in CFB boilers is very low and uniform compared to pulverized coal (PC) units, and the required water mass fluxes are rather low. Low heat fluxes allow normal smooth tubes to be used in the furnace walls, with a mass flux of 500 - 700 kg/m²s at full load.

In addition to the furnace walls, the design includes additional evaporation surfaces in the form of wing walls inside the furnace. These wing wall panels are required because the furnace wall area is insufficient to provide the amount of evaporation required within a reasonable furnace height.

6.3 Solids separator design

The solids separator design for the CFB 800 boiler is based on Foster Wheeler’s second-generation CFB design, with steam-cooled panel wall construction. The solids separator design is optimized for high collection efficiency and low flue gas pressure loss.

The design is based on eight (8) solids separators arranged in parallel, four on each side of the furnace. The separator size is only slightly larger than in the Łagisza boiler, and even larger separators are in commercial operation. As a result, no scale-up is required in this area.

The separators are designed with panel wall sections and have a thin refractory lining anchored with dense studding to minimize the amount of refractory required. The separator walls are manufactured using panel welding machines, eliminating the need for extensive manual welding. The separator wall tubes are steam-cooled, forming a second superheater stage. The flue gas ducts after the solids separators, i.e. the cross-over duct walls are also steam-cooled forming part of the superheater I.

6.4 INTREX™ Heat Exchanger Design

INTREX™ is a fluidized bed heat exchanger that extracts heat from the hot circulating bed material that is collected in the solid separators and from bed material taken to the INTREX chambers directly from the lower part of the furnace.

In the CFB800 boiler design, the INTREX heat surfaces serve as high pressure superheaters (the third and final stage) providing sufficient heat duty for the superheating in the entire boiler load range. The refractory linings in this part of the boiler are also minimized, due to
the use of water-cooled casings. This enables lower INTREX casings to be integrated with the furnace, eliminating the need for expansion joints and minimizing the distances required for transferring hot solids. The flow of hot solids is controlled very simply through the fluidization process, and no valves or other mechanical devices are required.

6.5 Auxiliary equipment

The combustion air system consists of primary and secondary air systems and a separate air system for fluidizing the INTREX heat exchangers and sealing devises. Radial fans with inlet guide vane control are used for the primary and secondary air fans. Two parallel fans for both primary air and secondary air are provided. For the induced draft (ID) fans, two parallel axial-type fans are used.

Downstream of the economizer, the flue gases are cooled in two parallel rotary air heaters. These are of a tri-sector design and have a diameter of approximately 17 m each. Part of the flue gas stream is led to a parallel gas path, consisting of a by-pass economizer, see Figure 6. Flue gases are cooled down to 125°C (excluding air heater dilution effect).

The coal feeding system consists of four similar fuel feed lines, two on both of the long walls of the furnace. Each fuel feeding line includes a fuel day bin, a drag chain feeder, a drag chain conveyor, and discharge to the feeding points.

An electrostatic precipitator (ESP) is provided to control particulate emissions, consisting of two parallel chambers and four electrical fields in series.

6.6 Flue Gas Heat Recovery System

The flue gas heat recovery system improves the efficiency of the boiler and power plant by reducing the flue gas temperature to 90°C. The system recovers heat from the flue gases, which results in an improvement of about 0.8% in total plant efficiency.

The HRS operates under clean gas conditions, after the ESP and ID fans. Cooling takes place in a heat exchanger made of PF plastic tubing to avoid corrosion problems.

A primary water circuit transfers the recovered heat to the combustion air system, and heat is transferred to both primary and secondary air. As the combustion air temperature before the rotary air heater increases, the air flow is unable to absorb all the heat available from the flue gases, and part of the flue gases has to be conducted to a separate low-pressure bypass economizer, where the heat from the flue gases is used to heat the main condensate, see Figure 7.
Figure 7. The Flue Gas Heat Recovery System.

7 SUMMARY

Circulating fluidized bed (CFB) technology has established its position as a utility-scale boiler technology. When considering either new plants or repowering old plants, efficiency and environmental issues are the key issues. High efficiency means lower fuel consumption, and lower levels of ash and air emissions, including lower emissions of carbon dioxide (CO₂). To achieve these goals, supercritical steam parameters have been applied. The first CFB power plant to utilize the supercritical steam parameters with once-through steam cycle technology is the Łagisza, 460MWₑ in Poland.

In December 2002, the Polish utility company Południowy Koncern Energetyczny S.A. (PKE), at that time Poland’s largest utility, selected Foster Wheeler as the boiler supplier for a 460 MWₑ once-through supercritical, coal fired power plant. CFB was found to be the most cost-effective option for PKE’s new power plant over the pulverized coal technology, enabling them to select any coal they like to burn in the new CFB.
Erection works of the boiler plant were mostly completed on July 2008. Commissioning of the boiler plant proceeded from cold commissioning to acid cleaning and steam blowing. Steam was taken to the turbine for the first time in 7th of February and synchronization took place in 15th of February. Full output power of the unit, 460 MWₑ, was achieved on 10th of March followed by fine tuning of controls and optimization of the boiler performance. After completing the 720 h trial operation Łagisza OTU CFB plant was handed over to customer on 27th of June 2009.

After twenty one months of commercial operation, it can be stated that the operation experience of the Łagisza boiler has been excellent. Boiler operation has been stable and easily adjustable. Heat fluxes to furnace walls on coal firing have been low and uniform as was expected. Adjustability of the large boiler with numerous fuel feeding points has turned out to be good. Mechanical scale up of the Łagisza boiler was successful.

Operating experiences of the world’s first CFB utilizing supercritical steam parameters have been excellent. Extensive development work combined with Łagisza experiences provides a good knowledge base for Foster Wheeler to propose CFB technology with super-critical steam parameters up to scale 800 MWₑ.
REFERENCES


/2/ A. Hotta et al.; ”Towards New Milestones In CFB Boiler Technology – CFB 800MWₑ / New 460 MWₑ super critical plant with CFB boiler in Łagisza - First experience update” Presented in P-GEN Europe 2010, Amsterdam, Holland, 9 June, 2010