# Cottbus – first PFBC plant to be fired with brown coal

**The first PFBC power plant to be fired with brown coal is currently under construction at Cottbus, Germany. With its pressurized fluidized bed combustion P200 module and two gas-fired peak-load boilers, the new combined heat and power plant will have a maximum output of 74 MWe and 220 MWth. It replaces an older pulverized coal plant on the same site and is designed primarily to supply steam and hot water to the town's two district heating grids.**

Cottbus is a town with about 130,000 inhabitants, situated south-east of Berlin, close to the border with Poland. The combined heat and power plant already existing on the Cottbus site has four small, conventional coal-fired boilers that can supply a maximum of 48 MWe and 230 MWth in the form of steam to one of the two municipal district heating networks. The second district heating grid is supplied with hot water from a pulverized coal-fired power plant in Jänschwalde, 9 km from Cottbus. All the plants burn local brown coal.

The Cottbus plant has a remaining lifetime of less than 30,000 hours and must be replaced before 2001.

**PFBC – the ideal option for repowering Cottbus**

Feasibility studies that had been carried out showed that PFBC is the ideal solution under the given circumstances as it will best allow the required performance to be achieved.

After offers had been requested from PFBC suppliers and financing agreements had been organized, the city of Cottbus awarded ABB Kraftwerke AG of Mannheim, in April 1996, the contract to build a new turnkey unit based on pressurized fluidized bed technology.

ABB has designed two standard modules – the P200 and P800 – for PFBC power plants [2–4]. The P200 module is used to build plants rated at 70 to 100 MWe (one module) or 140 to 210-MWe plants (two P200 modules combined with one or two steam turbines). The P800 module is used to build power plants rated at 350 to 425 MWe.

Cottbus power station **1** will have one P200 module and two gas-fired peak-load boilers for a maximum output of 74 MWe and 220 Mwth.

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ABB's PFBC technology has the commercial and technical advantage of being as yet the only such technology to be commercially proven. Four plants in the 80-MWe range (P200) are already operating in various parts of the world and a larger 360-MWe plant is under construction.

PFBC was judged to be the best option since it is a proven yet innovative technology that permits maximum utilization of the local brown coal whilst ensuring high efficiency and low environmental impact. This is important, as it also helps to keep jobs in the area. In addition, it positions Cottbus as a 'center of excellence' for the use of brown coal.

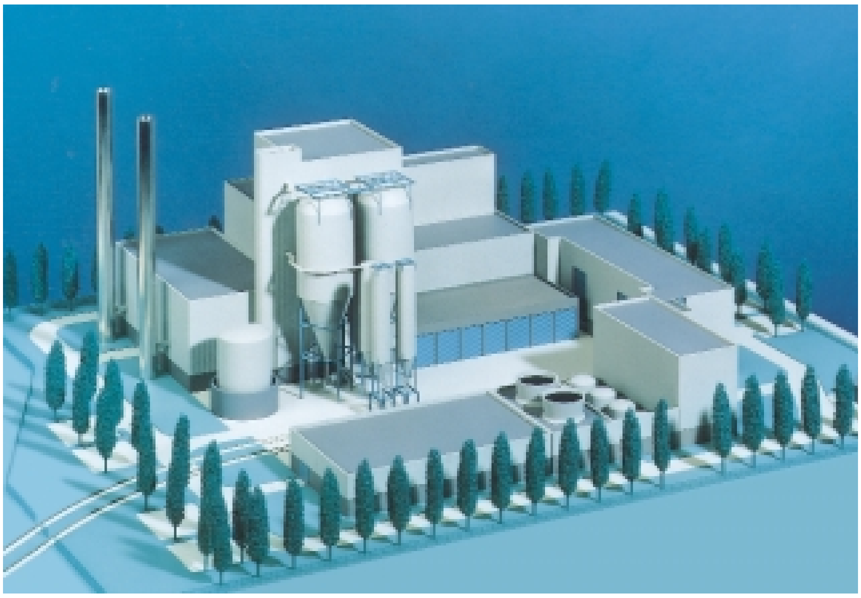
**Project requirements**

The plant **2** consists of one P200 module operating with separate high-pressure and low-pressure/intermediate-pressure steam turbines. The P200 module comprises a specially developed PFBC gas turbine **3**, connected to a pressurized fluidized bed boiler which generates the steam. The steam passes to the steam turbines for power generation, being afterwards fed into the district heating system. In addition to the P200 module, the plant has two gas-fired boilers for use during periods of high heat demand and as standby capacity (*Table 1*).

The Cottbus plant will be delivered under a turnkey contract which covers the civil works, district heating connections, coal and sorbent storage and transport systems, and electrical and control systems. The consortium leader for the turnkey supply is ABB Kraftwerke AG of Mannheim, ABB Carbon supplying the PFBC island consisting of combustor, gas turbine and auxiliaries. The two steam turbines, of type G32 and VEE63, will be supplied by ABB Turbinen Nürnberg GmbH. These two turbines have separate generators so that each can produce electricity separately. The electrical equipment and plant control system will be supplied by ABB Cottbus.

A long-term maintenance agreement was also signed, under which ABB Kraftwerke Service GmbH, Mannheim, and ABB Carbon will provide manpower and parts subject to wear for all scheduled overhauls over a 15-year period. The service agreement also covers operation and maintenance consultancy as well as access to ABB specialists.

Site work began in autumn 1996. The plant is scheduled to be on line in the summer of 1999.



***Model of the Cottbus PFBC plant.***
***The combined heat and power utility will have a maximum output of 74 MWe and 220 MWth.*** **1**

**Architectural considerations**

Architects and city planners were brought into the planning of the power station from the start to ensure optimum harmonization of the plant with its surroundings.

The industrial estate on which the power station stands is only about 2 km east of the 'Spreeaue' which cuts across the town from North to South. The estate is surrounded by residential areas.

Due to these circumstances, the city planners required a compact layout and design for the plant. Some of the key requirements were that:

- Full use should be made of the existing plant site.
- The buildings should be low in height in order not to obstruct the view from the nearby residences.
- The plant's design should combine discreetness with good architectural features.
- No unacceptable emissions (including noise) should be allowed.

The site of the new plant is next to the existing power station. The available space is almost square, being 165 m by 185 m. Essential plant parts and buildings, such as the coal silos, boiler, gas turbine and steam turbines, will be adjacent to each other **4**, with transformers, dust filter and auxiliary boilers close by. The switchgear building, water treatment and cooling towers are also integrated in the plant.

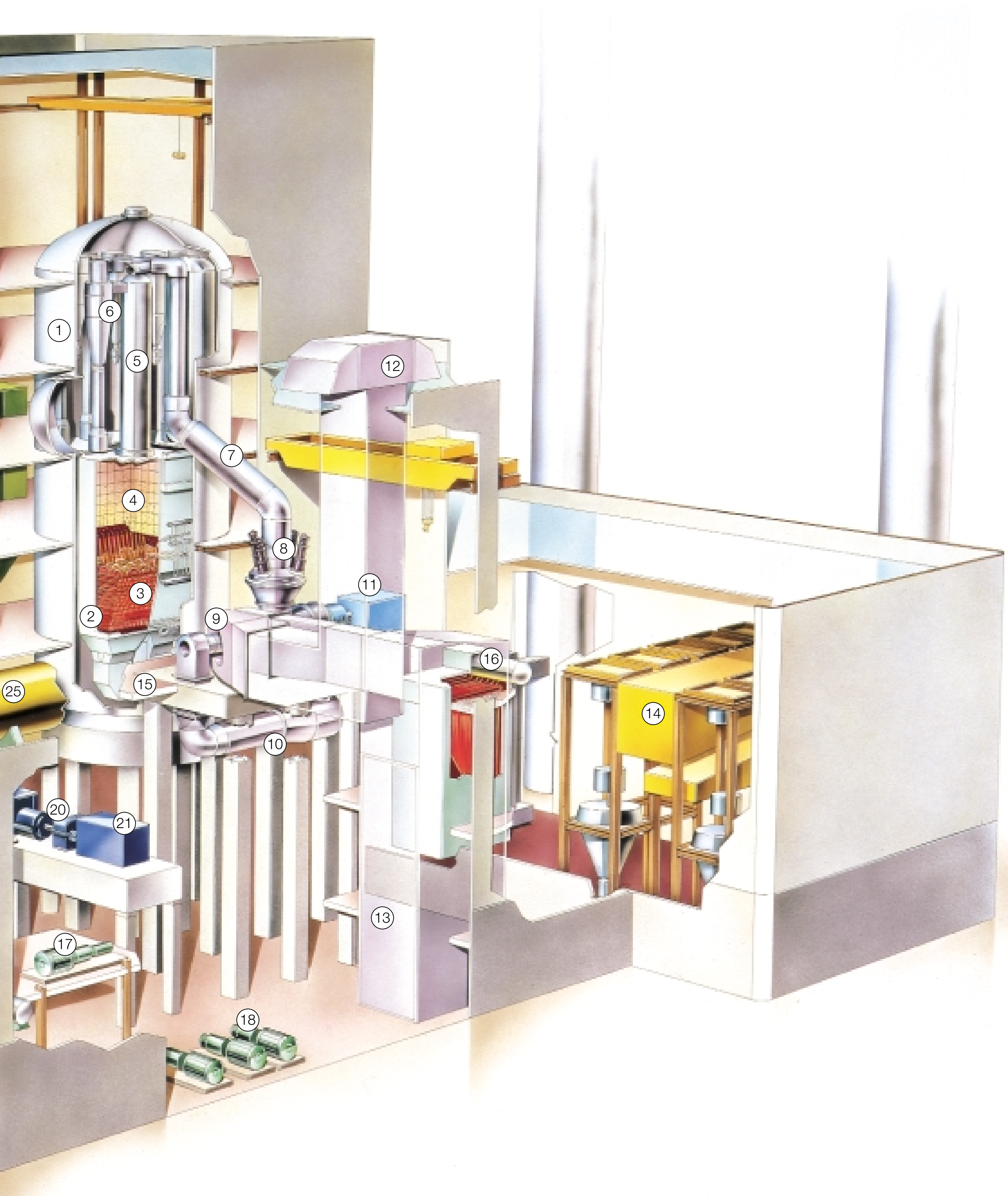
Existing rails can be used for transporting main components, fuel and ash. In and off loading will be optically and

**Table 1:**
**Technical details of the Cottbus PFBC plant**

| | | |
|---|---|---|
| *Combined cycle data* | | |
| Plant type | | 1 × P200, combined heat and power |
| Gas turbine | | 1 × GT35P |
| Steam turbines | | 1 × G32 + 1 x VEE63 |
| Net output | | 71 MWe/ 40 MWth (low heat demand) |
| | | 62 MWe/ 90 MWth (high heat demand) |
| | | 74 MWe/220 MWth (+ peak-load boilers) |
| *Technical data (full load, 15 °C)* | | |
| Fuel | – PFBC module | Lausitz brown coal |
| | – peak-load boilers | Natural gas or fuel oil, EL |
| Coal feed system | | Dry feed |
| Coal feed rate (kg/s) | | 11.3 |
| Sorbent, | type | Limestone |
| | feedrate (kg/s) | 1.0 |
| Ash flow (kg/s) | | 1.8 |
| Combustion temperature (°C) | | 840–860 |
| Steam data (bar/°C/°C) | | 142/537/537 |
| Condenser pressure (bar) | | 0.07 |
| *PFBC emission guarantees (weekly average)* | | |
| $SO_2$ (mg/Nm$^3$, 7 % $O_2$) | | 115 |
| $NO_x$ also $NO_2$ (mg/Nm$^3$, 7 % $O_2$) | | 115 |
| CO (mg/Nm$^3$, 7 % $O_2$) | | 50 |
| Dust (mg/Nm$^3$, 7 % $O_2$) | | 20 |
| Max. carbon content in ash (%) | | 5 |

***Cutaway drawing of the Cottbus PFBC power plant with ABB P200 module*** **2**

| | | | |
|---|---|---|---|
| 1 | *PFBC pressure vessel* | 15 | *Bed ash removal* |
| 2 | *PFBC bed vessel* | 16 | *Peak-load boilers* |
| 3 | *In-bed boiler tubes* | 17 | *PFBC feedwater pumps* |
| 4 | *Freeboard* | 18 | *Peak-load boiler feedwater pumps* |
| 5 | *Central duct* | 19 | *Hot-water pumps* |
| 6 | *Cyclones* | 20 | *HP steam turbine* |
| 7 | *Coaxial air and gas pipe* | 21 | *HP steam turbine generator* |
| 8 | *Intercept valve* | 22 | *IP/LP steam turbine* |
| 9 | *Gas turbine* | 23 | *IP/LP steam turbine generator* |
| 10 | *Intercooler* | 24 | *Condenser* |
| 11 | *Gas turbine generator* | 25 | *Feedwater tank* |
| 12 | *Gas turbine air intake* | 26 | *District heating hot water tank* |
| 13 | *Economizer* | 27 | *Auxiliary condenser* |
| 14 | *Baghouse filter* | 28 | *Control room* |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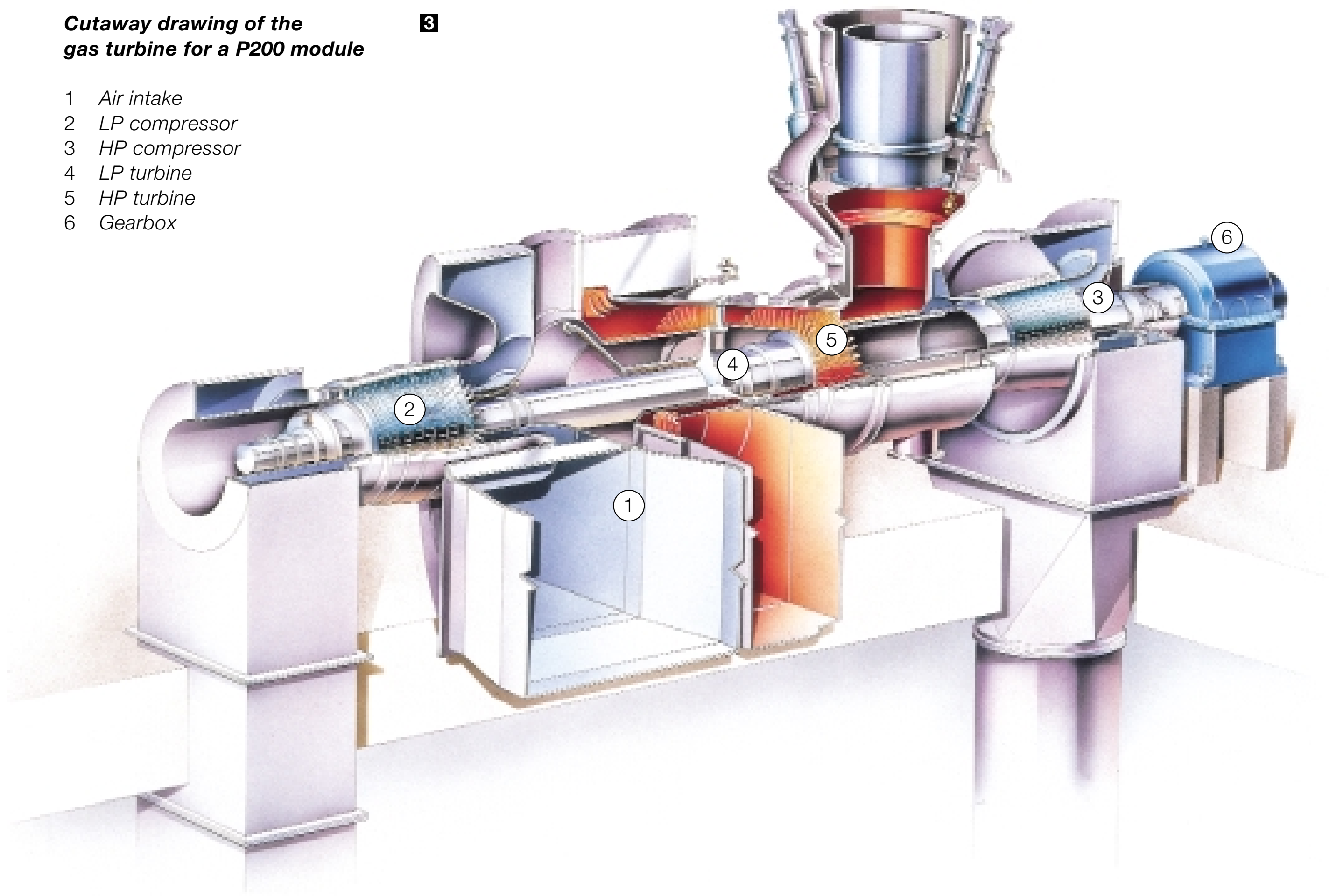
***Cutaway drawing of the gas turbine for a P200 module*** **3**

1 *Air intake*
2 *LP compressor*
3 *HP compressor*
4 *LP turbine*
5 *HP turbine*
6 *Gearbox*




acoustically shielded from the residential areas.

### Plant operation

The new combined heat and power plant will be operated primarily according to demand from the district heating systems in Cottbus. It is, however, also equipped with a condenser and cooling towers to allow electricity production even when there is no need for district heating. Operating hours for the P200 are expected to be more than 7,000 h per year, while operation of the oil or gas-fired peak-load boilers is estimated at a few hundred hours per year.

The plant will be equipped with a state-of-the-art ABB distributed control system providing a high degree of automation with maximum support for the operators. This will allow the plant to be operated with only 7 to 8 persons on each shift.

## PFBC plants for brown coal

### The role of brown coal in power generation

Brown coal is a major source of electrical power in Germany and Eastern Europe and is likely to remain so in the future. Many of the existing plants, particularly in former East Germany and the countries of Eastern Europe, are old and in need of repowering or upgrading. Domestic fuels are being used increasingly as they offer both economic independence and ease of transportation. In areas where it is already mined in large quantities, brown coal will continue to be used for both repowered and greenfield plants. There are also enormous unexploited reserves in many other parts of the world, China, USA, UK, New Zealand and Australia being some notable examples.

Brown coal is young coal with a low energy content, high moisture content (typically 35 to 70 percent), and often a high ash and sulfur content. Its high surface moisture makes the coal adhesive. This, combined with its high reactivity and short ignition time, has frequently led to handling problems in the past.

Known problems have been high emissions of $NO_x$, $SO_x$, $N_2O$, CO and unburned hydrocarbons as well as corrosion, agglomeration and surface deposits. PFBC avoids these problems through its lower combustion temperature (about 850˚C, as opposed to >1300˚C with conventional boilers) and its excellent fuel mix in the bed. The lower temperature prevents the formation of thermal $NO_x$ and reduces the baking of coal and ash, which is a characteristic of lignite.

Traditionally, brown coal has been used in pulverized coal plants, but it has also been used in fluidized bed plants in Germany since 1988, mostly with coal from the Rheinland. Until now the plants have been of the atmospheric type, with stationary or circulating beds. Efficiencies in some plants have been substantially below 40 percent.

### Improved efficiency with PFBC plants

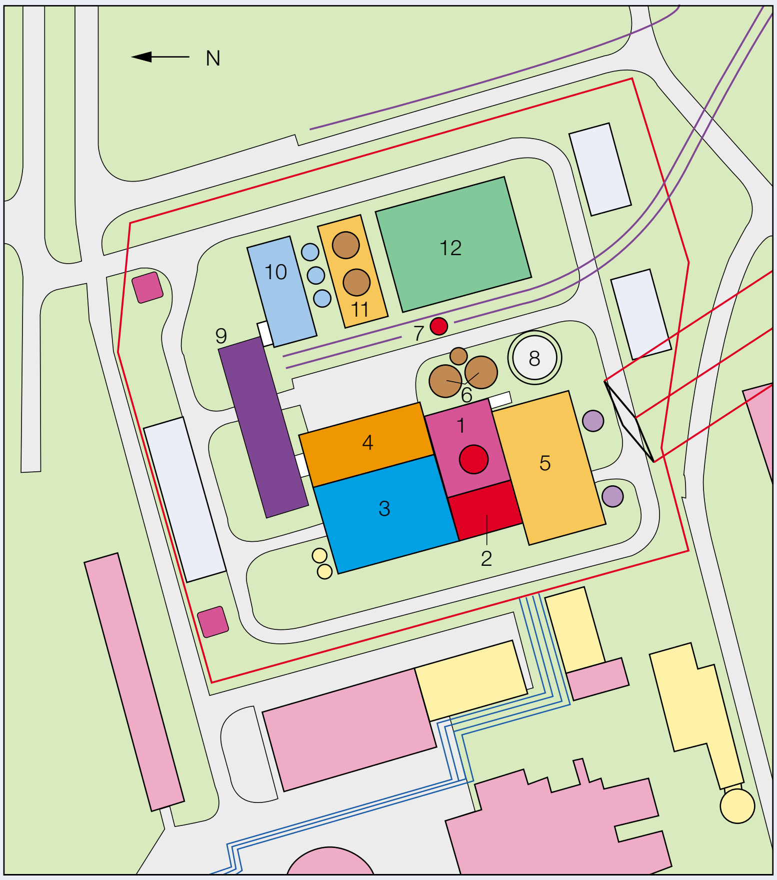
In addition to a conventional high-value steam cycle, the arrangement has the advantage that the hot gases resulting from the combustion in the PFBC boiler are cleaned and then used to drive a gas turbine for additional electricity production. In a PFBC plant, the steam turbine produces about 80 percent of the power generated, which means that the gas turbine adds a further 20 percent to the total output. This results in efficiencies higher than 40 percent.

A cogeneration plant enables highly efficient, cost-effective energy production in the form of electricity, heat and process steam. Another benefit of PFBC plants is that they are very compact and thus suitable for repowering of existing plants when space is limited. Because of their low emission levels, which are well below the most stringent limits set by the authorities, PFBC plants can also safely be built in residential areas.

Since the ash content of the coal affects the design of the power plant, the plant must be built to handle the specific characteristics of the lignite being used. The Cottbus PFBC plant will be built to use brown coal from the Lausitz area (*Table 2*).

**Table 2: Analysis of Lausitz brown coal (lifetime average values)**

| | |
|---|---|
| Lower heating value (kJ/kg) | 19,000 |
| Water (%) | 18.5 |
| Ash (%) | 5.5 |
| Volatiles (%) | 41 |
| Solid coal (%) | 34.5 |
| Sulfur (%) | <0.8 |



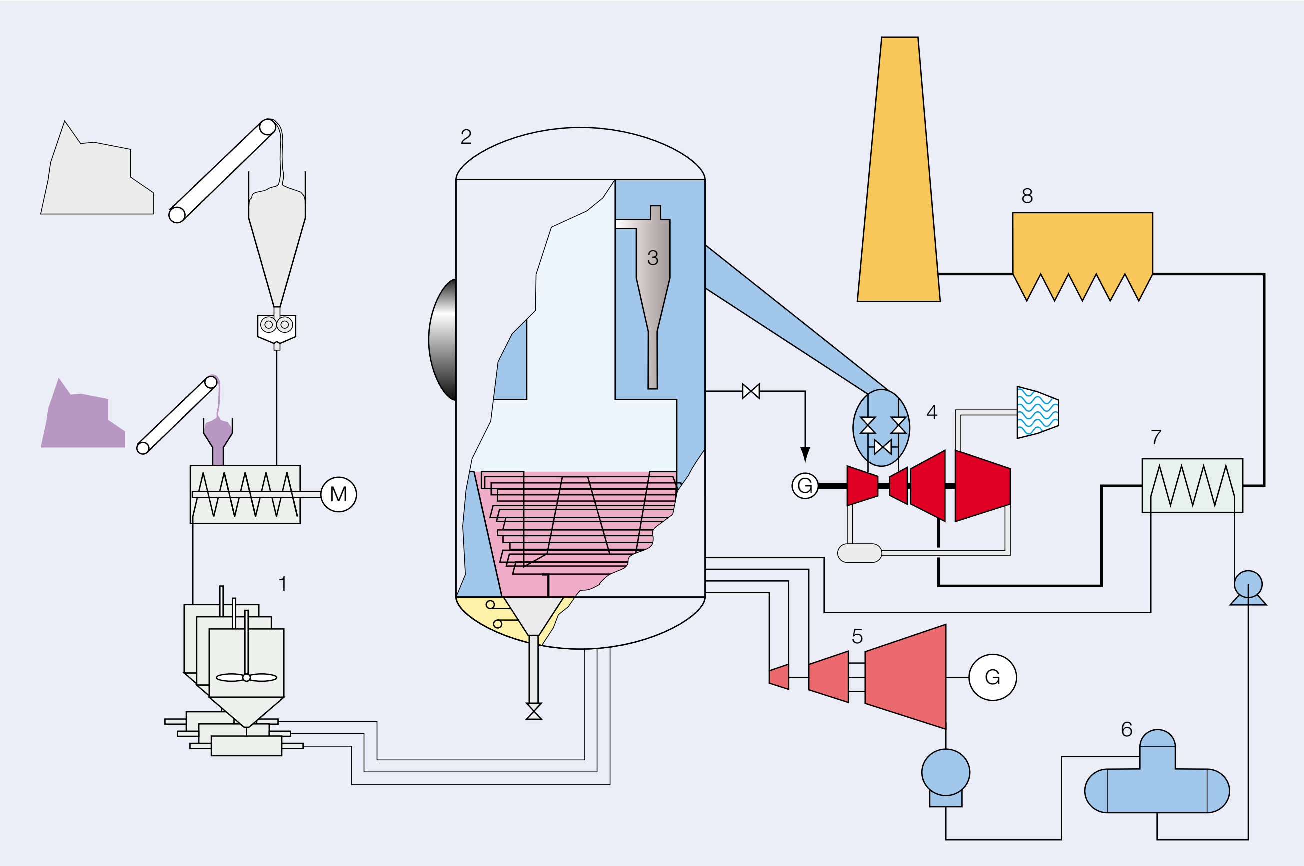

***Site plan of the Cottbus PFBC plant*** **4**

1 *PFBC combustor*
2 *Gas turbine building*
3 *Steam-turbine building*
4 *Switchyard*
5 *Peak-load boiler and baghouse building*
6 *Coal and sorbent silos*
7 *Ash silo*
8 *Fuel oil tank*
9 *Multi-purpose building with control room*
10 *Water treatment building*
11 *Cooling towers*
12 *Warehouse/workshop*

### Tests with FBC coal

Lausitz brown coal was tested in ABB Carbon's process test facility in Finspong, Sweden, during July and August 1995. The objectives of the tests were to verify brown coal operation in PFBC, determine any unexpected phenomena, and test continuous operation at both full and part load.

The tests were extremely successful. There were no problems in burning the Lausitz brown coal with PFBC, and low emissions were demonstrated. Despite




***Schematic showing the concept of a PFBC power plant with combined cycle*** **5**

1 *Mixing of fuel and sorbent*
2 *PFBC combustor*
3 *Cyclones*
4 *Gas turbine-generator set*
5 *Steam turbine-generator set*
6 *Feedwater tank*
7 *Economizer*
8 *Flue-gas filter*

the high reactivity of the coal, no problems arose with regard to baking of the ash.

## Plant configuration and operation

The characteristic features of an ABB PFBC plant are shown in **5**. The gas turbine and steam turbines in the combined cycle arrangement produce about 20 and 80 percent of the total electrical output, respectively. The fluidized bed combustor operates at an elevated pressure of 12 bar. As already mentioned, two standard module sizes based on ABB PFBC technology are available: The 70–100 MWe P200 module and the 350–425 MWe P800 module. By combining two or more of these modules, larger plants can be built.

The combined cycle arrangement at Cottbus is shown in **6**. The preheated feedwater enters the combustor and passes through the bed wall, in-bed tube bundle, evaporator and superheaters. The steam thus generated expands through the HP steam turbine back to the reheater and continues through the IP and LP turbine down to the steam turbine condenser.

Combined cycle arrangements with electric generators being driven by both a steam turbine and a gas turbine result in a higher thermal efficiency than with conventional steam plant. Typically, this advantage is around 3–4 percentage points for the same steam conditions, which corresponds to about a 10 percent saving in fuel. In PFBC repowering applications in which the steam data of the old plant are poor, the improvement will be even greater.

The fluidized bed boiler enables the plant to burn a very wide range of different fuels.

The sulfur emissions are reduced by 90 to 98 percent during the actual combustion. As the combustion temperature is relatively low (830–860˚C), $NO_x$ emissions are also low and can be further reduced by non-catalytic gas phase reduction.

Coal, crushed to the required particle size, is mixed with sorbent and conveyed pneumatically into the combustor.

The combustion air enters the process

via the gas turbine low-pressure compressor. It is then cooled in the intercooler in order to keep the temperature after the high pressure compressor down to 300˚C. The air leaves the high-pressure compressor via a concentric pipe that discharges into the pressure vessel, where it acts as the fluidizing and combustion air for the bed. After combustion, it flows, as hot gas, first into the freeboard above the bed. The combustion gas is then led through a parallel two-stage cyclone arrangement to separate the fly ash. The cleaned gas passes through the concentric pipe to the gas turbine, which drives a generator and the compressors. After passing through the gas turbine, the gas is fed to the economizer, which reduces its temperature to about 140–150˚C. Remaining dust is caught in the baghouse filter. The flue gas then leaves through the stack.

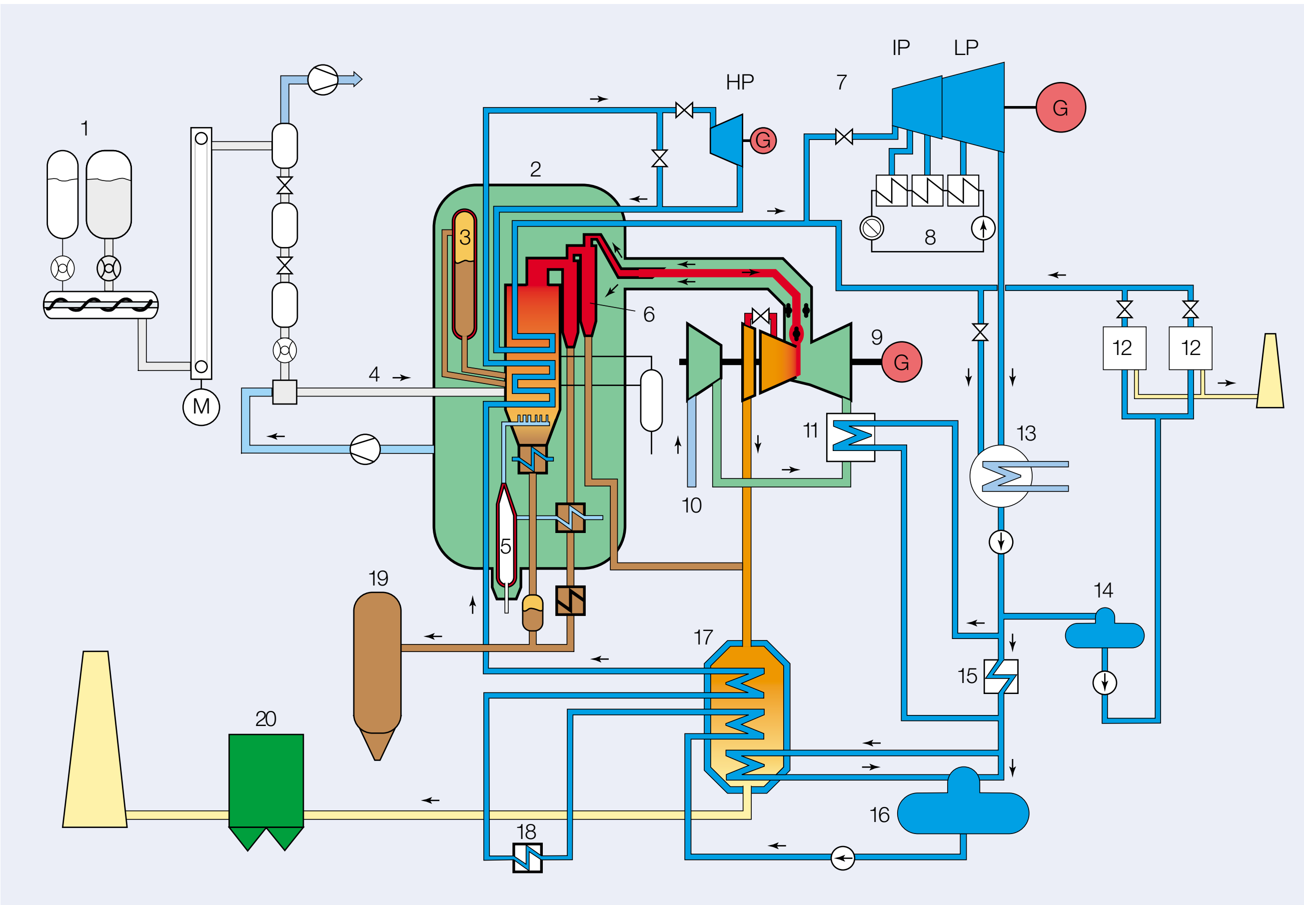
### Ash from the PFBC process

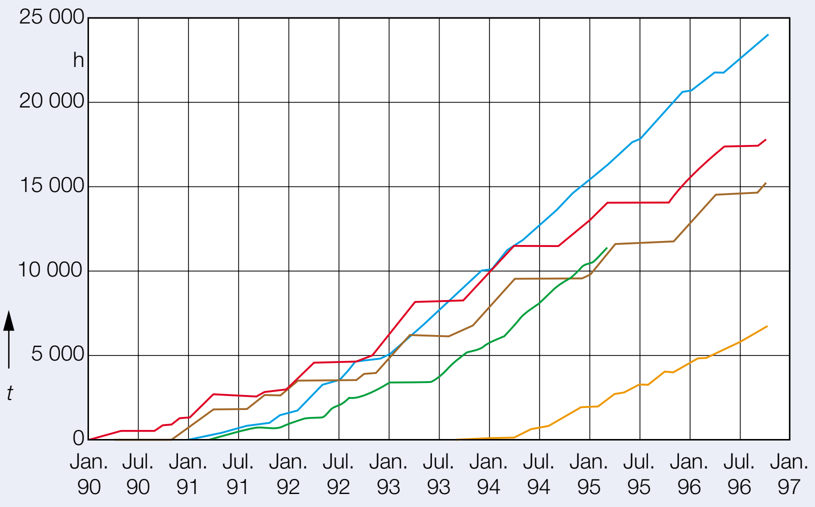
The ash produced by the PFBC process has two separate sources: fly ash is separated in the cyclones and the baghouse, while the bed ash is withdrawn via a lock hopper system through the bed bottom.

The low process temperature in PFBC means that the ashes are not fused. In a fluidized bed, contact between phases is very good, elevating the combustion efficiency. Consequently, the content of unburned coal in PFBC ash is very low. The ash can be harmlessly stored for a long period of time. After being cooled with feedwater, the bed ash is pressure-relieved and fed into the silos. Lightweight particles are separated from the flue gas in the two stages of the cyclones and by the dust filter. Thus, there are three fractions, known collectively as 'cyclone ash'.

***Flow schematic of the Cottbus PFBC plant*** **6**

1 *Sorbent/coal silos*
2 *Combustor vessel*
3 *Bed reinjection*
4 *Fuel injection*
5 *Bed preheater*
6 *Cyclones*
7 *HP, IP and LP steam turbines*
8 *Cottbus district-heating grid*
9 *Gas turbine*
10 *Air intake*
11 *Intercooler*
12 *Peak-load boilers*
13 *Condenser*
14 *Auxiliary feedwater tank*
15 *LP preheater*
16 *Feedwater tank*
17 *Economizer*
18 *HP preheater*
19 *Ash silo*
20 *Flue-gas filter*






***PFBC operating experience, accumulated hours*** **7**

Blue *Escatrón, Spain*
Red *Värtan P4, Sweden*
Brown *Värtan P5*
Green *Tidd, USA*
Orange *Wakamatsu, Japan*

The total ash content in Cottbus brown coal is 5–6 percent, which is fairly low and easily handled by the standard cyclone and ash removal systems. Ash from brown coal fluidized bed combustion has previously been a problem, resulting in high disposal costs. The residues of PFBC, by contrast, have a variety of potential uses that minimize the environmental impact and improve the overall economy of the plant.

An article in the next issue of the ABB Review will show how strong concrete-like materials with low permeability can be manufactured from PFBC ashes which are mixed with water and vibro-compacted. Possible uses are as fill material or synthetic gravel for road construction and for stabilizing soil or mine waste, or as a sealing layer for disposal sites and for manufacturing concrete.

## Operating experience with PFBC power plants

ABB developed PFBC technology in collaboration with power plant operators towards the end of the 1970s. The following plants have meanwhile run up a total of some 75,000 operating hours:

- Värtan cogeneration plant, Sweden
- Tidd, USA
- Escatrón, Spain
- Wakamatsu, Japan

These plants have given valuable feedback on performance and operation **7** [3–5]. The first 360-MWe size plant (P800) is now being built in Japan. The combined experience with widely different types of coal has demonstrated the viability of ABB's PFBC technology and also the general simplicity of the concept.

Special statistics based on availability results in the Värtan and Escatrón power plants are demonstrating a general trend towards increasing reliability and availability.

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