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Fuel Flexibility at Amager Unit 1 Using Pulverized Fuels

By

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1. Introduction

Biomass for heat and power production has traditionally been used in grate fired- and fluidized bed boilers. By the introduction of biomass pellets and milling plant, utilisation of large volumes of biomass can also be made with burners in direct-fired utility boilers.

In competition with fluidized bed technology Energy E2 (Denmark) ended up choosing a pulverized fuel fired boiler for their major boiler upgrade of Amager unit 1 (AMV 1) in Copenhagen. Energy E2's technical requirements included the following main constraints:

- Steam data see Table 1, are adapted to fit in with the steam based domestic heating system of central Copenhagen
- The boiler shall be designed for coal firing with as much biomass as possible
- Reuse of existing coal silos requires the supply of three coal mills
- Full boiler load on coal is with one mill out of service (n-1)
- Reuse of existing boiler house and if possible also the main boiler frame

The boiler contract was signed in December 2004 and the unit will be in commercial operation by January 2009.

The whole upgrade project includes the supply of: 500 t/h Benson boiler, steam turbine, deSOx- and deNOx-plants. The discussion below will be limited to the boiler and auxiliary equipment supplied by Burmeister & Wain Energy A/S.

2. Boiler and auxiliary equipment

The original coal/oil fired boiler from 1971 will be completely replaced by a new 500 t/h Benson boiler that will be placed inside the existing boiler house and suspended in the existing boiler frame.

The main new auxiliary components are:

- Three roller mills and coal pipes
- Twelve low NOx oil/coal/wood- and straw-dust burners

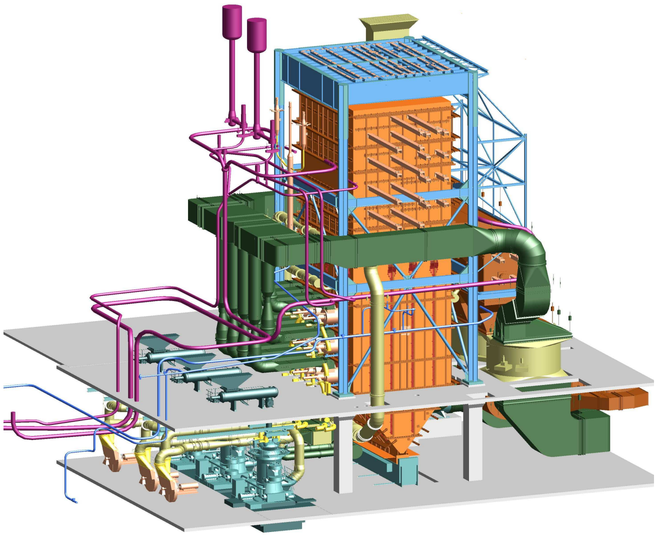

Figure 1 *The new AMV1 boiler.*

– Two rotary regenerative air preheaters, 7,670 mm in diameter, and ducts and fans for air and flue gas

The boiler, burners and air preheaters are of BWE design.

The use of biomass gives some constraints in operation as well as in the boiler design. This is further discussed in section 4. The limited space in the boiler house resulted in a 1½ pass boiler that has the economiser placed in the flue gas duct, see Figure 1 and 2. The supply of two air preheaters, which is not according to the traditional single train approach, is also a consequence of the existing boiler house layout.

The boiler will be part of the steam based domestic heating system for central Copenhagen (Denmark), thus, the steam parameters are optimised for that purpose. The fuel input of 350 MJ/s results in 71 MW power and 250 MJ/s heat with 17 bara back pressure. The boiler has

Table 1. *Main boiler data for the 500 t/h Benson boiler.*

		HP	RH
Temperature	°C	562	540
Pressure	bara	185	76
Flow	kg/s	139	123

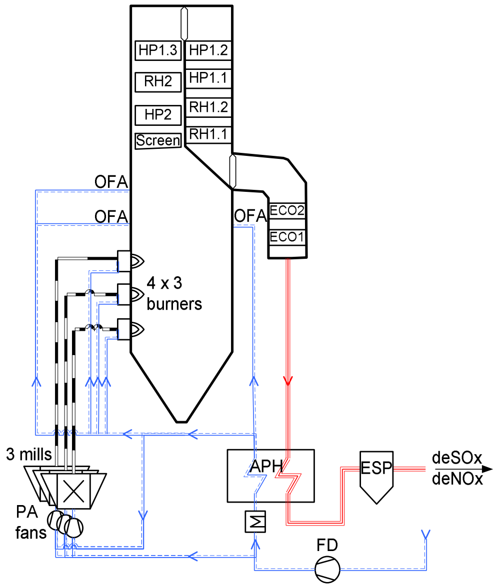

Figure 2. *Schematic presentation of the steam, fuel, air and flue gas system.*

single reheat and main boiler data are given in Table 1.

Minimum continuous boiler operation is 20% load while Benson minimum i.e. minimum once through operation, is 35%. The boiler can be operated in both sliding pressure and constant pressure mode, where the latter is down to 50% load.

The boiler is expected to have a yearly operation of approximately 5,000 full load equivalent hours. With 100% coal firing this represents 250,000 tons of coal. The yearly biomass consumption is planned to be 40,000 tons of wood pellets and 110,000 tons of straw pellets. This will substitute about 95,000 tons of coal and has a yearly potential for CO2 reduction of the order of 220,000 tons.

3. Combustion system

The boiler is wall fired with three rows of four burners where each of the three roller mills feed one burner row. The multi fuel burners are designed for coal, heavy fuel oil (HFO), wood- and straw-pellets. HFO will be for start and back up. Figure 2 shows the combustion- and air/flue gas system.

Table 2 provides the basic data for the combustion system that has the following main features:

- Milling plant uses air for drying and transport
- Only one fuel type per mill at the time
- Burners with controllable airflows and swirl
- Over fire air (OFA)

The milling plant uses air for transport of both coal and biomass. A safety measure for biomass is low air temperature. For coal the mill *exit* temperature is 90 - 110°C and the transport air will dry the fuel. For wood and straw the mill air *inlet* temperature is set to 80 - 90°C due to risk of ignition.

Each of the three fuel supply lines operates with one fuel type at the time such that the whole line i.e. mill, coal pipes and burners, can be optimised for the specific fuel in use. This is of special importance for the burners that will face fuels with a major difference in e.g. volatile matter when moving from coal to biomass. The fuel shift will be handled from the control system using pre programmed burner settings for internal air distribution (air split) as well as level of swirl. A fuel shift from coal to biomass and vice versa will require some minor mechanical changes to the mill such that it will be out of operation for about one day. Full load is, however, still possible on coal with the remaining two mills.

The circular burner is shown in Figure 3. The secondary- and tertiary-air are the main combustion air flows and represent typically 80% of the burner air. Both the level of swirl and the split between secondary- and tertiary air are controlled and can be optimised for a wide range of pulverised fuels. The optimised result is a flame where air is gradually mixed into the flame in a balanced manner - staged combustion - with low levels of NOx formation as a result.

Table 2. *Maximum fuel flow for coal, wood and straw.*

		Coal	Wood	Straw	HFO
Max input	MJ/s	350	350	320	350
CV	MJ/kg	24,7	17,5	15	39,7
Total fuel flow	kg/s	14,2	20,0	21,3	8,8
Per burner	MJ/s	43,8	29,2	26,7	35,0

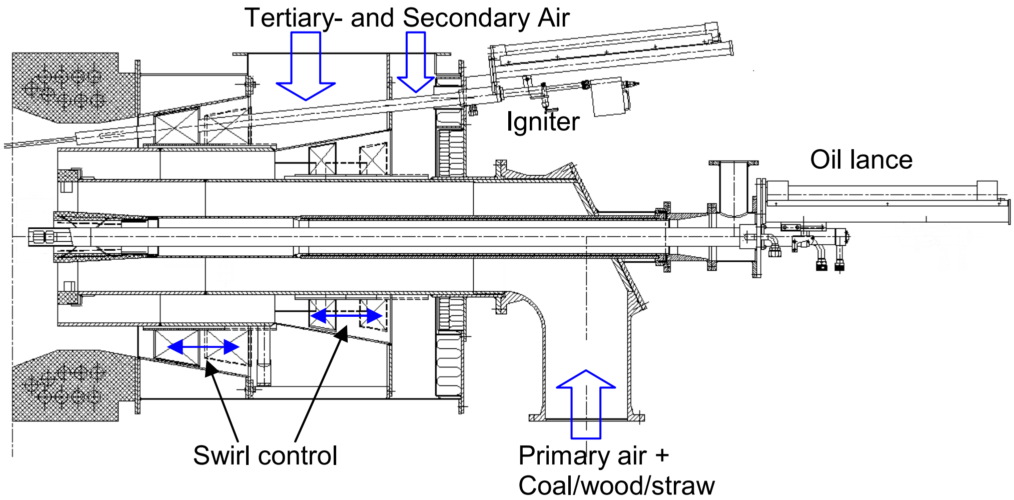

Figure 3 *Coal, oil, wood and straw burner.*

The principle of staged combusting is extended to the boiler furnace by use of OFA nozzles on both front and back wall. The excess air in the burner area will be just above stoichiometry and the OFA nozzles will add air up to the final excess air level of $\lambda = 1.15$.

4. Special measures for biomass operation

The experience with biomass co-firing at the 400 MWe USC boiler at Avedøre unit 2, supplied by BWE, is discussed by Bendixen (2005). The present project at AMV 1 continues the approach of Avedøre unit 2 where biomass is introduced as pulverized fuel using well proven utility boiler technology. There are, however, issues that must be addressed with a fuel diet comprising coal, wood and straw:

- Mill capacity is mass flow based such that thermal input drops with reduced heating value
- Load limitation for straw in order to avoid slag build up
- Increased pitch in HP- and RH-tube bundles and limited use of finned tubes in order to avoid slag blocking
- Enhanced corrosion resistance by the use of austenitic steel in superheaters
- Fully enamelled air preheater elements

The milling plant capacity is mass flow based such that the same mass flow can be maintained for coal, wood and straw dust. As shown in Table 3 this results in reduced thermal capacities for wood and straw. However, since the system is designed for full load with two

Table 3. *Relative heating value and total mill capacity for all 3 mills in operation.*

	Relative CV [-]	Total [%]
Coal	1	150
Wood pellets	0,7	106
Straw pellets	0,6	91

out of three mills in service on coal, wood pellets can also reach full thermal load by using all three mills.

In order to avoid slag build up in the second pass, ash softening temperatures for straw and wood have been considered. At 50% boiler load the flue gas temperature at the inlet of the second pass reaches the softening temperature for straw ash (650-700°C). The softening temperature for wood ash is above 1000°C, which is higher than the full load flue gas temperature at the inlet of the second pass. This indicates that load limitation must be put on straw and straw mixtures. However, experience must show which load levels are suitable for wood and straw.

The milling system is designed for operation with one fuel type per mill and some of the possible mill combinations are shown in Figure 4. In single fuel mode full boiler load can be achieved on coal or wood. Mixing of coal and wood can also meet full boiler load with 3 mills in operation. There is also capacity for full load on mixing of coal and straw as well as wood and straw. The typical utilisation of biomass will be single-firing on biomass or co-firing with one mill on biomass and one or two mills on coal. According to current standards (EN 450) fly ash from co-firing coal and biomass can be used in concrete as long as the minimum coal mass flow is 80%. However, alternative procedures are expected to allow up to 40% biomass in general and up to 50% in the special case of wood that have not been recycled.

The pitch for the HP- and RH-tube bundles in both first and second pass is increased compared to conventional design in order to avoid blocking by slag. The use of finned tubes is also avoided in the boiler and first introduced in the ECO after the coarse fraction of fly ash is removed.

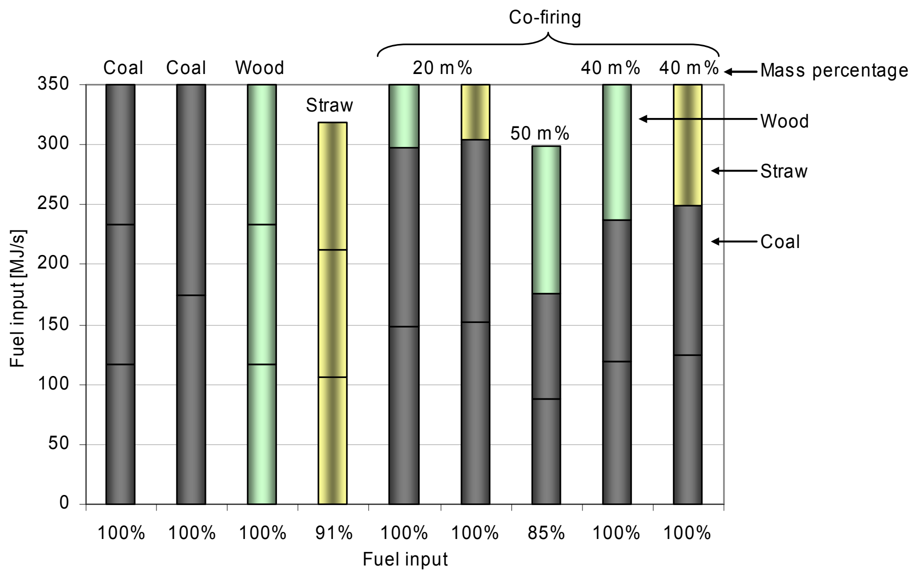

Figure 4 *Mill patterns for various combinations of coal, wood and straw. Typical co-firing will be with one mill on biomass and one or two mills on coal.*

In order to increase corrosion resistance austenitic steel (TP347HFG) is used for supporting tubes in the first pass and all HP-superheaters as well as final superheater for RH. Corrosion resistance is also addressed by the use of fully enamelled air preheater elements.

Coal ash as well as HFO combustion products have a positive effect in reducing harmful substances in the biomass ash, see e.g. Bendixen (2005). The presence of sulphur reduces e.g. the risk of chlorine corrosion. The present co-firing scheme with coal and biomass will provide an integrated coal ash source.

5. Conclusion

The new AMV1 Benson boiler has been designed for large scale utilisation of biomass including co-firing with coal. The project is based on well proven clean coal technology using pulverized coal and biomass.

The main issues are:

- Use of only one fuel type per fuel supply line; i.e. milling plant and burners
- Use of cold mill air for biomass
- Reduced milling capacity for biomass due to lower heating value compared to coal
- Increased pitch in HP- and RH-tube bundles and limited use of finned tubes

- Use of austenitic steel in HP and RH
- Use of fully enamelled air preheater elements

Finally coal ash from co-firing has a positive impact since the ash captures harmful substances from biomass

6. References

Knud Bendixen (2005), *USC Technology in CCT Boilers applying Biomass Co-firing*, Power-Gen Europe, June 28-30, 2005, Milan, Italy (www.bwe.dk/aarch/pge2005.html).