PELLETS TO REPLACE COAL IN LARGE POWER PLANTS

VÄSTHAMNSVERKET, HELSINGBORG, SWEDEN

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The reduction of emissions of CO2., NOx and SO2 is an important issue for the good future of our environment. This document will present conversion to full scale, commercial operation of co-firing pulverised coal and biomass pellets by means of existing, slightly modified milling and firing equipment

1 INTRODUCTION

The energy and environment policy of Sweden strongly favours renewable fuels and the decreasing use of fossil fuels. During the 80-ties many cogeneration plants were built co-firing wood, peat and coal in circulating fluidised bed boilers. An extensive amount of experience has been collected from theese plants.

2 PULVERISED COAL FIRING IN ORIGINAL DESIGN

2.1 EXISTING CO-GENERATION PLANT

Västhamnsverket is the major cogeneration plant of the City of Helsingborg, located on the Northeast shores of the straight of Öresund between Sweden and Denmark. The unit consists of a steam boiler of 78.5 kg/s, 110 bar and 540 °C supplying steam to an axial flow, single-casing, back-pressure turbine generating 65 MW, and 129 MW_{th}. Västhamnsverket was commissioned in 1983. Bituminous coals from around the world are pulverised in two roller mills, whereas a third mill is on stand-by. The original tangential firing system comprised three levels of coal nozzles, two levels of oil guns and one level of separated OFA-nozzles. A longitudinal section through the boiler is presented in **figure 1**.

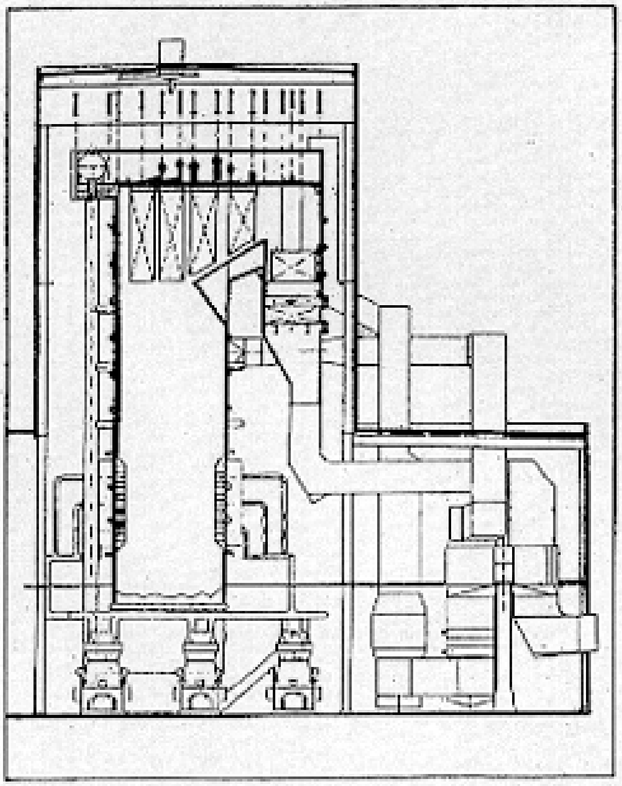

Figure 1: Sectional drawing of boiler at Västhamnsverket.

The boiler manufacturer was Götaverken Energy (now part of Kværner Pulping). The milling and firing equipment was supplied by ICL, Derby, England. The steam turbine and generator is of ABB make.
In 1986 a semi-dry desulphurisation plant was installed by ABB Flakt.
In 1994 gas firing equipment was installed having a capacity of 25 MW fuel input. Each coal nozzle is provided with four small gas nozzles.
Originally the plant steamflow capacity was 70.9 kg/s. By means of a step-wise analysing and testing program, it was found possible to increase the boiler load up to 82 kg/s with only a minor modification of the second and third stage superheater. Some 5 % of the tube surface had to be modified.
Presently, Alstom Power is installing its new industrial gas turbine GTX100. The steam from the heat recovery steam generator ("HRSG") will be fed to the existing steam turbine, which has been modified enabling it to take 82 kg/s from the pulverised fuel boiler and 15.5 kg/s from the HRSG. The extended plant will generate in total 126.7 MW_e and 186.4 MW_{th} with a power to heat factor of 0.68, a substantial improvement on the present 0.48. Total plant efficiency - 90.6 %.

2.2 NO_x REDUCTION MEASURES

The Swedish environmental authority ("Court of Concession") required from the beginning that the NOx emission shall not exceed 280 mg/MJ. The years following the commissioning of the plant in 1983, the annual average of NOx emission was recorded to be 165 - 175 mg/MJ depending on the mixture of coal suppliers. More stringent requirements were presented in 1987: < 200 mg/MJ. In Spring of 1988 new standards was set by the regional environmental authorities as of 1992-01-01: <150 mg/MJ with the target to achieve below 100 mg/MJ. A multi-step program was launched right away. The tangential firing system was modified to incorporate LNCFS ("LowNOx-ConcentricFiringSystem) and two levels of OFA ("OverFireAir") nozzles; see **figure 2**. A first test modification was done in the Summer of 1988 and the NOx-emission was reduced down to 125 - 130 mg/MJ firing Polish export coals. Full scale LNCFS system was installed in the Summer of 1989. The NO_x emission was reduced to 85 mg/MJ taken as annual values for any combination of mills in service and load levels firing mainly Polish export coals. Other coal qualities had normally some 10 mg/MJ higher emission

Now, the environmental authority is asking for further reduction of NOx emission. Västhamnsverket is now investigating technical alternatives and the economics of these.

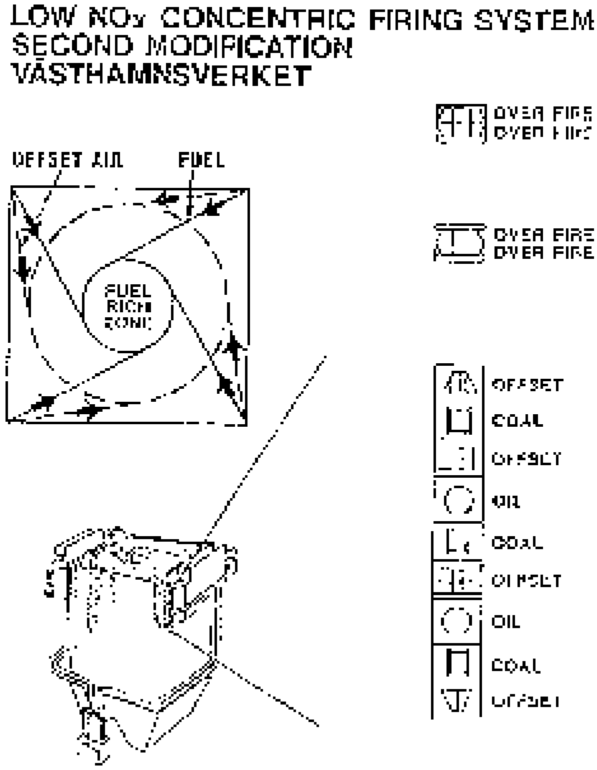

Figure 2 *Present tangential firing system with LNCFS and double separated OFA.*

3 STUDY ON FIRING OF PULVERISED BIOMASS

3.1 STUDIES AND TESTS AT VÄSTHAMNSVERKET

The most feasible alternative seemed to be to modify the existing pulverisers in order to accomplish co-firing of pulverised coal and pulverised wood pellets on a 50/50 heat input basis utilising one mill for coal and two mills for wood. Later on tests were performed to verify the practical side of this alternative. As part of these testing program, tests were also performed by ICL in Derby. The result was quite good and promising.

4 CONVERTING TO CO-FIRING OF PULVERISED BIOFUEL AND COAL

4.1 FUEL SPECIFICATIONS

As said above, a great variety of bituminous coals from around the world are fired at Västhamnsverket. The following is the original design specification for the pulverisers. The right column gives the main data for the biomass pellets, whereas these pellets contain only a very small amount of bark.

Proximate analysis	**Unit**	**Bituminous coal**	**Biomass pellets**
Net Calorific Value	MJ/kg, a.r.	24.0 - 25.6	17.8 - 18.2
Moisture	%, a.r.	8 - 10	4.4 - 5
Ash	%, a.r	10 - 16	0.2 - 0.4
Sulphur	%, a.r	0.5 - 0.7	<0.02
Nitrogen	%, a.r	1 - 1.4	0.2 - 0.3
Volatile matter	%, a.r	29 - 32	approx. 70
Grindability	Hardgrove	50 - 60	-
Ultimate analysis		**Typical - Polish**	**Typical**
Carbon	%, dry	73.2	50 - 52
Hydrogen	%, dry	4.3	6.0 - 6.3
Sulphur	%, dry	0.7	0.01 - 0.03
Oxygen	%, dry	6.8	40 - 42
Nitrogen	%, dry	1.2	0.2 - 0.3

Table 1. Analysis of fuels at Västhamnsverket.

4.2 GENERAL MODIFICATIONS

The overall target of the co-firing is to achieve at least 50 %, preferably 67 %, heat input from biofuel;
A step-wise program of modifications of existing systems and addition of new equipment took place between 1996 and 1998. Mainly during the summer months when the plant is down for annual overhaul. During the period end of May to mid September the heat demand is normally covered by utilising recovered waste heat.

In short the conversion comprises

- Modification of the existing pulverisers, see next paragraph.
- Sprinklerinstallations and fire-fly detectors on all conveyor belts.
- Covering of conveyor belts to aviod biomass dust
- Recirculation of flue gases from behind the electrostatic precipitator to the primary air upstream of the mills. Thus reducing the oxygen content in the pulverisers and the fuel lines to around 12 %.
- Modification of the fuel handling system including installation (1) of a vacuum cleaning system to remove biomass dust and (2) of explosion doors in the space above the three fuelbunkers.
- Erection of an A-frame storage 'barn' to accommodate the wood pellets, which are supplied by ship from producers in Sweden and North-America. This step also comprised new external conveyorbelt system feeding and reclaiming fuel in the barn.

The modified fuel handling system is now handling both coal and pellets.

4.3 MODIFICATION OF PULVERISERS

The three mills are of the Loesche type LM 16D, each with two grinding rollers using hydraulic cylinders to apply the correct crushing force on the fuel. A simplified view of the mills are presented in **figure 3.**
As there is a very large difference in density of pulverised coal as compared to pulverised biofuel, the volume flow conditions inside the mills will be very much different pulverising one or the other fuel. With the target as mentioned above, the volume flow of pulverised biofuel will be substantially larger as compared to coal, and so will be the need for transporting primary air. In order to accomplish this change in required performance of the pulverisers the following modifications have been done

- the design of the "LOUVRE RING" has been changed making it possible to adjust the opening depending on which fuel to pulverise; larger opening when milling biofuel.
- the design of the lower vertical cylindrical portion of the "INNER CONE" has been changed making it possible to adjust the vertical position of that cylindrical portion. When pulverising coal, that portion is in its original "top" position. When pulverising biofuel the cylindrical ring is lowered, thus enlarging the outlet area around the coal chute and thereby reducing the flow resistance and thus enabling larger volume flow for the same pressure drop across the mill.

In addition to these inner modifications of the mill,

- a rotary vane feeder has been installed on those mills, which are pulverising biofuel. This feeder can be slided away on rails, when the mill will receive coal.

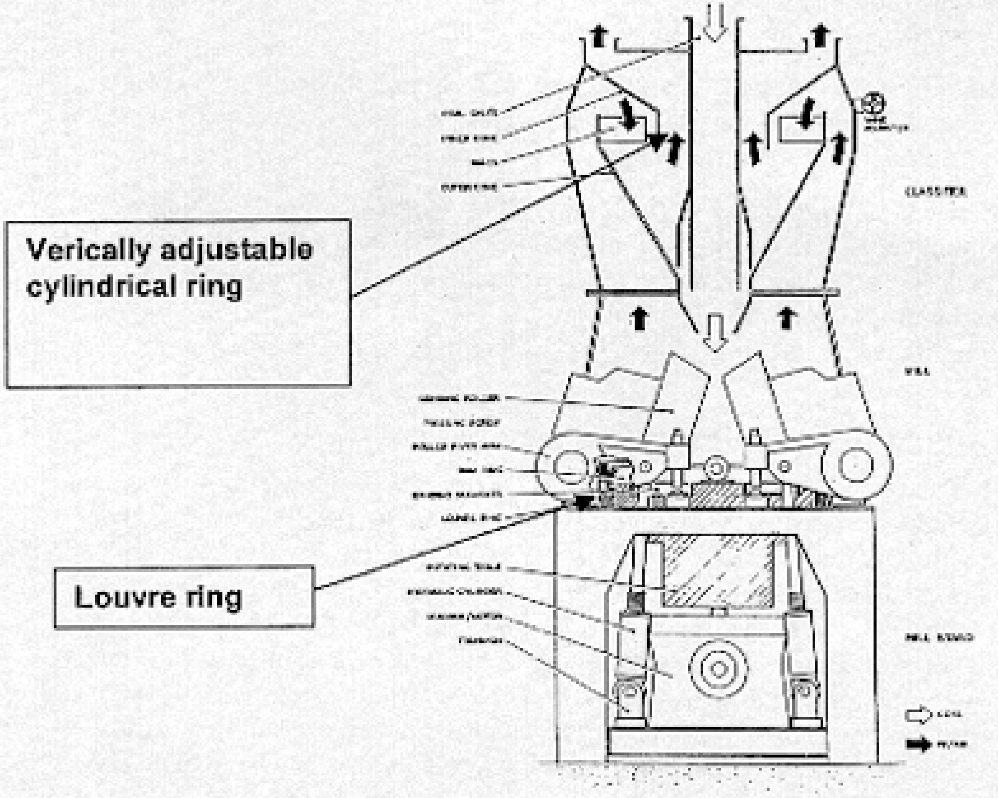

Figure 3. Simplified cut-away view of roller mills "Loesche LM 16D".

5 OPERATING EXPERIENCE

Since the middle of October, 1997 the boiler is on commercial operation in co-firing mode with one mill on coal and two mills on pellets. The operating record has been very good.

1997: 16,000 tons of bio-pellets and 99,000 tons of coal were fired.
1998: 64,000 tons of bio-pellets and 66,000 tons of coal were fired.
1999: 100,000 tons of bio-pellets and 46,000 tons of coal were fired.
2000: 101,000 tons of bio-pellets and 35,000 tons of coal were fired.

The following comments and conclusions can be made to the experience of three years of commercial operation co-firing pulverised coal with pulverised biofuel pellets:

1. The overall operating experience is very good.
2. External biofuel handling and storage must be added
3. Existing fuel handling to the boiler house bunkers: Dust removal system and explosion doors must be added.
4. The modifications to the existing pulverisers have been very modest.
5. So far no changes to the boiler itself was made.
6. After one full operating year with high portion of biofuel, manual cleaning had to be done in order to remove ash deposits on primarily the radiant superheaters.
7. The heat balance of the boiler is affected. Increasing portion of biofuel means less heat pick-up in the furnace and the superheaters close to the furnace. Thus, the temperature of the flue gas leaving the regenerative air heater ("RAH") is higher. Part of this temperature increase is due to the flue gas recirculation to the primary air for the mills. The feasibility of extending the boiler heating surface by a district heating economiser is now being studied.
8. The emission of NOx is reduced by some 25 %. In 1998 the annual emission was 66 mg/MJ, totalling 193 tons. Correspondingly, before starting the co-firing of coal and biofuel the emission was normally for coal only: 85 mg/MJ and 250 t/a. With the Swedish NOx-fee of SEK40 per kg of NO_x this means an annual reduction of 2.25 MSEK or USD 240,000. (1 USD = 9.35 SEK)
9. The amount of carbon in fly ash and bottom ash is somewhat higher when co-firing. However, the Swedish NO_x-fee means that the operation is optimised to reduce NO_x and accept some moderate increase in unburned carbon and CO.
10. The amount of sulphur emission have also been reduced. From the level of 45-50 mg SO_2/MJ to below 20 mg SO_2/MJ corresponding to from around 60 t/a of sulphur down to below 30 t/a. With the Swedish sulphur tax of SEK30 per kg of sulphur (S) this means an annual cost reduction of SEK 900.000 (=USD95,000).

6 ENERGY TAXATION IN SWEDEN

The main parameter for the overall economics of shifting to co-firing is of course the fuel cost. In Sweden all fossil fuels are heavily taxed; see **table 3.**

Fuel Year 2001	Unit	Energy SEK	CO_2 SEK	Sulphur SEK	TOTAL SEK	SEK/ MWh
Coal (0.5 % S)	1 ton	293	1329	150	1772	222
Oil (HFO, 0.8 % S)	1 m^3	684	1481	216	2381	220
Natural gas	1000 m^3	223	1144	0	1367	125
Woodpellets	1 ton	0	0	0	0	0

Table 3: *Swedish energy taxation. - Manufacturing industry pays less; no "energy tax", half "CO_2 tax" and full "Sulphur tax".*

Biomass fuels like wood waste and pellets do not pay any energy tax. For peat, the tax is limited to the sulphur tax.

For generation of electricity there is no tax on the fuel. The tax is on the produced electricity, or rather on the consumption, and depends on the category of user. Thus, for co-generation of electricity and district heating one can use fossil fuels with no tax up to the amount corresponding to the portion of the total fuel input, which is used for the electricity generation.

The use of different fuels are very typical for many Swedish municipalities. Starting with fuel oil. In the late 70-ties large scale utilisation of industrial waste heat started to be introduced. In the beginning of the 80-ies coal started to play a major role. In the middle of the 80-ies the first taxes on use of fossil fuels were introduced. These taxes have been increased stepwise up to the level presented in table 3.

The increasing taxes open up the market for utilisation of biomass fuels. Cheap electricity, especially during the Summer half of the year made large heat pumps a cost effective mean of generating district heating. In Helsingborg the heat pump plant has a capacity of 29 MW_{fuel} withdrawing the heat from the waste water leaving the sewage treatment plant.

8 CONCLUSION

The conversion of Västhamnsverket to co-firing of pulverised coal and pulverised biofuel pellets has been a success; technically, economically and environmentally. Three years of commercial operation is a true verification.