THE ANALYSIS REPORT OF PLANT NO. 1

Cofiring of biomass - evaluation of fuel procurement and handling in selected existing plants and exchange of information (COFIRING) - Part 2

Rauhalahti CHP Plant
Finland

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1. General information about the plant

A heat production company Jyväskylän Energiantuotanto Oy, owned by Fortum Heat and Power (60%) and the City of Jyväskylä (40%), owns in all 29 different types of boiler. Two of these are power plant boilers (the boilers of Rauhalahti and Savela). Fortum also owns one bigger fluidised-bed boiler that generates steam for the plywood mill of UMP-Kymmene Schauman Wood Oy at Säynätsalo. Three of these boilers are biomass-fired: the main boiler of Rauhalahti, the peat-fired boiler of Savela and the boiler of the plywood mill.

The main boiler of Rauhalahti plant was commissioned by Tampella Power (present Kvaerner Pulping Power Boilers) in 1986. This powder-fired boiler was converted into a fluidised-bed one in 1993. The boiler generates back-pressure district heat for the City of Jyväskylä and its surroundings and steam for Metsä-Serla Kangas Paper Mill and electricity for grid. Return water of district heating network is used to heat nearby greenhouse Viherlandia. Steam can also be generated by the oil-fired boiler of Rauhalahti (second boiler). The aim is to generate the base load with the main boiler. The Savela heating plant and oil-fired heating stations operate mainly as control units during peak output of district heat.

Specification of the main boiler:

- Boiler capacity 295 MW_{th}, electrical output 87 MW_e, district heat output 140 MW_{th} and process steam output 40 MW_{th} (max. 65 MW).

- Steam data: 110 kg/s, 135 bar, 533^{o}C.

The number of employees in Rauhalahti power plant is around 50. About 10 working years is used for maintenance.

2. Process description

Rear-unloading trailer lorries bring fuel to the receiving station (design capacity of fuel flow is 80 t/h). There are two lines at the unloading station, one mainly for wood fuel (sawdust/ bark) and the other line for milled peat. Coal is carried by train to the coal yard of the power plant and forwarded by a wheeled loader to the process when needed. At the receiving station, the fuel is pre-screened with disc screens. The screenings are disposed to the yard for crushing with a mobile unit operated by contractors. The pre-screened fuel is conveyed with belt conveyors to a separate screening building equipped with a disc screen and a crusher. The screened peat/wood and crushed screenings are conveyed with an ascending conveyor into a round-bottom intermediate storage, which is discharged with a screw unloader. From this storage the fuel is lifted with belts to two feeding bins. One feeding bin is discharged with an apron conveyor and the other with a screw unloader to a belt conveyor and further to a scraper conveyor. From there the fuel falls to a rotary air-lock feeder and flows forward via feeding tubes to three sites on both sides of the boiler.

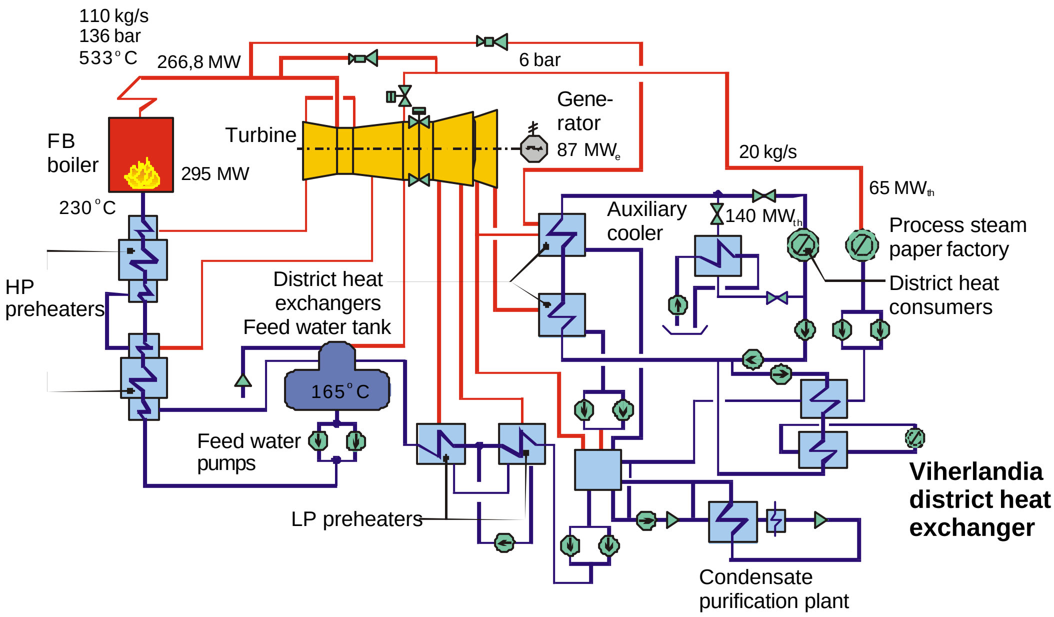

Fig 1. Process scheme.

A separate belt conveyor line feeds coal through a roller screen crusher to a coal bunker. From the bunker coal flows to mill and forward through a textile filter to pulverised coal bunkers. Coal is taken from these bunkers for pulverised-fuel burners. It is also possible to feed coal from the pulverised-coal bunkers through the peat line to the fluidised bed of the boiler.

The fuel receiving station is equipped with a weighing system called Sofia. The process is controlled with a Damatic system of Valmet Automation Oy. The screw unloaders of the peat/wood storage are controlled by level indicators of the boiler bins (radiation counter) on the basis of the boiler load.

Homogenisation and mixing is organised by conveying arrangements and by the conveyors of the unloading station. If the number of fuel flows is sufficient, the flows are mixed in the subsequent conveyor system.

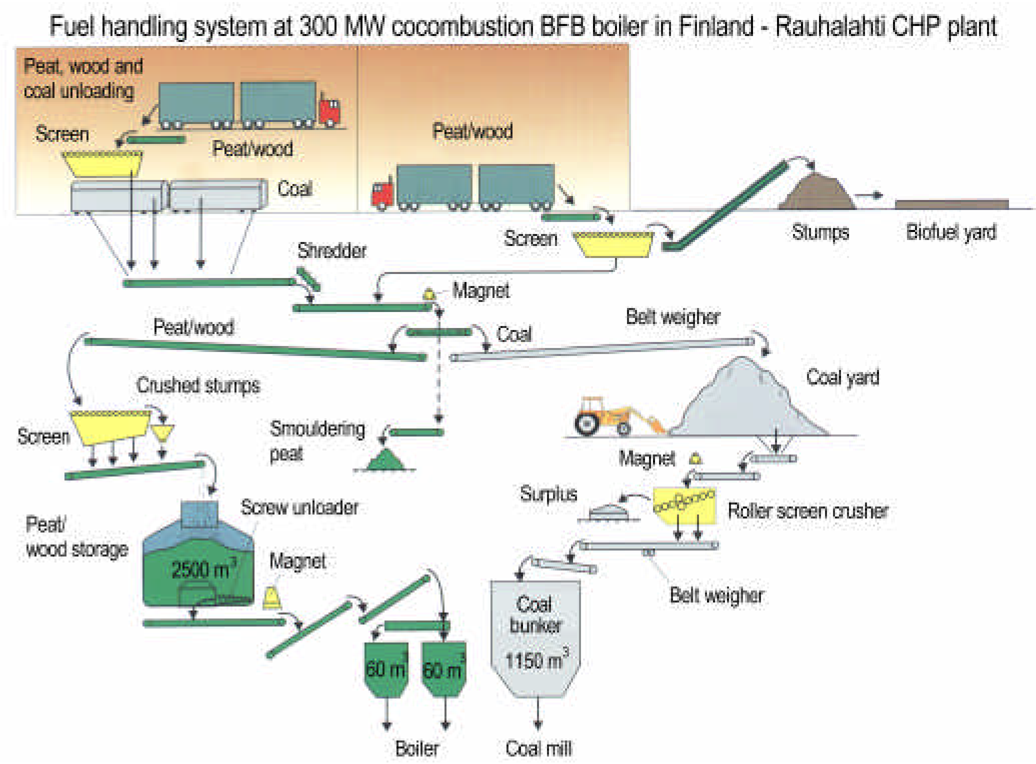

Fig 2. Fuel handling and conveying outside the boiler house.

3. Biomass and other fuels

The fuels of the main boiler are milled peat, wood fuels (sawdust, bark, cutter dust, wood chips) and coal. Oil is also used to some extent. The modification of the boiler made burning of wood fuels possible. Presently about 30% of the fuel flow is wood. In addition, burning of small amounts of crushed recycled fuel (REF) with wood is being tested.

Table 1. Consumption of fuel (TJ) 1994 – 1998.

Fuel	1994	1995	1996	1997	1998	1999
Peat	5086	5166	5230.8	5195	4 860	4147
Wood	698 11.5%	781 13.0%	925 14.9%	1228 19.0%	1303 20.5%	1400 21.4%
Coal	72	47	29	25	165 [1]	492
Oil	22	18	14	14	22	185
REF						328
Total	6 095	6 012	6 199	6 462	6 350	6 552

[1] Coal storage has been reduced intentionally

REF = source separated dry waste

The average moisture content of milled peat has been around 45% and the net calorific value about 10 MJ/kg. The moisture content of wood fuels has ranged from 45 to 50% and the net calorific value from 7 to 9 MJ/kg. The average energy density of wood chips was in 1999 0.7 MWh/m^3 loose (2.5 GJ/ m^3 loose).

The average price of the fuel is FIM 45/MWh (2.1 EUR/GJ) without taxes. In addition, there is a tax on peat. The wood fuels are tax-free. About 50 different fuel suppliers are taking care of fuel procurement.

Vapo Oy is the primary deliverer of peat. Fortum also produces some milled peat that is used for own energy generation as well. Sawdust/bark and cuttings come mainly from sawmills in Central Finland and from the mechanical wood-processing industry in the neighbourhood. The use of wood chips (logging waste chips) has been about 50 GWh/a. The large-scale use of bark (especially spruce bark) has caused problems in conveyors and feed equipment. Snow and freezing cause problems in wood chips and sawdust. The green matter of chips (alkali content) forms deposits in the superheaters. This problem has not appeared previously.

The forest residues are purchased by local entrepeneur, which is using roadside method. The plant has own receiving place for forest residues chips, and current use is about 3%. The transportation distance from forest to plant is 30 – 50 km.

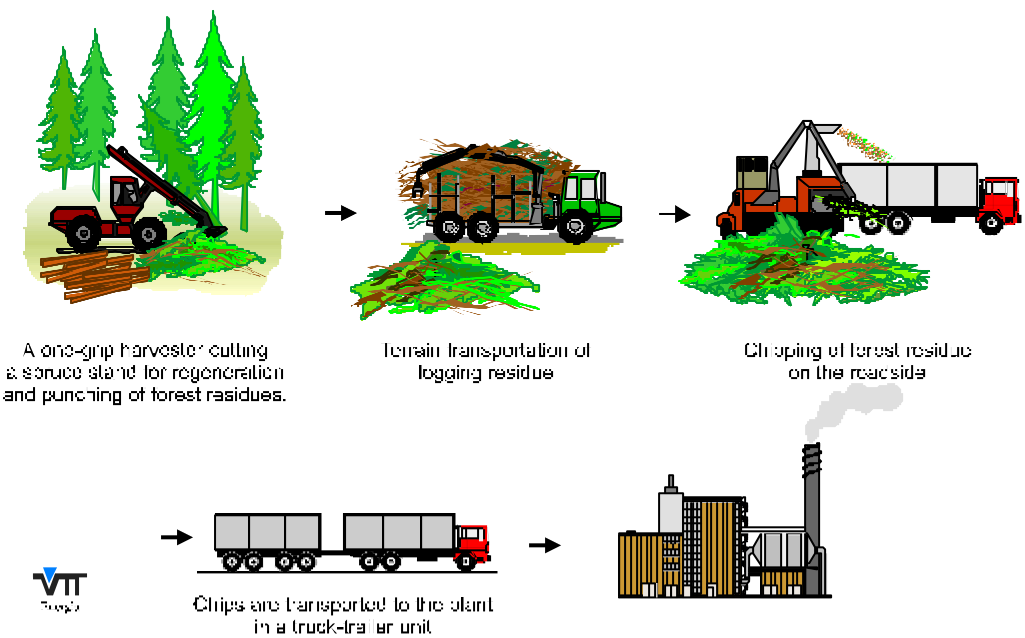

Fig 3. Harvesting chain of logging residue based on roadside chipping.

4. Fuel handling and conveyor systems

4.1 Fuel receiving station

Rear-unloading full-trailer lorries arrive to the unloading through the plant's own weighing system. The old side-unloading coal line, originally planned for railway wagons, has been changed mainly for rear-unloading of sawdust and bark. The materials are unloaded on a bottom (scraper) conveyor that conveys the fuel immediately onto the disc screen.

Milled peat is unloaded from the rear-unloading trucks to a drive-over floor scraper conveyor. This conveyor takes the peat straight to the disc screen. Screenings are led to the unloading yard. Stumps are crushed in separate contractor units to a size suitable for feed.

The screen discs are 180 x 180 mm apart from each other (screen hole), and their shape resembles a “ginger biscuit”. The nominal output of both screens is 1 200 m^3/h, but the screens are not exactly equal in length.

In wintertime, peat is brought to the unloading in three shifts. About 90 lorries can be unloaded (120 m^3, the biggest ones 160 m^3) in a day. The largest material flow on the conveyors is 80 t/h (design value). At the busiest time 3.6 lorries are unloaded in an hour. Three trucks unload peat and one unloads wood fuel simultaneously.

The unloading station is continuously staffed in winter (three shifts) and in one or two shifts in summer. There is also a camera-monitoring system in the area.

Sampling is performed according to the peat/wood quality instructions. In Finland quality instructions for peat trade were given in 1989 and in 1991 and the respective instructions for wood fuel in 1998.

The lorry drivers take the fuel samples manually, about 4 l/load. According to the sampling instructions, 2 x 1-litre samples are taken from the lorry and from the trailer. The samples of ten loads are combined (in one bucket) by each deliverer. The samples are mixed in a mixer delivered by Vapo Oy. From the mixed sample a 2-litre sample is taken for Vapo Oy and 4 litres for the laboratory of Rauhalahti. Half of the sample is stored. Automatic sampling has been considered. This idea has been given up mostly due to too high a cost of investment. Problems appeared in Rauhalahti are due, i.a. to the fact that there are several deliverers, especially of wood fuels.

Problems:

- unloading area is dusty (peat and dry wood), which is both a safety and work-hygiene risk, smouldering fires have not been found (only one case during the operation time of the plant)
- chains and bearings of the floor scraper conveyor have been changed
- there have been freezing problems in the scales → lifting the scales has improved the situation
- rear unloading is a slow system of unloading → the lorry traffic gets jammed (in winter mornings)

4.2 Screening and crushing

The initial handling system (Kone Oy) comprised one screen (screener/crusher) in the conveyor line (screening/crushing). Afterwards, separated sparse disc screens for pre-screening and the lines for screenings were installed in the receiving station.

The disc screens at the reception are of open type. The disc screen in the line is encased. The initial disc distance 25 x 50 mm (screen hole) has been changed to 40 x 50 mm. The capacity is 1 000 m^3 /h. At present the screening result is good, particularly after the fine-crusher. Long/large wood sticks passing the pre-screening cause problems in the bins of the distributing station.

The thickness of the screen discs at unloading is 10 mm and material is AISI 304. The discs of the in-line screen are of normal structural steel.

The crusher is a slowly revolving two-rotor roller crusher with automatic reversing arrangement. The design output of the crusher is 30 - 60 m^3/h. The blades are of hardened steel (Oxar 360). The blades and sluggers are hard-surface welded.

There is one sprinkler nozzle in the crusher case. The result of crushing has been sufficient; the residue is of “fist size”.

The belt magnet is located at the distributing station before the in-line screen (fine screen). Another fixed magnet is located at the end of the belt conveyor coming from the peat/wood storage. Iron separation is necessary. The belt of the belt magnet has sometimes got broken.

Problems:

- long (spruce) bark blocks the screeners and crusher
- dust
- the gear of the screen has broken up a couple of times

4.3 Conveyors

Most conveyors at the power plant are belt conveyors. All outdoor peat conveyors are belts. The speed of the belts has been increased close to 2 m/s. The speed has generally been increased by about 30%. For instance, the speed of the belt from distribution to screening has been raised from 1.3 => 1.8 m/s by changing gearing (gear unit of gearbox changed). Frames and motors of the gearbox have not been touched. The surface temperatures are still low. The capacity of the initial engines has been sufficiently high.

The belts have worn hardly at all. All belts have been changed about 1/10 a. Bundle tightening has been added afterwards. Thermal expansion has been observed in long conveyors, and consequently expansion joints of conveyor frames have been modified. The outdoor conveyor tunnels are heat-insulated and heated by district heat water. The inside walls of the tunnels are of smooth aluminium plate that prevents dust from sticking and makes cleaning easier.

"Travelling" has been observed in belt conveyors. Control steering has been added also to the return line and bearings have been rifled. One long belt lacks flexible belt tightening. This has caused side-sliding. At present, travelling of belts has not caused problems.

Most conveyors in the tunnels are open. Two conveyors have been encased with steel covering, sealed with 10 mm rubber gasket, which slightly touches the belt.

Static “plough”–type cleaners are used as belt cleaners. The upper ends of the belts are equipped with carving cleaners and hard-metal moulds. Active belt cleaners have not been used. Blockages have occurred in cleaners.

Dropping funnels at crossings of conveyors are made of fine steel.

There are inductive, capacitive and mechanical blockage guards at dropping sites. The present blockage guards are based on radiation and are camera-monitored.

Problems:

- there are lots of dust, peat fallen on the floor and sawdust in conveyor tunnels
- wall plates of conveyor tunnels have been changed because of smouldering fires
- in winter wet sawdust together with warm peat has caused a “snow-ball-effect” at unloading of storage

4.4 Storage

The peat/wood storage is cylindrical and it is discharged with a screw unloader. Its volume is 2 500 m^3. At full load the storage is sufficient for 6.5 hours. A mixing lattice was added to the feed of the storage about five years ago. The wall surface of the lower zone is of concrete. The bottom is equipped with underfloor heating.

Capacity problems have occurred occasionally in the conic screw unloader. The screw was shortened by about 0.5 m from the wall and the rotational speed was increased. The base of the thread was changed in summer 1995. The screw bearing is a critical point. The worm of the screw is of 10 mm stainless steel. The shredder of the screw thread is hard-welded. The screw pipe was originally encased with stainless plate.

The storage can hardly be used for homogenisation. Homogenisation occurs at the unloading station by unloading fuels of poor quality into the old coal bunker and higher-grade fuels to the rear-unloading. The operator of the unloading station attends to homogenisation with the aid of unloading conveyors.

Problems:

- wet bark and warm peat have frozen, and frozen peat lumps have lead to a restriction of power two times
- arching is formed easily close to storage walls
- the shredder teeth wear out easily when crushing wood fuels

4.5 Boiler feed

There are two A-frame boiler bins or feeding bins (á 60 m^3) for the boiler. The fuel is distributed by a chain conveyor into the bins. The boiler bins are encased with stainless plate. The coarser fuel fraction tends to flow into bin II.

One feeding bin is discharged with an apron conveyor and the other with a four-screw bottom unloader, which consist of four screws. There is a shredder/mixer at the end of the apron conveyor.

The boiler bins feed the fuel onto a scraper conveyor for forwarding to the distributing conveyors (scraper). These forward the fuel to three feeding sites located at both sides of the boiler. The two first feeding sites are equipped with feeding screws and at the end the scraper drops the fuel drops straight on the last rotary air-lock feeder. From the rotary air-lock feeders (6 feeders) the fuel drops through a feeding pipe into the fluidised bed. The feeding pipe is equipped with textile bellows as an expansion joint. Throwing air flows to one point in the feeding pipes.

The boiler load controls the unloaders of the feeding bins simultaneously. Normally one bin is kept full, and the top surface in the other bin controls the capacity of the unloading screw in the storage.

When conveying light material, the knots of the apron conveyor do not move fuel properly. In summer 1995, additional rods were welded in the conveyors. The chains of the apron conveyor were changed after 45 000 operating hours. Bearings have also been changed occasionally. The apron conveyors of one bin were later changed to a screw bottom, and at the same time the apron unloader of the other bin was overhauled.

The chains, the drive wheels and the idlers of the scraper conveyors eventually stretch and wear out. The joggles and sleeves have been changed to those of stainless induction harden steel (AISI 420). The blockage guards of the feeding screws have caused problems. There have been corrosion problems in the rotary air lock feeders (in rotor). The feeding pipes are of stainless steel.

Problems:

- the burner line clogs up before the rotary air-lock feeders (if fuel is too wet)
- the heaviest fuel fraction flows through the first feeding point
- the feeding screws clog up
- the expansion joints of feeding pipes (“telescope type” made of steel sheet is superior)
- wear of rotary air-lock feeders

4.6 Combustion

The combustion process has been steady; i.e. differences in bed temperatures are small. Non-stability is mainly due to great differences in fuel composition and quality.

About 1 000 t sand is consumed in the fluidised bed per year. Combustion of coal may lead to a quicker change of sand.

Melting of ash has not occurred. However, deposits were formed on superheaters when the combustion of fresh wood ships was started.

Steam production and consumption are stable in winter. In summer, the demand of steam varies more.

By changing the combustion method from pulverized peat/coal combustion to bubbling fluidised bed combustion the capacity of the boiler has increased from 265 to 295 MW and the use of wood chips came possible. By using more wood-based fuels the emissions has reduced: SO_2 emissions from 355 to 214 mg/MJ, NO_x emissions from 247 to 145 mg/MJ and particles from 68 to 8 mg/MJ. Also firesafety has improved and odours emissions from peat drying has been solved.

4.7 Ash handling

The bottom ash of the boiler is dropped into water on a wet slag conveyor. The wet slag conveyor lifts extinguished slag up onto a scraper conveyor, which lifts the material to the ash bin. From the ash bin the ash drops to a transport platform. Wear problems have occurred in the scraper conveyor of dry slag ((rails, chains, idlers and drive wheels).

Fly ash is conveyed into a fly ash bunker by pneumatic conveyors. There is a damping screw at the discharge of the bunker. The pneumatic conveyor lines wear out.

Ash is used foundation and landscaping in the adjoining ground.

5. Fire safety and certification

There is a sprinkler system at the unloading station, in conveyor lines and in the storage. The conveyor lines are also equipped with a temperature-detector wire and gas detectors (CO). Inert gas is available for boilers feeding bins and feeding lines when needed.

Fortum Service Company has obtained an ISO 9002 certification for usage and maintenance of power plants. In environmental operations, the Rauhalahti power plant follows the ISO 14 001 standard.

6. Cleaning operations

The conveyor tunnels are wet-cleaned twice a week. The operators try to avoid wetting the belt. (Getting wet causes that the belt goes to the side. This has happened about two times/operation period => emergency stop).

The precipitation tanks are emptied once a month.

There are no suction systems in the tunnels.

During the annual outage all spaces are washed. The sprinkler system has been utilised in the cleaning.

7. Investment and maintenance (costs), and availability

The total investment in the power plant including buildings was about EUR 84 000 000 (1986). The investment in conveying and handling systems until the feeding bins amounted to about EUR 3 400 000.

In 1988, changes were made in the unloading station and the inner conveyors were renewed (two disc screens, two platform conveyors and an outlet scraper conveyor). The total costs of conveyors and screens amounted to about EUR 340 000.

The modification costs of the boiler, including necessary control and automation improvements, amounted to about EUR 8 400 000.

Kone/Roxon Oy delivered the outdoor conveyors and BMH Wood Technology the indoor conveyors.

The indoor conveyors were renovated during the boiler change in 1993. These were included in the delivery of Tampella Power Oy (present Kvaerner Pulping Power Boilers) (subcontractor was BMH).

For example, the maintenance cost of outdoor conveyors during the renovation was around EUR 88 000 in 1995. During the operation period, the maintenance costs amount to about EUR 42 000 (repairs EUR 12 000 - 17 000). The biggest object during the renovation in 1995 was the screening and crushing system (abt EUR 44 000). The investments in the unloading station amounted to about EUR 32 000 and those in conveyors to EUR 12 000.

The annual maintenance costs of indoor conveyors amount to EUR 35 000 - 50 000.

Table 2. Operating time and availability in 1994 - 1998:

Hours/year	**1994**	**1995**	**1996**	**1997**	**1998**
Operating time	8 116	8 328	8 159	8 136	7 952
Down time	184	8	29	59	30
Renovations, abt.	412	376	524	517	730

8. Remarks

The change of the primary boiler to the fluidised bed has been an excellent solution with regard to the economy, availability and emissions of the plant. It has made possible to use a large range of fuels and moist wood fuels. Emissions, especially odours caused by the combustion method, were eliminated. The use of renewable fuels reduces CO_2 and sulphur emissions.

Double screening of fuels ensures the operation of the subsequent conveyors and storage. The new system was chosen on the basis of experience. The improved homogenisation of fuel grades and mixing of fuels might also prevent problems due to freezing.

Manual sampling increases work and stay in dusty spaces. The discharge capacity of the fuel receiving station is low due to the insufficient forwarding capacity of conveyors.

The rise in the speed of belts may have increased dust and peat powder in conveyor tunnels. The conveyors operate in extreme limits in wintertime. This reduces the scope in different run situations.