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Construction and Operating Experiences of the RHKW Linz (Austria)

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Residue derived fuels have a high potential to substitute fossil fuels such as oil, gas and coal in power plants units close to large cities, especially when district heating systems are available. Another driving force is the Kyoto protocol for CO_2 reduction resulting in state support for green power electricity substitution of imported primary energy and multi-fuel concepts together with RDF.

Additionally, to the conventional grate based waste to energy solutions combustion of RDF in fluidised beds gains more and more importance. This is driven by the fact that this technology is capable for a high degree in fuel flexibility combined with low emissions. Further, fuels with very high water content such as sewage sludge can be disposed easily.

In Linz Strabag Energy Technologies (SET) has erected a new 72 MW_{th} fired RDF fluidised bed boiler. The boiler is designed as a SETCIA *bubbling fluidized bed* applying multi-staged combustion technology. The fuel is gasified in the bed to yield combustible gases (mainly H_2 and CO) which are then combusted stepwise in the post combustion chamber.

The substochiometric bed operation allows a bed temperature control in the range between 600 °C – 900 °C. Therefore, fuels with low ash melting temperature can be safely combusted and the alkali release to the flue gases is reduced. The stepwise combustion of the yielded gases reduces the formation of NO_x as well as the formation of melted or softened ashes.

1. Introduction

Strabag Energy Technologies provides fluidised bed boiler solutions for biomass, waste and other residue derived fuels with steam capacities from 30 to 160 t/h. The combustion system has been developed to allow maximum flexibility in the range of fuels. Beside environmentally sound combustion with low emissions, maximum boiler efficiency is the main target.

In this paper the operating experience of a new installed RDF-fired plant with high fuel flexibility in Linz/Austria is presented.

2. Combustion Technology

The main feature of the SETCIA technology is the principle of the multi-staged combustion of the fuel. The oxygen level in the fluidised bed is limited and hence only a part of the fuel is combusted, whereas the rest of the fuel is gasified. This can be achieved by adding a substoichiometric amount of oxygen (air/fuel ratio approx. 0.35) to the fuel. However, in order to keep a constant temperature in the bed, this would result in a fluctuation of the fluidisation air volume flow and hence in fluidisation of the bed in accordance to the heating value of the fuel. Since this effect is not desired, the primary air is mixed with recirculated flue gas, allowing a control of the bed temperature independent of the fluidisation gas flow to the bed.

The fluidised bed itself consists of quartz sand with a mean diameter of approx. 800 µm (range 300 – 1,200 µm) and it is directly integrated in the boiler. The limiting membrane walls are protected from the erosive sand particles by a layer of highly resistant refractory lining.

The substoichiometric bed operation allows the control of the bed temperature in the range between 600 °C – 900 °C. Therefore, also fuel with low ash melting temperature can be processed without major sintering problems in the bed. The standard operation temperature of the fluidised bed depends on the combusted fuel; in case of RDF it is approximately 630 °C.

The gasification gases rising from the bed are fully combusted by adding a mixture of secondary air and recirculated flue gas at further stages to the boiler. The mixture of air and recirculated flue gas at each stage is set in a way that the most possible uniform temperature profile is achieved. This way, hot spots which might lead to ash softening of even ash melting are avoided (see gradual rise in temperature and oxygen content in Figure 1). The secondary air nozzles are designed in a way to ensure maximum turbulence in the combustion chamber and thus very good mixing properties of the oxygen with the remaining combustible gases.

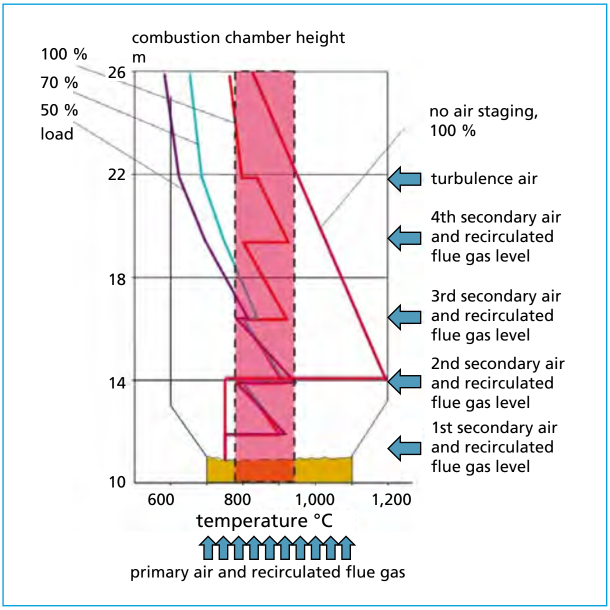

Figure 1:

Temperature profile of the first path at different loads

The staged combustion concept results in a homogenous and moderate temperature profile in the furnace and first pass of the boiler. This leads to reduced fouling problems from softened ash particles and low NO_x emissions. The high turbulence in the combustion chamber further allows very little CO emissions. If needed, NO_x emissions can be easily controlled by installing a SNCR at the appropriate temperature level in the boiler. These properties enable the bubbling fluidised bed to handle a broad fuel range with different heating values (e.g. net calorific values in a range of 3 to 20 MJ/kg) as well as corrosive fuels.

3. Waste derived fuel fired power plant Linz/Austria

The residue fired thermal power plant Linz is one of the most modern and efficient power plants using solid recovered fuels (SRF) in Austria. The SRF power plant is built on the site of the existing district heating plant Linz-Mitte instead of decommissioned old plants. The mechanical biological treatment plant which generates the SRF fuel has been built on an adjacent site near to the tank port.

The system consists of the following main parts:

- waste delivery, treatment and storage (see Figure 2),
- fuel transport to the power plant (460 m tubular belt conveyor),
- SRF-power plant.

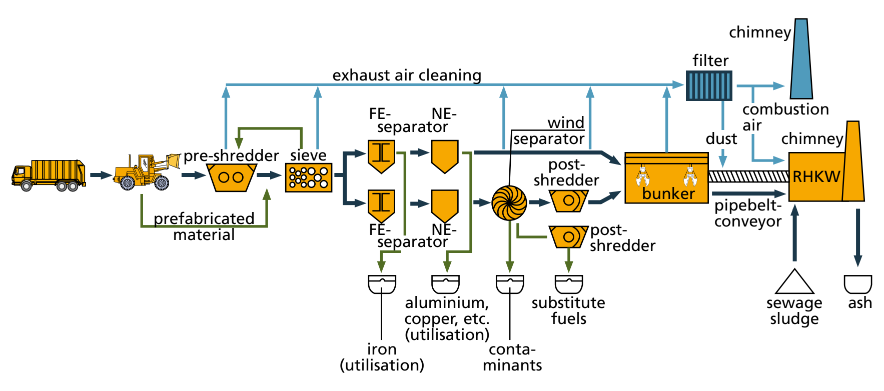

Figure 2: Waste treatment concept

The SRF-power plant consist of the following main parts

- fuel dosing system for SRF, sewage sludge and screenings,
- combustion unit and boiler,
- multi-stage flue gas and waste water treatment,
- ash handling and storage facilities,
- steam turbine with district heat extraction,
- cooling tower.

RHKW Linz completes the portfolio of existing power plants at the location and increases the proportion of non-fossil energy in district heat production from the current 17 % to approximately 40 %. The plant has a fuel thermal input of 72.6 MW which corresponds to the yearly disposal of approx. 230,000 tons of waste material (including 50,000 tons of sewage sludge). The boiler produces 89 t/h live steam at 420 °C at 45 bar(a). The plant delivers 17 MW electrical power output and 25 MW district heat power output, which corresponds to the supply of 37,000 households with electricity and 11,000 households with district heat. SET is responsible for the supply of the core part of the plant, the fluidized bed combustion as well as the sewage sludge, the screenings reception and feeding and the sludge treatment system.

3.1. Basis for the design of the fluidized bed combustion

Considering fuel properties and range of heating values, the decision was made to use a bubbling fluidised bed boiler type with substoichiometric combustion in the bed and a multi-staged combustion system in the post combustion chamber.

The following emissions are half hour average values related to 11 % O_2 content in dry flue gas (as half hourly average).

Table 1: Design Values

parameter	unit	value
max. fuel heat rate	MW	72.6
Lower heating Value	kJ/kg	7,000/18,000
Ash content	%	max. 40
Fuel flow	t/h	~ 32.5 (waste + sludge)
Control range	%	60/100
Combustion temperatures	°C	850/920

Table 2: Emission guarantee and limit values

Pollutants according decree	Guarantee after boiler	Emission limit after flue gas treatment
	mg/Nm³	
Carbon monoxide CO	45	100
Nitrogen oxides (as NO_2)	200	60

Due to the fact that an extensive flue gas cleaning is foreseen after the boiler no further emission values had to be obtained with the fluidized bed combustion.

Together with the waste and the sewage sludge, incombustible parts such as stones, pieces of glass, ceramics and metals are usually fed to the fluidized bed, where they collect and hinder the fluidization. To prevent this, an open type air distributor was installed. This air distributor enables the drain of bed material over the whole bed cross section during operation.

To maintain a constant fluidization of the bed at a constant bed temperature recirculated flue gas is added to the primary air in direction to the bed.

3.2. Plant description

Fluidized Bed Combustion and Steam Generator

The steam generator is designed for the following data:

Table 3: Design values

parameter	unit	value
Live steam flow	t/h	89
Live steam pressure	bar(a)	45
Live steam temperature	°C	420
Feedwater temperature	°C	130

The steam generator is a bottom supported 2-pass boiler with natural circulation, where the passes are integrated in the evaporator membrane-walls. After the second pass a tail end pass housing the superheaters is installed. The bubbling fluidized bed is situated in the lower part of the 1st pass.

The membrane-walls in the fluidized bed and a part of the post-combustion chamber are covered with refractory material due to erosion protection and thermal reasons. Backside air-vented refractory tiles are used, which on the one hand show lower agglomeration behaviour of the ash and guarantee an optimal protection of the membrane walls against corrosion. The primary air enters the bubbling fluidized bed via the open type air distributor with refractory lined nozzles. These nozzles are resistant against erosion of the fluidised bed and corrosion of the combusted fuels.

The secondary air and recirculated flue gas is separately mixed and fed to the boiler at four different levels. As first level the freeboard burners are used. Above three more individual air and recirculated flue gas injections are installed. Additionally, at full load a tertiary air is introduced with high speed at the top to enhance the mixing at the outlet of the combustion chamber. This results in a staged combustion and a temperature increase of 900 °C to 1,000 °C in the first pass. The exit temperature of the first pass is controlled to approx. 850 °C, to avoid slagging in the following heating surfaces.

The first pass is followed by an empty pass to reduce the flue gas temperature down to 650 °C before the tail end pass. At this temperature, the partial pressure of alkaline chlorides has been reduced to a far extend. For the cleaning of the membrane walls in the second pass, water cannons have been installed.

In the tail end pass the major superheaters are situated, SH3 in co-current flow, thereafter SH5 and SH4 in counter-current flow. Before each superheater a protective evaporator row is installed. Each half of the superheater bundles can be lifted out of the tail end for repair or replacement. The tail-end bundles are cleaned by a rapping device.

After the tail end four cyclones separate the high temperature dioxin-free ash from the flue gas. Afterwards the flue gas is further cooled to 170 – 180 °C in additional superheater and economiser bundles in a vertical boiler path. The dedusting of the flue gases takes place in a bag house filter, followed by a two staged scrubbing system and a SCR system.

Solid Fuel System (internal)

The solid fuel is supplied by a belt conveyor from the external fuel preparation plant into a fuel distribution chute inside of the boiler house and is split to two surge bins by a closed belt system. In the surge bins a minimum level must be maintained to enable proper working of the rotating reclaimer and to ensure the air exclusion to the boiler.

From each surge bin, two separate feeding lines to the boiler are installed. The fuel is extracted by the rotation reclaimer to the extraction screw conveyors. From there the fuel is transported via a further screw conveyor into a smaller dosing bin. The actual fuel dosing is accomplished by a metering belt which allows very precise fuel feeding. This is imperative since the quality of the fuel may vary quite fast. The belt speed directly determines the fuel heat input into the furnace. From this value the combustion air demand is derived.

For the dosing of the sewage sludge, two separate feeding lines are installed of which only one is working at the same time. The feeding line has four different feeding spots into the furnace which constantly alternate. Screenings from the water treatment plant can also be combusted in the furnace. This material is mixed with sewage sludge and then delivered to the furnace with a special pump. Both, sludge and screenings are injected with steam supported lances into the furnace.

Burner System

The start up of the fluidized bed boiler is carried out with natural gas burners, heating the bed material to the ignition temperature of the solid fuel. Two burners are installed in the freeboard of the bubbling-fluidized bed.

Bed Material and Ash Handling

The ash handling system consists of 2 different systems:

Bed ash system

The bottom ash from the combustion chamber (1st pass) is handled in this system. The bed material, ash and coarse particles are drawn off at the bottom of the furnace by twelve hoppers via four cooling screw conveyors. With the aid of an air sifter, the coarse particles are separated from the fine particles. Fine particles are conveyed pneumatically back into the furnace in order to reduce sand consumption of the boiler. The separated coarse particles are processed on a further sieve and a metal separator before being collected in containers. In order to handle the very high content of coarse particles in the fuel, the bed material is recycled every 4 – 6 hours.

Boiler ash system

Since the ash from the 2nd path, the tail end and the cyclone separators is extracted at elevated temperatures (and thus dioxin free and with only little heavy metal content), it is collected and disposed separately from the economiser and filter ash. The ash is collected via cooled screw conveyors and transported pneumatically to two ash silos. Before being loaded onto trucks, the ash is mixed with water to form a concrete which is then used as filling material at the nearby landfill. According to the logistic concept of the client, trucks deliver the sewage sludge form the water treatment plant to the power plant site, take humidified ash from the silos to the landfill and then return to the water treatment plant.

Economizer and filter ash system

The ash from the economiser and filter is transported to a separate ash silo by pneumatic means. The transport from the site is done in dry form in closed trucks.

Cleaning of the Heating Surfaces

For the cleaning of the heating surfaces in the tail end pass rapper devices are installed. The grid between 1st and 2nd pass as well as the grid between 2nd and tail end pass are cleaned by long retractable sootblowers. For the vertical tube bundles rotating element sootblowers are installed. Currently, different proposals are evaluated to replace these rotating element sootblowers to a sonic system or to an explosion system to increase the cleaning efficiency and reduce the steam consumption. Water cannons are installed in the 2nd path to remove fouling layers from the membrane walls.

Arrangement of heating surfaces

The heating surfaces are arranged in a way that the risk for corrosion from chlorine is reduced as far as possible. The flue gases are cooled in the 2nd path and an evaporator bundle down to approx. 600 °C before entering the superheater section. Further, a low temperature superheater (SH3) is place before the final superheater (SH5) and it is streamed in co-current flow. The first row of each superheater bundle in the tail end pass is arranged as an evaporator surface and acts as a strainer to ash particles. However, compared to hot superheater tubes, the formed deposits are much easier to remove from relatively cold evaporator tubes. A chlorine corrosion diagram is shown in Figure 3.

Operation Results

The commissioning started in September 2011 and the three month trial run is currently ongoing.

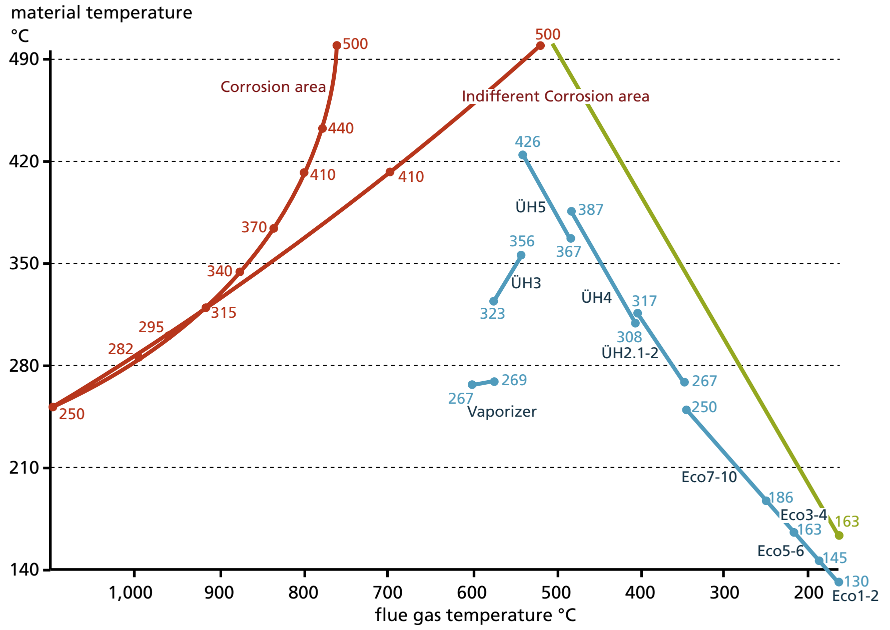

Figure 3: Chlorine corrosion diagram

The feeding of the waste has shown reliable performance. The major problem is caused by tapes and lines which accumulate around the screw conveyors. These materials are manually removed once per day. Blockages in the single fuel chutes occur rarely and are detected by measurements before causing problems.

After nearly two month of operation the multi-staged combustion system has proven its capabilities to avoid slagging. The exit of the first pass is still very clean with only minor deposits. Some fouling is found in the second pass but it seems that this material can be removed with the installed water cannons. The deposits on the superheater tubes in the tail end are very well removed by the rapping device. The heat transfer after approx. seven month of operation is still very high, much higher than expected. Currently it seems that the superheaters are over dimensioned which is reflected by a somewhat increased steam temperature after the final superheater. This phenomenon is counteracted by a reduced cleaning frequency of the final superheater.

Problems with fouling are encountered in the vertical pass after the tail end pass. The cyclone separators before the vertical pass remove most of the heavy and large particles and thus only very fine dust is found afterwards. This dust caused thick layers which are very hard to remove by the means of sootblowing. Currently explosion cleaning is conducted approximately once per month. Additionally, two concepts for improving the cleaning efficiency are evaluated: sonic cleaning with low frequency sound level and integrated explosion cleaning devices.

The coarse particles from the fuel are successfully withdrawn with the bottom ash system from the fluidized bed. After a shut down in January 2012 where agglomeration of these coarse particles was found in the fluidised bed, the recirculation rate in the bed was increased. This has shown the expected results and no further problems have occurred there.

The guaranteed emissions are easily met. Currently CO emissions are below 5 mg/Nm^3 and NO_x emissions are below 200 mg/Nm^3, referring to 11 % O_2 and dry flue gas. Also the unburnt content in the ash is below the guaranteed level and the ash is easily disposable.

Finally, it can be stated that this power plant, especially considering broad fuel range together with the low slagging behaviour, is a big step forward in the green energy production from solid wastes.

4. Conclusion

The multi-staged fluidised bed combustion technology is capable to combust waste derived fuels and sewage sludge within a broad operation range securely with low emissions and slagging behaviour. The operating experiences from the plant in Linz are the basis for the further development of the technology. The new boiler concept comprises a compact solution with an easy maintenance approach which provides the basis to convert waste derived fuels to steam and finally electricity and district heating. This is a major contribution to enhance green power production on an environmentally friendly basis.